BOOK OF ABSTRACTS

Editors

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Polish Air Force University
Dęblin 2025

X International Conference of Computational Methods in Engineering Science – CMES'25
November 19th-21st, 2025, Kielce, Poland

Book of Abstracts

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ABOUT THE CONFERENCE

The X International Conference on Computational Methods in Engineering Science (CMES'25) marks a milestone in the history of this event — its 10th anniversary edition. The jubilee edition will be held on November 19–21, 2025, in Kielce, Poland, and is jointly organized by the Polish Society for the Promotion of Knowledge, Lublin University of Technology (Faculty of Mechanical Engineering, Faculty of Electrical Engineering and Computer Science, Faculty of Management, and Faculty of Environmental Engineering), and the Polish Air Force University (Faculty of Aviation). The CMES'25 conference accompanies the celebrations of the 100th anniversary of the Polish Air Force University in Dęblin.

A Decade of Growth and Achievements

Over ten editions, the CMES Conference has gradually broadened its thematic scope and attracted participants from an increasing number of academic and research centers in Poland and abroad. The event has been held in various cities across the Lublin Voivodeship — including Lublin, Kazimierz Dolny, Zamość, and Puławy/Dęblin — as well as in the Świętokrzyskie Voivodeship (Sandomierz), as shown in Figure 1. In 2020, due to the COVID-19 pandemic, the conference was held online for the first time, rather than in Lviv (Ukraine). Until then, the conference will be held in a hybrid form – scientific committee members and other participants can attend it remotely via an online platform. The choice of locations for individual editions was intended to highlight the cultural and historical richness of the Lublin Voivodeship and its surroundings.

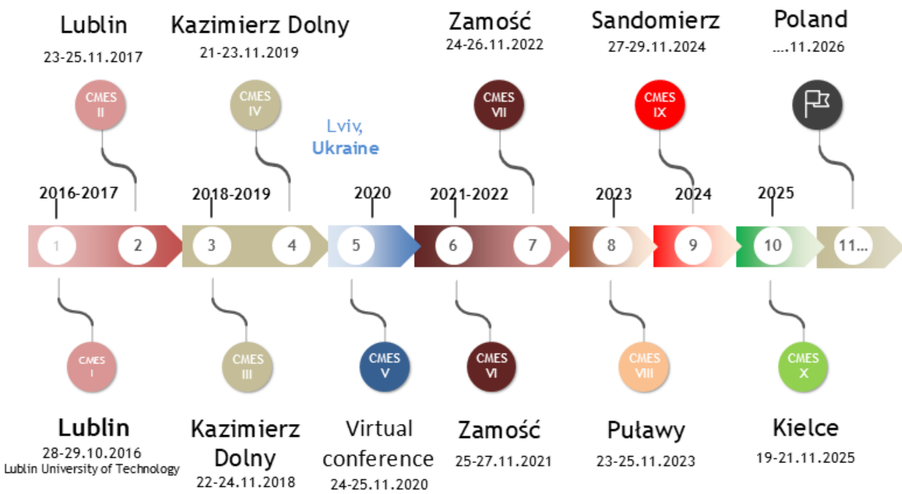

Figure 1. Timeline of the decade of CMES conference locations

From year to year, not only did the number of participants increase, but also the academic quality and international profile of the event. The total number of participants over the decade of CMES is approximately 900, and the annual counts of participants and presented topics (oral and poster presentations) are shown in Figure 2. Considering the 770 subjects presented over the decade of CMES, 38% were oral presentations. Moreover, the scientific committee of CMES has increased over the decade, as shown in Figure 3, and the average number of foreign members is 39%. The current international CMES community, comprising both participants and scientific committee members from Poland and foreign countries, is shown in Figure 4. The first edition, held in 2016, attracted only a few dozen participants, mainly from Polish academic institutions. In the following years, the number of attendees steadily increased, expanding the CMES community not only from Polish technical universities, but also from scientists from five continents: Africa, Asia, Europe, South America, and North America (see Figure 4).

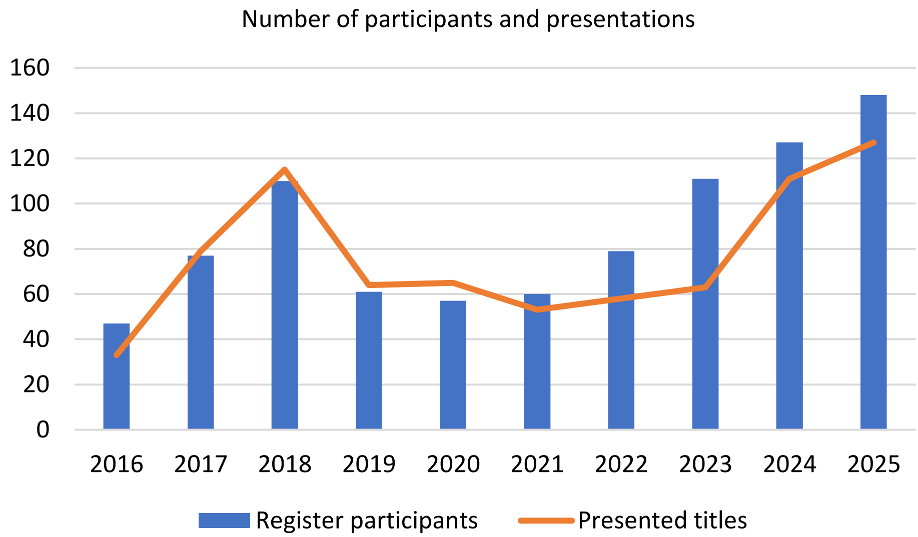

Figure 2. Statistics of CMES 2016-2025 participants and presented titles (orals + posters)

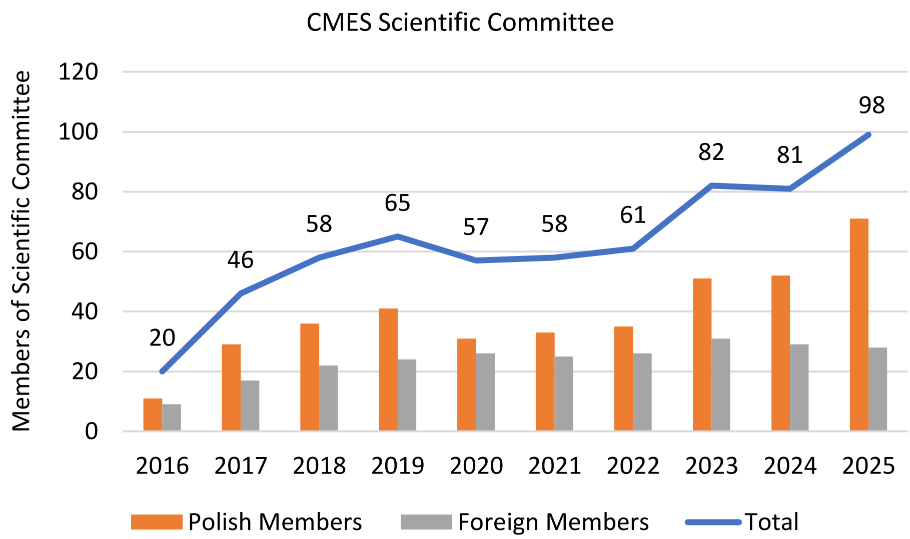

Figure 3. Statistics of CMES 2016-2025 Polish and foreign Scientific Committee Members

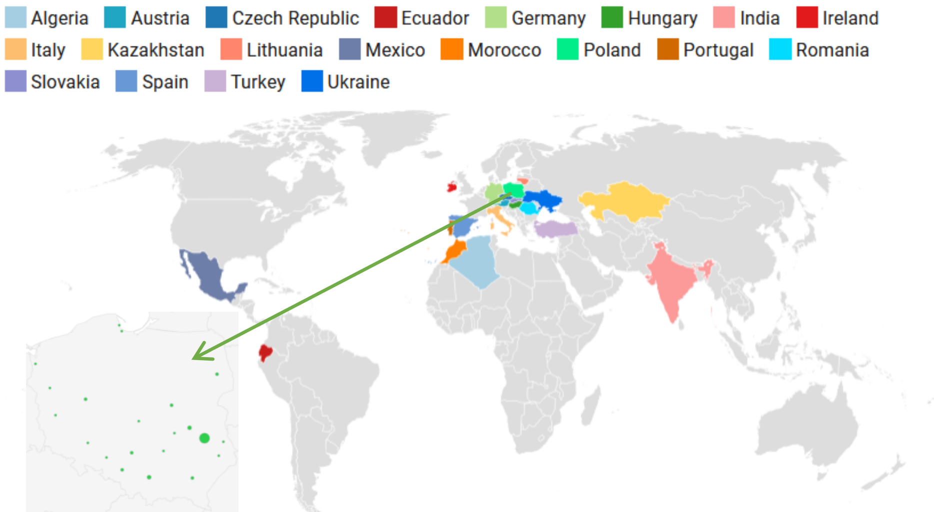

Figure 4. CMES community represented by CMES scientific committee members and conference participants over the 2016-2025 period [created with Datawrapper]

The decade of CMES tradition is, above all, a story of a worldwide community of young scientists, experienced researchers, and engineers who have co-created this event by sharing their knowledge, experience, and passion for science. The conference has become a place for integrating the scientific community and an inspiration for collaboration between universities, research centers, and industry.

Scientific Scope and Vision

The 2025 edition is expected to bring together around 150 experts, including keynote speakers from abroad and representatives of industry. As in previous years, the topics of the conference covers a wide spectrum of topics, including but not limited to:

- analysis and modeling of engineering processes,
- computer-aided design, simulation, and optimization,
- artificial and computational intelligence,
- Computational Fluid Dynamics (CFD),
- Finite Element Method (FEM) and related numerical approaches,
- experimental and computational methods in materials and structural research,
- production engineering and quality control,
- technology management in energy and sustainable processes.

The program of CMES’25 will include plenary lectures, thematic sessions, and industry presentations.

The primary goal of CMES is to highlight emerging trends in computational engineering methods and to enhance the visibility of ongoing research results. Throughout its history, the conference has contributed to the dissemination of knowledge through its proceedings and subsequent publications in reputable scientific journals. After a positive peer-review process, selected papers from CMES’25 will be considered for publication in journals such as:

- Advances in Science and Technology Research Journal
- Acta Mechanica et Automatica

- Archives of Electrical Engineering
- Applied Computer Science
- Journal of Ecological Engineering
- Management Systems in Production Engineering
- Advances in Materials Science

Towards the Future

The 10th anniversary of CMES is both a celebration of the past and a commitment to the future. Over the past decade, the conference has established itself as an interdisciplinary platform that bridges research fields and fosters cooperation between academia and industry — both nationally and internationally.

In the coming years, the CMES Organizing Committee plans to further strengthen the international character of the conference by attracting an even greater number of participants. Particular emphasis will be placed on developing closer cooperation with industry, so that the conference becomes a platform for dialogue and the initiation of projects with significant practical impact. These efforts are expected to result in an increase in the number of high-quality scientific publications as well as the establishment of lasting relationships between universities, research institutes, and companies. CMES enters its second decade with the ambition of continued growth and development.

More information about CMES'25 and previous editions is available on the official website:

🌐 www.cmes.pl.

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CMES'25 Organising Committee structure and team members
from the left: J. Pizoń, M. Szala, J. Kujawska, M. Kulisz, Z. Czyż,
K. Falkowicz, M. Badurowicz, W. Cel.

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This year's edition of CMES'25 (International Conference on Computational Methods in Engineering Science) is part of the celebrations marking the 100th anniversary of the Polish Air Force University in Dęblin.

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OPTISLANG: HOW TO APPLY ADVANCED OPTIMIZATION ALGORITHMS TO ACHIEVE BETTER DESIGNS

Wojciech Danek, PhD, Eng.
Symkom Sp. z o.o.

ABSTRACT

OptiSLang is an advanced software for parametric optimization and stochastic analysis, widely applied in modern product development processes. A key element of the tool is its methodology based on the automation of simulation workflows, beginning with a Design of Experiments (DoE) to efficiently explore the design space. Based on this, a sensitivity analysis is performed to identify the most influential input parameters.

Subsequently, optimization algorithms allow for finding the best possible design solution that meets specified criteria. The software also enables precise model calibration, both at the material properties level and in the validation process of global computational models, ensuring the correlation of simulations with experimental data. In the context of quality analysis, OptiSLang supports the assessment of product durability and reliability (Robustness and Reliability) by considering the variability of input parameters and their impact on the final solution.

One of the fundamental advantages of OptiSLang is its open architecture, which allows for integration with a wide range of CAE, CAD, and other tools from various vendors within a single, cohesive workflow. The final outcome of this work, in addition to an optimized design, can also be the creation of a dedicated application. This is made possible through the democratization of parametric analysis based on a reduced-order model (ROM), making advanced simulations accessible to a broader audience.

SPEAKER BIOGRAPHY

Wojciech Danek, Ph.D., An expert in advanced simulations and technical project management. At Symkom, he holds a dual role: Technical Global Account Manager, overseeing collaboration with global clients, and Mechanical Team Leader, where he leads a team of engineers responsible for technical support and project delivery.

He built his academic foundation at the Silesian University of Technology, working on innovative projects in the fields of crash test analysis, composite materials, and 3D printing. He has participated in numerous scientific conferences and research projects.

CONTROL OF MAGNETIC NOISE AND VIBRATIONS IN ELECTRIC MACHINES AND DRIVES WITH SIMULIA MANATEE

Rafał Wojciechowski,
DSc, PhD, Eng.
TECHNIA Sp. z o.o.

Dominik GAWLE, M.Eng.
SIMULIA Sales Representative
at Dassault Systèmes

ABSTRACT

The electrification of powertrains presents new challenges in Noise, Vibration, and Harshness (NVH). Unlike traditional systems, electric drives generate high-frequency tonal noise (e-NVH) caused by electromagnetic (Maxwell) forces. This phenomenon is amplified when exciting forces align with the structural modes of the powertrain, leading to resonance.

This presentation introduces SIMULIA Manatee, a specialized software solution for the assessment and control of magnetic noise. Manatee simulates the complete multiphysics e-NVH chain: from the electrical circuit and electromagnetics to structural mechanics and acoustics.

A key focus is enabling collaboration between different engineering disciplines. Manatee utilizes standardized interfaces, such as Magnetic Look-Up Tables (MLUT) and Modal Basis, for efficient data exchange between electrical and mechanical teams. The software provides significant productivity gains, running up to 1000 times faster than general-purpose FEA suites for this application.

Manatee includes dedicated root-cause analysis tools and allows for the rapid evaluation of over 15 e-NVH mitigation techniques (e.g., skewing, notching, control strategies). It provides a fast, accurate, and collaborative environment for predicting, analyzing, and solving e-NVH issues throughout the entire design process.OptiSLang is an advanced software for parametric optimization and stochastic analysis, widely applied in modern product development processes. A key element of the tool is its methodology based on the

automation of simulation workflows, beginning with a Design of Experiments (DoE) to efficiently explore the design space. Based on this, a sensitivity analysis is performed to identify the most influential input parameters.
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One of the fundamental advantages of OptiSLang is its open architecture, which allows for integration with a wide range of CAE, CAD, and other tools from various vendors within a single, cohesive workflow. The final outcome of this work, in addition to an optimized design, can also be the creation of a dedicated application. This is made possible through the democratization of parametric analysis based on a reduced-order model (ROM), making advanced simulations accessible to a broader audience.

SPEAKER BIOGRAPHY

Assoc. Prof. Rafal M. Wojciechowski received the MSc degree in Electrical Engineering from the Poznan University of Technology in 2005, PhD and D.Sc. degree in 2010 and 2017, respectively. His scientific interests are numerical modeling and analysis of electrical machines and devices using the multi-stage approach of the finite elements method (FEM). He has published over 70 papers on the electrical machines, electrical and electronic devices, systems of wireless transmission power; and the computation of electromagnetic field and induced currents in multiply connected conductors. He is an co-author of 3 international patents and 9 patent application for invention on electrical devices designs. From 3 year he co-operetes with Technia Poland, as the Simulation expert in EM field.
Dominik Gawle has been associated with the CAD/SIM/CAM/PDM software market for engineers for 20 years. He possesses extensive knowledge of Dassault Systèmes solutions, having previously worked for one of their partners in both technical and sales roles. He is happy to share his acquired knowledge with interested parties. He is a graduate of Cracow University of Technology in the field of Automation and Robotics, as well as a postgraduate of AGH University of Science and Technology in Project Management. He is currently responsible for leading projects and developing sales in the SIMULIA domain, supporting Dassault Systèmes clients and partners in Poland.

APPLICATION OF MACHINE LEARNING METHODS IN TRIBOLOGICAL STUDIES OF ION-IMPLANTED MATERIALS

Mariusz Kamiński, PhD, Eng.
Lublin University of Technology
Faculty of Mechanical Engineering
Department of Automotive Vehicles

ABSTRACT

A machine learning-based methodology is proposed to investigate the tribological properties of ion-implanted surface layers in advanced engineering alloys. The study analyzes and predicts friction and wear behavior using datasets comprising microhardness, surface topography, chemical composition, friction coefficient evolution, and quantitative wear indicators. Data preprocessing combined statistical analysis with domain-specific criteria to identify key parameters influencing tribological performance. Several predictive models were trained and validated to ensure robust predictions, while interpretability was enhanced by examining the effects of implantation conditions, microhardness variations, and compositional gradients. The results demonstrate the potential of machine learning to capture complex, time-dependent phenomena in wear tests of ion-implanted materials, while also addressing challenges related to data quality and model accuracy.

SPEAKER BIOGRAPHY

Dr. Mariusz Kamiński is an Assistant Professor at the Faculty of Mechanical Engineering, Lublin University of Technology, where he has worked since 2015. In 2021, he received his PhD with honors in mechanical engineering, defending a dissertation on the impact of ion implantation on the mechanical properties of materials used in internal combustion engines.

His research focuses on the effects of medium- and high-energy particle irradiation on the structure and properties of engineering materials, increasingly supported by the implementation of modern machine learning and deep learning techniques.

He has authored 27 peer-reviewed publications, one scientific monograph, and two patents. He is also the Principal Investigator of a National Science Centre project (Miniatura 8, 2024–2025) dedicated to evaluating the effects of nitrogen ions on the properties of Inconel 718 nickel superalloy.

Currently, his work combines tribology, surface engineering, and artificial intelligence to improve the understanding and prediction of complex wear phenomena in engineering materials. He has presented his findings at numerous international conferences, emphasizing the application of advanced machine learning approaches to the analysis of tribological changes in ion-implanted materials.

THE POWER OF DECISION-LEVEL FUSION: ENHANCING CLASSIFICATION THROUGH INTELLIGENT AGGREGATION

Paweł Karczmarek, DSc, PhD
Lublin University of Technology,
Lublin, Poland

ABSTRACT

This speech explores the transformative potential of decision-level fusion in modern classification systems. Starting from the classical Choquet integral, we delve into its powerful extensions—pre-aggregation functions, generalized and smoothed variants, and novel interpolation strategies. These advanced aggregation tools enable more flexible and accurate fusion of classifier outputs, especially in challenging settings such as federated learning and deep learning architectures. By integrating theory and practice, we uncover how intelligent aggregation can significantly boost the robustness, interpretability, and performance of AI systems.

Beyond the theoretical foundations, this keynote highlights the unifying idea of classifier aggregation as a catalyst for innovation. We revisit classical operators while introducing novel ones designed for today's data-driven challenges. Their reach extends far beyond theory: strengthening anomaly detection in dynamic environments, unlocking new strategies for complex multi-class tasks, guiding critical decisions in medical contexts, and empowering federated learning where collaboration meets privacy. By tracing these threads, we reveal how intelligent aggregation not only refines our models but also reshapes the very way we think about building trustworthy and impactful AI systems.

SPEAKER BIOGRAPHY

Paweł Karczmarek received the Ph.D. degree in mathematics from the University of Gdańsk in 2010 and the Habilitation degree in computer science from the Systems Research Institute of Polish Academy of Sciences in 2019. He is currently a Professor with the Department of Computer Science, Lublin University of Technology. He serves as President of the Scientific Council of Information Technology and Telecommunication and Head of the Department of Computational Intelligence. He has authored more than 100 research papers and one monograph. His main research interests include Computational Intelligence, anomaly detection, aggregation operators, and hybrid AI models, with applications in medicine, cybersecurity, and industrial optimization. Beyond academia, he is the co-founder of Deepmetric Systems Sp. z o.o. By combining academic leadership with entrepreneurial practice, he bridges fundamental research with real-world innovation, advancing both the theory and application of modern AI systems.

APPLICATION OF SIGNAL PROCESSING TO CALCULATE POLARISATION ANGLE ON THE BASE OF LIGHT SPECTRUM ANALYSIS

Grzegorz Kozieł, PhD, Eng.
Department of Computer Science, Electrical Engineering and Computer Science Faculty, Lublin University of Technology, Lublin, Poland

ABSTRACT

Sensors are a fundamental component of modern industrial systems. Often, there is a need to miniaturise sensors, enhance their resistance to electromagnetic radiation, or ensure safe operation in potentially explosive environments. For this reason, fibre optic sensors using tilted fibre Bragg gratings (TFBG) are utilised. They enable the measurement of numerous physical and chemical parameters. The measurement can be read by either assessing the power of light propagating at a specific wavelength or by analysing the light spectrum numerically. The latter method offers significantly greater possibilities but requires extracting light spectrum features and performing complex numerical calculations. This presentation will demonstrate the application of various signal processing techniques, such as wavelet and Fourier transforms, to determine the measurement results based on light spectrum analysis. The analysis will be illustrated using an example of sensors that measure the angle of rotation of the polarisation plane of light propagating through an optical fibre.

SPEAKER BIOGRAPHY

Grzegorz Kozieł, Ph.D. (Eng), graduated from the Faculty of Electrical Engineering at Lublin University of Technology in 2003. He also completed his doctoral studies at the same university. In 2011, he obtained his Ph.D. degree from Lublin University of Technology. He is a specialist and researcher in the fields of information security, digital signal processing, and analysis. He is the author or co-author of over 90 publications and three patents. Between 2013 and 2019, he served as deputy director of the Computer Science Department. Currently, he is the head of the Division of Cybersecurity and Cloud Technologies.

THE USE OF MACHINE LEARNING IN EXPLORATORY ATTITUDE ANALYSIS: THE CASE OF INFORMAL EMPLOYMENT

Marcin Gąsior, DSc, PhD, Eng.
Associate Professor
Lublin University of Technology

ABSTRACT

Modern data exploration methods based on artificial intelligence (artificial neural networks and unsupervised clustering) open up new possibilities in the study of social attitudes, especially when working with data that is high-dimensional, complex, and partially nonlinear. This research applies such techniques to identify latent types of attitudes among respondents, based on their answers to a set of questions evaluating a multifaceted socio-economic phenomenon. The chosen context for this investigation is informal employment - defined as both work conducted without a formal contract and the performance of tasks beyond the official scope of duties. While often economically or organizationally motivated, this phenomenon carries legal, social, and moral implications. The study examines various evaluative dimensions of informal employment, including normative moral judgment, perceived utility, social and cultural acceptability, loyalty to the employer, and interpersonal dynamics. Additionally, it considers respondents' attitudes toward legal norms and public institutions, alongside socio-demographic factors.

The data analysis will involve dimensionality reduction techniques based on artificial neural networks. Both the full dataset and the reduced representations will then be subjected to clustering using density-based methods. In parallel, Kohonen's Self-Organizing Maps will be employed as an exploratory tool for visualizing nonlinear relationships between response profiles. The outcome of the study will be the identification of standardized, empirically derived types of attitudes such as pragmatic, moralistic, or conformist and their associations with socio-demographic and institutional characteristics.

SPEAKER BIOGRAPHY

Dr. habil. Marcin Gąsior is a distinguished academic and researcher currently serving as the Dean of the Faculty of Management and Head of the Department of Marketing at Lublin University of Technology. He earned his postdoctoral degree (habilitation) in 2020 on the basis of a research monograph devoted to modeling consumer phenomena from a nonlinear perspective using artificial neural networks. His research focuses on consumer behavior, with particular emphasis on information acquisition processes, consumer satisfaction, and the structure of perceived risk. He is also deeply engaged in the theory and methodology of measuring social and psychological phenomena, integrating quantitative modeling with behavioral insights. Beyond academia, Dr. Gąsior has an extensive record of collaboration with businesses and non-governmental organizations, participating in numerous research and consulting projects aimed at translating data-driven insights into strategic decision-making. Currently, he serves as an expert at the WAB2 (Eastern Business Accelerator 2) acceleration program, where he supports startup development through the design of research tools, marketing research, competitive analyses, and the formulation of sales and marketing strategies. Over the course of four program editions, he has delivered with his team more than 2,000 hours of expert mentoring and advisory work.

ABSTRACTS

ANALYSIS OF ENGINEERING PROCESSES

MODELLING AND MACHINE LEARNING IN CUTTING PROCESSES

Jerzy Józwik, Lublin University of Technology, Lublin, Poland j.jozwik@pollub.pl

Abstract: Modeling is a valuable tool that enables the extension of the time scale (which is strongly limited in the cutting process), the identification of specific intermediate states, and the extraction of factors whose influence is not explicit within the complex mechanism of interaction concentration. The advantage of modeling and simulation lies in their ability to approximate the dispersion measures of non-measurable feature values. In modeling and simulating the process, it becomes necessary to determine a compromise between the generality of analytical descriptions, the clarity and interpretability of the model, and the justification for including numerous complex and interrelated interactions. A high level of model detail requires abandoning simple deterministic relationships. The development of new data processing methods and technical means has led to a dynamic increase in the ability to extract, analyze, store, transmit, and share detailed information about investigated processes and objects. The automation of data processing, new modeling methods and algorithms, as well as the development of process theory, are becoming new scientific challenges, particularly in the field of machining. Modeling, virtualization, and machine learning in machining processes have become ubiquitous. Experimental research on cutting processes contributes to science in three ways: through comparing experimental results with pre-established theories, through implementing theoretical results into specific applications, and through efforts aimed at understanding or presenting the theory itself. Experimental results either provide information for model construction or serve for their verification. A common error in research practice is assuming that experiments are intended to confirm or refute a theory. In fact, experimental studies cannot confirm a theory, as the same dataset may be consistent with multiple, differing theories. However, they can demonstrate the usefulness of a theory within a specific application domain. Usefulness and correctness are two qualities characteristic of a well-developed theory. The development of machining theory and technology are mutually intertwined. The emergence of new theories often prompts their verification, initially under experimental conditions and later in production environments. In the current era of artificial intelligence and machine learning, the latest applications provide a foundation for new and more refined descriptions of phenomena occurring in technological processes.

Keywords: Modeling, virtualization, machine learning, machining processes, metrology, data acquisition, data processing.

COMPARISON OF THE MICROSTRUCTURE AND SELECTED PROPERTIES OF THE CERMET COATINGS SPRAYED ONTO AZ91 MAGNESIUM ALLOY SUBSTRATE BY USING THE HVOF METHOD

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Abstract: Magnesium alloys are widely used in various industries, mainly because they combine low density, the best structural material known today, and a high strength-to-weight ratio. However, the use of magnesium alloys is limited due to their poor abrasion and corrosion properties and high chemical reactivity. The main goal of the present study is to compare thermal sprayed coatings deposited by high velocity oxy fuel (HVOF) method with a combination of two different spraying distances: 360 and 400 mm. Commercial powder, agglomerated and sintered WC- 10Co-4Cr was thermally sprayed to deposit coatings onto magnesium alloy substrate AZ91. The observed microstructures are dense, homogenous and well adhered to the substrate, as well as with low porosity level. So it could be say, that they are typical for HVOF deposits. In addition, small cracks and unmelted carbide particles embedded in the metal matrix were found in the sprayed coatings. The phase composition of the sprayed coatings consists of two hexagonal carbides: WC and W_2C, hexagonal Co and a cubic solid solution of tungsten in cobalt with a composition of $Co_{0.9}W_{0.1}$. The obtained results revealed that higher spray distance results in greater porosity 3.0±0.7 % for 320 mm and 3.3±0.8% for 400 mm respectively. Also it could be observed the relationship between coating microhardness values and spraying distance, c.a. 1198±135 HV0.3 for shorter spray distance, whereas for longer one it was 998±172 HV0.3.

Keywords: HVOF thermal spraying, microstructure, properties, AZ91 magnesium alloy, phase composition.

EFFECT OF THE PUNCH GEOMETRY ON THE CHARACTER OF FORCE WAVEFORMS IN BLANKING PROCESS

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Abstract: The paper concerns the analysis of a selected technological process in the field of forming sheet metal products. The process of blanking from sheet metal is mainly used in industry as a preliminary stage for preparing the starting material for deep drawing of drawpieces or flanging of collars. The aim of the research in the paper was to determine the influence of the shape of the working part of the punch on the character of changes in the cutting force. Different shapes of punches were used: flat, concave, flat-concave and spherical. For the flat punch, additional investigations were performed with different clearance values. The tests were carried out for sheets of different materials (aluminium, copper, brass and five types of low-carbon and alloy steel) for which the properties were determined in a static tensile test. The research used an industrial blanking tool with the possibility of replacing punches mounted on a hydraulic press with a maximum load of 1MN equipped with sensors for measuring forces and displacements (first metrological class of measurement). The results were recorded using specialist *Test&Motion* software from Labortech company. The relative thickness of the obtained blanks was the same and amounted to g_0/D x100=2.5 (where D is the diameter of the blank and g_0 its thickness). Based on the obtained results, it was shown that the shape of the working part of the punch affects not only the value of the maximum cutting force, but also the character of their changes as a function of displacement. The analysis of the results presented in the paper may be helpful in developing technological processes of deep drawing or flanging in production conditions at the stage of preparing the starting material.

Keywords: Metal forming, punch, waveforms of force, blanking process, front surface of punch.

NOISE SOURCE ANALYSIS OF NITROGEN GENERATION SYSTEM

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Abstract: This study presents a comprehensive noise source analysis of a nitrogen generation system installed at an industrial production facility. The primary goal of the investigation was to determine the location of the dominant noise sources, as well as to identify their respective sound pressure levels and frequency characteristics under operational conditions. Detailed measurements were conducted using a 16-microphone array combined with the CAE Noise Inspector software for accurate sound field visualization and analysis. Experimental tests were carried out at three distinct locations within the system: the nitrogen generation installation itself, the nitrogen storage tank, and the ejection tube for exhaust gases, with the latter further subdivided into three specific measurement points (down, middle and upper part) to account for variations along the tube length. Each acoustic measurement session lasted three seconds, with data captured at a high recording frequency of 204.800 Hz to ensure precise resolution across the frequency spectrum. The operational cycle of the nitrogen generator was divided into two main phases: first phase: characterized by the transient sounds associated with valve actuation, and second phase:, dominated by the continuous noise generated during nitrogen transfer to storage tanks and exhaust gas expulsion. Recordings taken at nitrogen generation installation captured both operational phases, while measurements at nitrogen storage tank, and the ejection tube for exhaust gases, were focused exclusively on second phase to isolate relevant noise sources. The results provide a detailed and quantitative characterization of the acoustic emissions associated with the nitrogen generation process, offering valuable insights that can inform the development of targeted noise reduction strategies and contribute to the future optimization of the system's mechanical design and operational efficiency.

Keywords: Microphone array, noise source, nitrogen generation, frequency.

CONCEPTUAL APPROACH TO USING MULTI-VALUED LOGIC TREES FOR THE OPERATIONAL ANALYSIS OF THE 3PW-SEW-08-28-2-776 GEAR PUMP

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Abstract: The study presents an advanced analytical methodology focused on the application of multi-valued logic trees and the Quine–McCluskey algorithm for evaluating operational parameters in the 3PW-SEW-08-28-2-776 gear pump. This pump was developed as part of a completed research project, with the primary objective of enhancing efficiency through comprehensive data acquisition and decision modeling. The analysis is based on a dataset comprising extensive measurements of flow rate, torque, and various efficiency metrics, collected under varying operating conditions, including fluid temperature, discharge pressure, and rotational speed. The proposed methodology involves a two-stage analytical approach. First, static characteristics were determined to describe the relationships between operational parameters and overall pump efficiency. Subsequently, multi-valued logic trees were employed to establish a hierarchical structure that ranks the significance of each parameter. This hierarchical structure is achieved through the transformation of logical decision trees using the Quine–McCluskey algorithm, which enables the minimization of individual partial multi-valued logic functions. The study not only demonstrates the potential of multi-valued logic trees as a decision-making tool in hydraulic systems but also highlights the methodological advancements in data-driven parameter analysis. Future work will focus on integrating the proposed logic-based framework with existing optimization methods to further refine the decision-making process and provide actionable guidelines for gear pump design and operational control. The Quine–McCluskey algorithm facilitates the conversion of multi-level decision trees into minimal complex alternative normal forms (MZAPN), eliminating isolated branches and minimizing the number of realizable logical paths. This allows for the identification of critical operational parameters that have the most substantial impact on pump efficiency, providing a systematic framework for further optimization.

Keywords: Gear pump, Multi-valued logic trees, Quine–McCluskey algorithm, Parameter importance ranking, Hydraulic systems, Efficiency analysis, Decision modeling, Data-driven optimization, Logical minimization, Operational parameter assessment.

DETERMINATION OF AIR-FUEL RATIO (AFR) FOR TWO-STROKE ENGINES FUELED WITH GASOLINE, ETHANOL (E5 AND E10 BLENDS), AND TWO-STROKE MIXING OILS (MINERAL, SEMI-SYNTHETIC, AND SYNTHETIC)

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Abstract: Exhaust emissions and engine power output in internal combustion engines largely depend on the composition of the air–fuel mixture. Different fuel types are characterized by different air-fuel ratios (AFR). A lambda coefficient equal to 1 corresponds to the air-to-fuel ratio that provides optimal conditions for complete combustion (stoichiometric mixture). For gasoline, this value is 14.7:1 (i.e., 14.7 kg of air per 1 kg of fuel), for ethanol 9:1, and for paraffinic oils (chemically similar to typical two-stroke mixing oils), approximately 14.5:1. The aim of this study is to determine the AFR for a mixture composed of three components— gasoline, ethanol (E5 or E10 fuel), and two-stroke oil (mineral, semi-synthetic, or synthetic)—which forms the fuel blend commonly used in two-stroke engines, such as those found in chainsaw powertrains. The paper presents a theoretical analysis of AFR determination for these fuel blends, along with experimental measurements of the lambda coefficient in chainsaws using various measurement techniques. The conducted analysis provides data for correction factors applicable to exhaust gas analyzers that are originally calibrated for standard fuels such as gasoline, LPG, or CNG. The derived correction coefficients ensure accurate evaluation of blended fuel mixtures using standard commercial analyzers of air–fuel mixture composition.

Keywords: Petrol chainsaws, spark-ignition internal combustion engine, fuel mixtures, stoichiometric lambda coefficient, exhaust gas testing.

INFLUENCE OF TANK FILLING LEVEL AND INCLINATION ON THE DOSING PROCESS OF GRANULATED MATERIAL: A CASE STUDY OF TRITICALE

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Abstract: Uniform seed distribution is a critical factor that affects both the quality and yield of crops. In small and medium-sized farms, mechanical seeders with a working width of up to 3 meters are the most common. These machines are typically mounted on low- and medium-power tractors. To evaluate the influence of tank filling level and inclination on the precision of granulated material dosing, a laboratory test stand was used. The stand was equipped with a mechatronic drive system for the seeder’s dosing unit, enabling precise control of the seeding rate. Additionally, a prototype piezoelectric impact sensor was installed to count the number of seeds dispensed. The purpose of the study was to determine the effects of the angle of tilt angle relative to the vertical axis and the filling level on the seeding dose. The tilt of the tank by +15° from the vertical (simulating downhill operation) was found to reduce the mass of dispensed seeds by up to 8.15%, while a tilt (simulating uphill operation) increased it by up to 22.88%. However, the fill level of the tank did not have a statistically significant effect ($p = 0.05$) on the seeding rate. The results provide new information on factors that affect seeding precision and may support the development of improved control strategies for agricultural machinery.

Keywords: Discrete Element Method, precision agriculture, metering unit inclination, particle size distribution, granular fertilizer.

EXPERIMENTAL DETERMINATION OF THE PRESSURE CENTER SHIFT IN A WHEELCHAIR ANTI-ROLLBACK MODULE BASED ON CONTACT FORCE AND ROLLING RESISTANCE TORQUE

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Abstract: The efficiency of manual wheelchair propulsion is largely determined by rolling resistance, which depends on tire pressure, surface type, and wheel construction. A particularly significant source of energy loss arises from anti-rollback modules, where the contact between a rigid roller and an elastic tire generates an additional braking torque. The aim of this study was to experimentally determine the displacement of the pressure center (x_0) within the contact zone between the roller of the anti-rollback module and the wheelchair tire, as a function of the normal load (F_0) and the internal tire pressure (p_t). The experiments were conducted using a custom-built test stand equipped with a torque transducer and a force sensor. The results showed that increasing tire pressure reduces tire deformation, enhances contact stiffness, and decreases the braking torque by approximately 10–15%. The displacement of the pressure center decreased with rising pressure: for F_0 = 25 N, x_0 decreased from 11.6 mm (3 bar) to 9.1 mm (8 bar), and for F_0 = 200 N, from 18.5 mm to 16.0 mm. The linear model $x_0(F_0, p_t)$ achieved a determination coefficient of R^2 = 0.957, confirming strong agreement with experimental data. Maintaining tire pressure in the range of 6–8 bar minimizes rolling resistance torque, thereby improving propulsion efficiency and user comfort.

Keywords: wheelchair, rolling resistance, tire pressure, braking torque, contact mechanics.

DEVELOPMENT AND OPTIMIZATION OF SMALL-SIZED ARTICULATED HAMMERS FOR FEED MILL APPLICATIONS

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Abstract: This study addresses the development of optimized working elements for feed crushers, focusing on articulated hammer designs for efficient processing of plant-based agricultural waste into animal and poultry feed. The primary objective is to design small-sized feed crusher hammers that enhance comminution efficiency while reducing material usage. Four hammer prototypes with varying sidewall inclination angles (15°, 30°, 45°, and 60°) were developed and tested. Experimental results indicate a significant correlation between sidewall angle and hammer mass, with the most substantial weight increase (13.5%) observed between 15° and 30°. Further increases to 45° and 60° resulted in 5.3% and 1% mass gains, respectively. Grinding tests on corn grain revealed that hammers with a 15° inclination provided superior particle size distribution, achieving 92.6% of particles under 3 mm, and only 7.4% in the 3–4 mm range. These findings suggest that lower sidewall angles yield more stable and finer grinding performance. Moreover, geometric and surface area analysis confirmed that smaller angles contribute to reduced metal consumption, with the novel hammer designs using up to 31% less material than conventional rectangular hammers. The proposed designs present a promising approach to improving feed crusher efficiency through geometry-based hammer optimization, aligning with sustainability and cost-reduction goals in agricultural machinery development.

Keywords: Articulated hammer, sidewall inclination angle, metal reduction, grinding performance, feed processing, corn grain crushing.

NUMERICAL-EXPERIMENTAL PREDICTION OF THE LIFESPAN OF PERFORATED SIFTING SURFACES WITH HOLES OF COMPLEX GEOMETRY

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Abstract: The processes of separation of loose materials are realized with perforated sifting surfaces (PSS) of vibrating equipment. The presence of abrasive wear and vibration leads to a decrease in the thickness of the PSS, leading to stiffness loss and appearance of deformations in the form of cracks between the holes. The limit lifespan of the PSS is expressed by the appearance of cracks, which causes mixing of fractions of loose material and, accordingly, a significant decrease in the quality of the separation process. The developed methodology is based on numerical FE modelling (AbaqusCAE) and experimental observations, analysis and generalization of data. The experimental observation allowed to determine the intensity of wear of the PSS by its final thickness. FE modelling with the determined PSS thicknesses and variable external loads allowed identifying stress concentrators, checking the strength conditions and the absence of deformations. The study takes into account the design of the PFS in the form of parameters of basic circular and developed epicycloidal holes, parameters of partitions, properties of bulk material in the form of distributed load and operating time. The main result was the dependence of stresses in the critical zones of the PSS onits actual thickness, which, together with experimental data, enableded predicting final operational lifespan of thePSS. Using the research data, it is possible to make appropriate changes to the reliability of the PSS at the design stage, to develop technical specifications for diagnosing the critical thickness of the PSS during its service and to deepen the relevant area of research.

Keywords: Lifespan, abrasive wear, perforated sifting surfaces, finite element method, wear intensity, stress concentration.

APPLICATION OF COMPUTER PROGRAMS IN TECHNOLOGY

DESIGNING AN UNDERWATER TOWED VEHICLE USING NUMERICAL METHODS

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Abstract: The demand for energy resources and information exchange in the 21st century has brought significant developments. Numerous natural gas pipelines, power lines, telecommunications cables, and fiber optics run across the seabed. Offshore wind farms are being constructed in the Baltic Sea. These installations, like any technical devices, require supervision. In recent years, they have also become targets of terrorist attacks and sabotage. This work presents a concept for an underwater towed vehicle designed for monitoring underwater installations. It is a relatively low-cost solution that can be easily adapted to specific needs and purposes. The vehicle's shape is proposed, along with the method for calculating its dimensions, strength calculations using CAE software, and drag and lift force analysis using CFD software. A simple propulsion and depth control system is also proposed. The results of engineering calculations and numerical simulations are presented.

Keywords: Underwater Towed Vehicle, inspection of underwater infrastructure, CAE, CFD.

AN IMPROVED ALGORITHM FOR MEASURING THE POLARISATION PLANE ROTATION ANGLE

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Abstract: Sensors using tilted fibre Bragg gratings (TFBG) are now widely used and intensively developed due to their high precision, interference immunity, small size and low price. One of the parameters that can be measured with them is the angle of the light polarisation plane rotation (LPPR) propagating in the optical fibre. Existing TFBG sensors are based on measuring the power of light at a selected wavelength, which results in a limited measurement range and low precision. Other methods are based on advanced algorithms that process a selected range of the TFBG spectrum using a wavelet (DWT) or Fast Fourier Transform (FFT). However, achieving high precision over the entire measurement range is impossible due to the similar FFT and DWT coefficient variation. The present study establishes that the FFT coefficients calculated from various wavelength ranges of the TFBG spectrum for different rotation angles allow the formation of functions that are shifted with respect to each other as a function of the LPPR angle. This phenomenon was used to develop a method for calculating the measurement result from the values of the FFT coefficients. The values of the FFT coefficients were calculated for each of the selected spectrum fragments. Based on the chosen FFT coefficients calculated for angles 0,2,4,…,180°, a calibration was carried out. An algorithm was developed to select the FFT coefficients to be used to calculate the measured rotation angle. The developed solution allows to measure the light polarisation plane rotation angle with equal precision in the range of 0-180 degrees. Applying the proposed method has improved the accuracy by 8% compared to existing solutions.

Keywords: TFBG, Bragg, sensor, polarisation, measurement, angle.

INDOOR REAL-TIME LOCATION SYSTEM FOR RESOURCE LOCALIZATION IN MULTISTORY BUILDINGS

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Abstract: This paper presents the practical implementation and empirical evaluation of a commercial Bluetooth Low Energy (BLE) based Real-Time Location System (RTLS) within a multi-story university building, an environment characterized by significant architectural and electromagnetic interference. The study addresses a gap in existing research, which often focuses on simulations or single-story deployments, by analyzing the system's performance in a real-world, challenging setting. The system, integrated with enterprise-grade wireless infrastructure, was subjected to five test scenarios designed to assess its core functionalities: real-time tracking accuracy, reliability of geofencing and alarm features, and performance under severe interference and in a multi-floor context. The results demonstrated high reliability for room-level identification, achieving a location accuracy between 1.5 and 3.0 meters under normal operating conditions. Furthermore, location-based alarm and geofencing functions proved to be fully effective and instantaneous. However, the study identified two critical limitations: a complete failure of the system when the tracking tag was placed within a shielded metal enclosure, and an inability to distinguish between floors, which led to incorrect location projections and false alerts. The findings conclude that while BLE-based RTLS is highly effective for room-level asset management in standard office environments, its successful implementation in multi-story buildings is critically dependent on installing dedicated infrastructure on each floor and acknowledging its technological limitations in heavily shielded areas.

Keywords: indoor asset tracking, RTLS, bluetooth-based positioning, IoT in facility management, real-time location system.

SYSTEMATIC DRIFT CHARACTERIZATION IN LEGO EV3 ROBOT USING EXTERNAL VR TRACKING: EFFECTS OF ROUTE COMPLEXITY AND MOTION DYNAMICS

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Abstract: This paper presents a systematic methodology for quantifying and characterizing odometric drift in LEGO EV3 robots, focusing on discrete point-to-point movements and leveraging external HTC Vive motion tracking as an independent ground truth. The study was guided by three primary objectives: to develop a reproducible framework for drift measurement, to investigate how geometric complexity and turn dynamics of polygonal routes affect drift accumulation, and to evaluate the suitability of consumer-grade VR tracking for precise and scalable robot navigation assessment. Through 405 automated experimental trials spanning a comprehensive matrix of motor configurations and route geometries, the results reveal that both route complexity and turn size significantly influence drift patterns. Specifically, routes with higher geometric complexity (12–15 segments) exhibited 22% greater positional error than simpler paths, while medium-sized turns (61–110°) induced 18% more drift than smaller or larger angles. The analysis, employing advanced metrics such as the Normalized Drift Contribution Index and Allan Variance, identified systematic bias and random fluctuations as the dominant error regimes, and demonstrated that the external tracking approach achieved a mean positional accuracy of 0.55 cm—substantially outperforming traditional manual video analysis in both precision and efficiency. These findings confirm that the proposed methodology not only enables robust, high-resolution drift characterization but also provides a cost-effective and accessible validation framework for both educational and research applications. The work offers actionable insights for optimizing robot programming, calibration, and curriculum design, and establishes a scalable protocol for benchmarking autonomous navigation systems in real-world scenarios.

Keywords: Data processing automation, multicriteria trajectory evaluation, autonomous vehicles, lego mindstorms, spatiotemporal analysis.

USER INTERFACES OF SCIENTIFIC JOURNAL WEBSITES: A USABILITY AND ACCESSIBILITY ANALYSIS OF WEBPAGES DESIGNED BY HUMANS AND GENERATED BY ARTIFICIAL INTELLIGENCE

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Abstract: The issue of usability and accessibility in scientific journals is of crucial importance for effective knowledge communication, with a direct impact on user satisfaction. These aspects must be considered at every stage of website development, from needs analysis and planning, through design and implementation, to testing, maintenance, and further development. In the contemporary digital landscape, a discernible trend has emerged for websites to be designed by the principles of Universal Design (UD). Furthermore, tools based on artificial intelligence (AI) are playing an increasingly significant role in their development. The present study involved the execution of two independent experiments. In the first study, a comparative analysis was conducted between the existing website of a scientific journal and a prototype manually developed by a designer, adhering to UD principles. In the second experiment, the existing website was compared with two prototypes generated by different AI-based tools. The evaluation of usability, accessibility, and user satisfaction was conducted utilising a combination of methodologies, including the eye-tracking technique, an author survey, and automated tools designed to assess compliance with WCAG guidelines.

Keywords: Usability, accessibility, websites, user interfaces, AI, Universal Design, Scientific Journals, eye tracking.

TOP-LEVEL SMART CITY TRAFFIC MANAGEMENT SYSTEM WITH RFID-BASED ROAD EVENT DETECTION

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Abstract: Smart cities are transforming urban environments by integrating advanced technologies to optimize infrastructure, mobility, and public services. A key part of this transformation is the rise of semi and fully autonomous vehicles, which require seamless interaction with smart city systems to ensure safe, efficient, and adaptive transportation networks. These vehicles must be able to respond not only to static road features, but also to dynamic events that occur in real time. To address this challenge, an RFID-based system was developed that enables real- time information exchange between vehicles and a centralized smart city management platform. Through this communication, vehicles are able to receive timely updates about road conditions, hazards, and regulatory changes, allowing them to adapt dynamically to the evolving traffic environment. To validate the system's effectiveness, a mock-up smart city environment was constructed, replicating common urban traffic scenarios. Various road events, including construction zones, reduced speed areas, intersections, and other critical conditions, were simulated across the layout. RFID transponders embedded within the infrastructure continuously transmit event-specific data to RFID readers installed in vehicles. This system ensures that vehicles are consistently aware of their surroundings beyond what onboard sensors can detect, enhancing overall safety, traffic flow, and the integration of autonomous mobility into future smart cities.

Keywords: RFID, traffic management, dynamic identification, Smart City.

BRINGING RIGID BODIES TO LIFE: IMMERSION STUDY IN MOTION CAPTURE-BASED VIRTUAL REALISTIC ANIMATION OF VEHICLE MOVEMENT

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Abstract: Movement mapping in 3D space is a commonly applied computer technique. Due to the growing demand for games, films, and cartoons, developing methods for creating and generating high-realism object animations has become essential. Current advanced methods based on motion capture systems mainly focus on humanoid figures, while rigid bodies are often animated based on the keyframes or physics of objects. This study pursues an innovative approach to producing rigid body VR animations, which utilizes data acquired from a passive optical motion capture system. The key task is to obtain high-quality recordings with continuous trajectories of markers attached to tracked objects. The great demand is put on preprocessing of c3d data in MotionBuilder software, preparing the object and rigging the 3D model to obtain the highly realistic animation. It is further transferred to a VR environment where an ablation study is performed to analyze the effect of animation baking factors on users' perception. Comprehensive ablation studies concerning the VR immersive experience, involving the 10-person research group, are performed. They verified to which extent the real environment is engaging and convincing enough. The obtained results highlight that the animation has a high level of movement realism and corresponds with great user immersion.

Keywords: Motion capture, rigid body animation, realistic animation, VR animation, immersion.

ALCHEMYNAVIGATION: AN INNOVATIVE NAVIGATION SYSTEM FOR IMMERSIVE VIRTUAL WORLDS IN UNITY

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Abstract: Navigation systems play a crucial role in modern game engines by enabling intelligent agents to move effectively within virtual environments. This study presents a detailed evaluation of AlchemyNavigation, a custom navigation system developed for the Unity engine, and compares it with Unity’s built-in solution, NavMesh. A dedicated Unity-based application was created to execute identical testing scenarios for both systems. Key performance indicators such as frame rate, CPU usage, and memory consumption were measured under varying hardware configurations and agent densities. The results indicate that while NavMesh demonstrates superior stability and efficiency in large-scale simulations, AlchemyNavigation offers greater flexibility and adaptability. The findings support the idea that custom navigation tools can rival native solutions while offering additional functionalities tailored to specific project needs.

Keywords: Navigation systems, unity engine, navmesh system, AlchemyNavigation system.

THE ALGORITHM OF CHOSEN TFBG SPECTRUM FEATURES EXTRACTION

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Abstract: Tilted fibre Bragg gratings (TFBG) are used as sensors in the measurement of many physical and chemical quantities. Measurement is performed indirectly by analysing the power of light transmitted at a specific wavelength or in a selected range of light wavelengths. The wavelengths to be used are chosen arbitrarily by the researcher. However, the change of parameters of the TFBG grating requires the reselection of the wavelengths to be used in the measurement. Due to the fact that the TFBG spectrum most often shows the most significant sensitivity to changes in the measured parameters in the cladding modes region or a shift of the Bragg resonance, these are most often used in measurements. The need for human selection of the wavelength range to use was the motivation to undertake research into a method for automatic feature extraction of the TFBG spectrum, allowing the identification of the cladding mods’ minima and the range of wavelengths at which they occur and the wavelength at which the Bragg resonance occurs. In addition, the heights of the cladding mods’ minima and the Bragg mod were calculated. The developed algorithm allows the identification of chosen features of TFBG transmission spectra measured at P or S polarisation. It automates the detection of the range of cladding mods, identifying their minima and heights. Furthermore, it allows the determination of the position and height of the Bragg mod for TFBGs with tilt angles up to 6 degrees. The presented solution is a pioneering work providing a basis for automating the selection of wavelength ranges or spectrum features for use in TFBG-based sensors.

Keywords: TFBG, Bragg, fibre, feature, extraction.

APPLICATION OF THE M-ESTIMATOR IN THE WEEDER WORKING ELEMENT POSITION CONTROL

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Abstract: This paper highlights the problem of weed control in broad-row crops and discusses the construction of machines used for mechanical weeding and image processing algorithms. During cultivation, it is important to correctly position the working section of the weeder in relation to the row of protected plants.

Position control using a vision system has been proposed, which determines the position of plants in real time and calculates the desired setting of the working tool on this basis.

An algorithm was developed to determine the potential position of a row of plants in a video using linear regression. The coordinates of individual points were determined by classic image processing operations such as binarisation, median filtering and morphological transformations. In order to minimise the impact of accidentally detected weeds on the incorrect determination of rows, an M-estimator in the form of a Huber function was used.

The effectiveness of the proposed method was evaluated on the basis of field tests. The use of the Huber function reduced the average deviation of the potential location of the plant row from the reference position by 26% compared to the biased estimator.

Keywords: Image processing, M-estimator, Huber function. mechanical weeding.

DESIGN AND EVALUATION OF A 433 MHZ LORA-BASED WIRELESS COMMUNICATION SYSTEM FOR AGRICULTURAL MONITORING

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Abstract: This study presents the design and experimental evaluation of a low-cost data transmission system based on LoRa technology (433 MHz) for applications in precision agriculture. The aim of the study was to design, implement, and test a low-cost, energy-efficient system capable of wirelessly transmitting information from sensors deployed in agricultural fields—such as soil moisture, temperature, and sunlight data.

The tests were conducted with three transmission rates (0.1, 1.0, and 10 kbps) and varying bandwidths and spreading factors. The results showed that transmission at 0.1 kbps with bandwidths of 7.8 kHz and 20.8 kHz achieved less than 1% packet loss up to 150 m. However, this configuration required up to 140 times higher energy consumption compared with high-rate settings (10 kbps). At 10 kbps, almost all packets failed to reach the receiver at distances exceeding 100 m. Variations in reception between test paths were observed and were attributed to terrain and structural conditions (e.g., building reflections), which affected both RSSI and SNR values.

The results demonstrate that LoRa technology operating at 433 MHz can provide a reliable foundation for autonomous, distributed monitoring systems in agriculture. This study provides novel quantitative evidence of how specific transmission parameters influence the trade-off between communication reliability and energy efficiency under real field conditions. The findings offer practical guidelines for designing optimized LoRa-based telemetry systems, supporting more informed decision-making in irrigation, fertilization, and crop protection.

Keywords: Wireless transmission, low-cost system, LoRa, precision agriculture.

EVALUATION OF POINT CLOUD FILTERING TECHNIQUES IN OBJECT DIMENSIONING VIA VISION-BASED GEOMETRIC MEASUREMENT SYSTEMS

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Abstract: In this study, we evaluate the influence of different cloud point filtering algorithms on the process of accurately dimensioning objects. This is critical in vision-based measurement systems, particularly for logistics and packaging applications. We assess three smoothing algorithms: bilateral filtering, statistical outlier removal, shadow filtering algorithm alongside baseline unfiltered data. We extract object dimensions by fitting a convex hull applied to the processed point cloud, and evaluate across different positions, parcel types, and edge lengths. We employ various statistical metrics to evaluate algorithm performance. Our research utilizes point clouds of cardboard boxes for evaluation, collected with the ToF Kinect v2 depth camera. Study includes both cuboidal objects and distortion-simulated shapes. We assessed a dataset of 639 point cloud samples. The data was collected under controlled lighting with top-down camera orientation and processed using the PCL library. Our findings show that shadow filtering consistently and significantly outperformes the other methods on standard cuboid geometries. However, in the presence of shape distortions, it occasionally introduces large-magnitute outliers, reflecting overly aggressive filtering behavior. Additionally, we observe scale-dependent error pattern across all object types, with dimensional accuracy decreasing as object size increases.

Keywords: Point cloud processing, Time of Flight depth camera, filtering algorithms.

EVALUATING THE IMPACT OF THE TOOL AND ADDITIONAL FRUIT CUTTING ON CHANGES OF PITTED CHERRIES USING DIGITAL VOLUME CORRELATION WITH COMPUTED TOMOGRAPHY

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Abstract: The paper presents the use of computed tomography examinations to assess the effect of the pitting process on the structure of cherry fruit. The Digital Volume Correlation (DTC) method was used to assess fruit pitting. The aim of this article is to evaluate internal changes in fruit volume, measure deformation, changes in weight, and changes in cherry volume as a result of pitting with various tools. For pitting there are using conventional cross tool head and innovative pitting technology using a rotary knife and a three and four-needle head. The modern VG Studio computer program, designed for tomographic reconstructions, was used for the qualitative analysis of pitting in cherry fruit. The use of modern tools for the analysis of tomographic reconstructions facilitates a range of procedures, including qualitative analysis, measurements, porosity analysis, division into materials, determination of the share of individual materials. Additionally, as evidenced in the present study, digital volume correlation is a valuable tool. Tomographic reconstructions allowed for non-destructive measurements of deformations and damage to the fruit during the pitting process. The voxel displacement tracking method was used to determine the deformations of cherry fruit caused by different pitting technologies. The research results are presented in graphical form, including histograms that taking into account the changes in mass and volume deformations. Furthermore, an analysis of fruit mass losses was performed in order to validate the DVC method. The relative change in fruit volume and mass caused by the pitting process was assessed. The research results indicate that the innovative pitting method with three-needle head is characterized by less deformation and damage to the fruit and a smaller loss of the pericarp volume. The study points that three-needle and four-needle tools result in a reduced degree of fruit degradation in comparison to cross-shaped tools. However, when assessing the exterior surface, it should be noted that additional cutting of the fruit facilitates the removal of the pit and reduces damage to the fruit during the process.

Keywords: X-ray, computed tomography, digital volume correlation, material deformation, non-destructive testing.

GEO-INFORMATIC TECHNOLOGIES SUPPORTING THE ANALYSIS OF THE STRUCTURE OF STORMWATER SYSTEM CATCHMENTS

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Abstract: Within the study, a GIS database was created for use in modeling stormwater catchments of urbanized areas. The database prepared with QGIS open-source geo-information software was the basis for the catchment investigation used in the next step to prepare the statistical analysis of the data and their visualization using R programming environment. The analyzed multidimensional data concerning urbanistic and infrastructure aspect was considered both from temporal and spatial points of view. An attempt was made to analyze the spatial structure of the urbanized areas and the related degree of imperviousness using the entropy measures taken from information theory. Using plugins and exporting preliminarily prepared and pre-processed data for external open source software, namely RStudio and SWMM, allowed for optimization of conduit routing and the location of stormwater inlets, as well as the selection of stormwater management methods in the essence of sustainable water retention in urbanized areas. The work also includes different classical calculation methods used in design practice to determine the amount of stormwater to be discharged from a paved area as well as a comparison of the calculation results for the adopted assumptions and structure of the surfaces of urbanized areas.

Keywords: Geographic Information System, QGIS, structure analysis, stormwater system catchments.

APPLICATION OF ENTROPY-BASED INDICES FOR BIOFILM COMMUNITY STRUCTURE ANALYSIS IN BIOINDICATION RESEARCH OF AQUATIC ENVIRONMENT

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Abstract: Dynamic industrial and urban development, as well as climate change, increase anthropogenic pressure on aquatic ecosystems. One of the factors contributing to the degradation of surface water quality is stormwater, which transports pollutants from urban areas to storm sewer systems and subsequently to rivers. In this study, bioindication based on the structure of biofilm communities in the Bystrzyca River was used to assess the impact of stormwater on the status of the waters. Research material was collected from five points located along the river section, including one reference point upstream of the stormwater discharge. Twelve selected species of freshwater algae were analysed, and their abundance was determined during subsequent sampling dates. The data were analysed using entropy-based indices derived from information theory (e.g. the Shannon Index) by R statistical programming language (RStudio), which made it possible to assess both diversity and the structural balance of the communities. The results indicate clear differences between the points exposed to stormwater discharge and the reference site. The use of an approach based on entropy-based indices allows for a precise assessment of the impact of stormwater on biofilm structure and confirms the validity of biological methods application in surface water quality monitoring.

Keywords: Entropy-based indices, biofilm community structure, bioindication, aquatic environment, water quality, data visualization.

THE USE OF CAD/CAM MODELING AND 3D PRINTING TO EXTEND THE FUNCTIONALITY OF A MICROSCOPE TO THE LEVEL OF AN AUTOMATIZED ELECTRONIC EYE FOR THE STUDY OF ACTIVATED SLUDGE

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Abstract: With the growth of the population, the amount of pollution generated by people is also increasing. The operation of wastewater treatment plants is, in most cases, based on the mechanical separation of solid pollutants and the removal of undesirable chemical compounds from liquids with application of biological methods. Living organisms – such as bacteria, rotifers, ciliates, nematodes, and others – are used for this purpose. They participate in the processing of carbon, nitrogen, and phosphorus compounds, but are living organisms susceptible to the effects of substances that are toxic to them. Monitoring the operation of a bioreactor is crucial for its functionality, and the use of an electronic eye enables activated sludge evaluation as well as process control with minimal human resource involvement. The electronic eye requires appropriate design to collect material for investigation as well as perform the acquisition and analysis of digital images. The CAD/CAM technology and the use of additive manufacturing (3D printing) allow for the rapid production and real-world testing of individual modules of the electronic eye under actual conditions. During the work related to the development of the electronic eye station, sets of components were modeled in Autodesk Inventor and then printed using PLA filaments and ABS reinforced with fiberglass. A wide range of materials allows for the creation of both working prototypes and fully functional components with increased durability. Among other things, the components were designed to modify a microscope stage to enable electronic positioning, a camera holder, and a lighting module.

Keywords: CAD/CAM modeling, 3D printing, electronic eye, optic microscope, image acquisition, automatic image analysis, activated sludge.

APPLICATION OF EXPLAINABLE ARTIFICIAL INTELLIGENCE METHODS (XAI) TO THE ANALYSIS OF MODELS PREDICTING THE QUALITY OF SURFACE WATER AND TREATED WASTEWATER

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Abstract: Artificial intelligence and machine learning models are often used in environmental engineering, including for predicting the quality of wastewater from treatment plants and surface water as well as drainage systems. These models are trained to quickly and effectively diagnose symptoms of failure at treatment plants or screening tests for surface water quality changes. Scientists usually choose black-box models for this purpose, as they predict the correct data classes with high accuracy. This is due to the complexity of the relationships that can be modeled using such models. However, these models are not interpretable, and this approach often causes errors in their training, does not allow for sufficient model improvement and interpretation. Explainable artificial intelligence methods (XAI) help researchers train models in such a way as to eliminate as many errors as possible and allow them to interpret the model's decisions both in terms of the importance of variables in the model's output and the model's individual response to a specific observation. Moreover, another XAI method involves training surrogate approximation models, which, unlike black-box models, are interpretable. The study is focused on presenting the available XAI methods, applying them to the selected machine learning models that classify water from wastewater treatment plants and surface water, as well as comparing them in the context of both models.

Keywords: Machine learning, data classification, explainable artificial intelligence, water, wastewater, surface water.

ARTIFICIAL AND COMPUTATIONAL INTELLIGENCE

PREDICTIVE MODELING AND DECISION SUPPORT USING MACHINE LEARNING IN BUSINESS CONTEXTS

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Abstract: With the growing emphasis on data-driven decision making, artificial intelligence (AI) methods have become increasingly important in managerial practice. This study aims to develop and evaluate supervised machine learning models for predicting customer brand loyalty and satisfaction based on selected behavioral, attitudinal, and programmatic attributes. This paper presents a lightweight decision support application that leverages machine learning techniques - specifically, Artificial Neural Networks (ANN) and Support Vector Machines (SVM) - to predict key customer-related indicators: brand loyalty and satisfaction. The models were trained on behavioral and attitudinal inputs and achieved excellent predictive performance, with test accuracies reaching 100%. The novelty of this study lies in the deployment of these models within an intuitive graphical user interface (GUI), enabling real-time predictions by non-technical users. Unlike traditional approaches focused solely on algorithm development, this research demonstrates a practical implementation of computational intelligence for operational and tactical business decision-making. The tool supports managers in profiling customers, optimizing loyalty programs, and enhancing customer engagement strategies through accessible AI-powered insights.

Keywords: Machine learning, machine learning, neural networks, support vector machines, decision trees, decision support systems, customer satisfaction, brand loyalty.

DEEP LEARNING-BASED STOCK PRICE TREND PREDICTION USING IMAGE REPRESENTATIONS OF MARKET CHARTS

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Abstract: This study explores a novel approach to stock price trend prediction by leveraging deep learning techniques applied to image representations of market charts. Traditional numerical methods for forecasting stock prices often struggle to capture complex market patterns and investor sentiment reflected in price movements. To address this challenge, we transform time-series stock data into candlestick chart images, which visually encode market behavior over time. These images are then processed using convolutional neural networks (CNNs), which are well-suited for pattern recognition tasks in visual data. The proposed method is evaluated using historical stock data from multiple companies across various sectors. We assess model performance based on trend classification accuracy and compare results with conventional machine learning algorithms using raw numerical features. Experimental findings demonstrate that CNN-based models trained on chart images significantly represent results compared to traditional approaches in detecting short-term trend directions, indicating the viability of image-based representations in financial forecasting tasks. Additionally, this research highlights the potential of combining visual financial data with advanced AI techniques to gain deeper insights into market dynamics. The proposed framework offers a scalable, automated solution for enhancing decision-making processes in algorithmic trading and investment analysis.

Keywords: Deep learning, prediction, image recognition.

MICROWAVE REFLECTIVE TOMOGRAPHY SYSTEM FOR INDOOR USER LOCALIZATION USING RF SENSING AND SIGNAL RECONSTRUCTION TECHNIQUES

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Abstract: This paper presents the development of a distributed system for indoor user detection and localization based on reflective microwave signal analysis using radio frequency (RF) tomography. The work focuses on the integration of Doppler radar principles with tomographic reconstruction techniques, enabling the mapping of human presence and motion patterns in closed environments. The hardware infrastructure includes a microwave probe operating at 10 GHz, equipped with a microstrip antenna and a Cortex-M4-based STM32 microcontroller supporting data acquisition via a CAN bus network. A key contribution lies in the real-time collection and synchronization of probe data with high-frequency precision, allowing consistent input for signal processing and machine learning models. This approach compensates for multipath interference typical in indoor environments by reconstructing spatial signatures based on differential RF responses. The paper discusses the system architecture, probe calibration methodology, signal sampling procedures, and the implementation of data preprocessing techniques. The final section outlines the use of neural networks and inverse modeling strategies to extract movement characteristics and spatial awareness from the measured signals. Results demonstrate the feasibility of obtaining a tomographic radar portrait of human motion, enabling effective indoor monitoring through the synergy of microwave engineering and AI-based analytics.

Keywords: Radio frequency tomography, reflective microwave sensing, indoor localization, doppler radar, signal reconstruction, real-time monitoring, microstrip antenna, machine learning, embedded systems, CAN bus synchronization.

OPTIMIZATION OF MACHINE LEARNING MODELS FOR EFFECTIVE ANOMALY DETECTION IN INDUSTRIAL IOT SYSTEMS

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Abstract: In the era of increasing Industrial Internet of Things (IIoT) devices, effective and efficient anomaly detection in network traffic is crucial for ensuring the security and reliability of industrial systems. This paper presents research findings on the application and optimization of multi-parameter machine learning methods based on decision tree algorithms (RandomForest, ExtraTrees, AdaBoost, XGBoost, CatBoost) for detecting various threats in data from IoT networks. The research utilized the dataset containing realistic network traffic and attack simulations. The analysis included evaluating the impact of various data preparation strategies, such as class balancing (Over/UnderSampling), data aggregation in time windows, and sampling on model performance. Optimization was also performed through the selection of the most significant features and hyperparameter tuning, with a particular focus on the XGBoost model. The results demonstrate that appropriate data preparation and model parameter optimization, especially for XGBoost, enable high detection accuracy (over 92% for binary classification and 87% for multi-class classification post-optimization) while maintaining computational efficiency (short training time, small model size). The presented approach significantly reduces the amount of data needed to detect a threat and reduces the computing power requirements needed for security systems. The research results can be used to develop more resilient and efficient cybersecurity systems for industry, smart city and IIoT environments.

Keywords: Anomaly detection, Machine Learning, XGBoost, Industrial Internet of Things, IIoT, Network Security, Data Optimization, Computational Methods in Engineering, cybersecurity, smart city, Industry 4.0.

REAL-TIME MONITORING AND OBJECT DETECTION IN MULTIPHASE INDUSTRIAL PROCESSES USING A MULTIMODAL ULTRASONIC TOMOGRAPH

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Abstract: This paper presents an advanced multimodal ultrasonic tomography system developed for monitoring and optimizing multiphase industrial processes. The proposed solution integrates deterministic time-of-flight (TOF) based reconstruction with machine learning techniques for object detection within heterogeneous media. The tomographic system comprises a high-performance signal acquisition platform equipped with an array of ultrasonic transducers operating in both transmission and reflection modes over a wide frequency range (40 kHz to 1 MHz). Real-time visualization of density changes is achieved using the damped Gauss-Newton method with Tikhonov regularization. Additionally, an intelligent detection module utilizes K-Nearest Neighbors (KNN) classification based on waveform characteristics to localize and estimate the dimensions of inclusions with high accuracy. Experimental studies, including crystallization monitoring and phantom object detection, demonstrate the system's effectiveness in identifying spatial variations and objects in complex flow environments. The tomograph's architecture supports scalability and algorithmic customization, making it a versatile platform for process control in industrial applications. Achieved reconstruction quality and object detection precision, with a determination coefficient up to 93%, confirm the utility of the proposed multimodal system for comprehensive process diagnostics.

Keywords: Ultrasonic tomography, multiphase processes, time-of-flight, machine learning, inverse problem, K-nearest neighbors, crystallization monitoring, process control, object detection, real-time diagnostics.

OPTIMIZING TRAFFIC VOLUME PREDICTION: LINEAR REGRESSION VS. RANDOM FOREST

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Abstract: In this work, two series of regression models were built and tested – one consisting of models based on a machine learning method in the form of Random Forest algorithm, and the other based on linear regression. The models were fitted to the data on traffic flow within chosen intersections in the city of Rzeszow and optimized by manipulating the explanatory variables and input parameters. Construction process and optimization efforts have been extensively documented in this article. The performance of both types of models was gauged in a series of tests, including fitness to the empiric data, residual distribution, new data prediction, and model training time. Both kinds of models passed the tests favourably, while pointing out some of the advantages and disadvantages of the regression methods used. The results are illustrated on various charts and the most interesting parts of the program code used are presented.

Keywords: Machine learning, linear regression, Random Forest, computer network traffic flow.

COMPARATIVE ANALYSIS OF MACHINE LEARNING MODELS FOR MULTICLASS ANOMALY DETECTION IN IOT NETWORK TRAFFIC USING THE RT-IOT2022 DATASET

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Abstract: Nowadays, the development of technology, especially in the area of the Internet of Things (IoT), is proceeding at a dizzying pace. With this development comes an increasing number of threats that can affect IoT network users. Network traffic is increasingly becoming the target of various attacks, and the consequences of these attacks depend on the type of attack and the attacker's objectives. The purpose of the paper is to analyze the application of machine learning and artificial intelligence algorithms to analyze data for detecting anomalies and threats in IoT networks. The paper compares less complex machine learning algorithms with more advanced artificial intelligence methods in terms of performance and prediction accuracy. The research used the "RTIoT2022" 2022 dataset, which enabled the identification of specific patterns of attacks on IoT networks and the evaluation of the effectiveness of selected detection methods.

Keywords: Machine Learning, Linear Regression, Random Forest, SVM, KNN.

KNOWLEDGE DISTILLATION FOR MULTIMODAL EMOTION AND SPEAKER RECOGNITION IN EDGE DEVICES

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Abstract: This paper presents a study on the implementation of knowledge distillation techniques for cross-modal human perception tasks in embedded systems. The research involved developing a multimodal "concierge" device designed to detect individuals and assess their emotional state based on visual and auditory inputs. A set of four specialized teacher models was compared to a unified multimodal model. These teacher models served as the basis for training smaller, resource-efficient student models through a knowledge distillation process that included soft label supervision and the application of the Temperature SoftMax function. The main objective was to enable real-time operation on limited-resource platforms such as Raspberry Pi 4 and Jetson Nano while maintaining recognition accuracy above 94%. Comparative analysis revealed that student models, although slightly less accurate than their teacher counterparts, demonstrated substantial improvements in inference speed. Notably, the multimodal student model achieved an 18.18% inference time reduction on Jetson Nano, validating the approach for practical deployment in embedded AI systems.

Keywords: Knowledge distillation, cross-modal perception, embedded systems, soft labels, temperature softmax, emotion recognition, speaker recognition, deep learning optimization.

ADVANCED MACHINE LEARNING ALGORITHMS FOR ELECTRICAL IMPEDANCE TOMOGRAPHY IN UROLOGICAL DIAGNOSTICS

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Abstract: This paper presents a novel approach to the application of machine learning methods in mobile wearable diagnostic systems based on Electrical Impedance Tomography (EIT) for the assessment and monitoring of urinary tract function. The proposed solution integrates hardware innovations with advanced data processing techniques to support non-invasive, continuous diagnostics of bladder activity. The core of the system is an EIT measurement device built with a 16-bit ADC and FPGA-controlled analog front-end capable of generating sinusoidal currents and acquiring high-resolution voltage signals. A set of proprietary algorithms addresses the inverse problem of image reconstruction from impedance data. To enhance diagnostic capabilities, the study investigates several machine learning models, including neural networks and regression-based methods. Training data were generated through extensive simulations reflecting various physiological states of the bladder. A unique methodological contribution involves the training of a separate model for each image pixel significantly improving spatial reconstruction fidelity. Comparative analysis reveals that neural network-based models (NNET) offer the highest reconstruction accuracy, while regression models (e.g., LARS) provide faster yet less precise outcomes. The work underscores the potential of hybrid systems combining deep learning and fuzzy logic elements to yield interpretable medical diagnostics. Future research directions include real-time integration with other modalities, such as ultrasound, and optimization of learning algorithms for clinical deployment.

Keywords: Electrical impedance tomography, urological diagnostics, bladder monitoring, neural networks, machine learning, deep learning, image reconstruction, wearable medical devices, fuzzy logic, inverse problem.

POWER LAW DISTRIBUTIONS EVIDENCES IN CACHE MEMORY BYTES – WINDOWS PERFORMANCE COUNTER

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Abstract: In this paper, the main attention is paid to the analysis of Windows operating system counter Memory Cache Bytes. Thanks to the Windows Perfmon tool, it was possible to gather long time series that show interesting, from statistical point of view, behaviour of different Windows Desktop operating system versions (Windows 7, 8, 10) in idle and loaded mode. The comparative analysis of this counter behaviour, understood as time series that represents cache memory, will show that based on internal memory management mechanisms power law distributions are omnipresent phenomena. We focused on McCulloch, Kout methods and Hill estimator for calculations of alpha stability index and Q-Q plot with Anderson-Darling test for distribution normality test. All of the tested time series indicated the existence of deep probability distribution heavy-tails for extreme values, confirming that operating system has to deal with anomalous cache memory behaviour. This feature is common for all tested 64-bit hardware configurations regardless of the workload mode.

Keywords: Operating systems, counters, performance tests, long-term behaviour, long-range dependencies, Lévy processes, power laws.

ADVANCING CHEMICAL COMPOUND CLASSIFICATION WITH OPTICAL TOMOGRAPHY AND RESIDUAL NEURAL NETWORKS

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Abstract: This paper presents an innovative approach to chemical compound identification by integrating optical tomography with Fourier Transform Infrared Spectroscopy (FTIR) and deep learning algorithms based on residual neural networks (ResNet). The research addresses the limitations of traditional analytical techniques in terms of speed and equipment complexity by proposing a method that significantly enhances the classification accuracy of 120 different chemical substances. A dedicated optical measurement system was constructed, and FTIR spectra were collected across a wavelength range from 1000 to 2500 nm. The spectra were processed using a ResNet model specifically designed to extract meaningful features from one-dimensional input signals. Performance metrics such as Top-3 categorical accuracy, area under the curve (AUC), precision, and recall were used to validate the model. Results demonstrate that the proposed ResNet-based system outperforms conventional convolutional neural networks (CNNs), achieving a Top-3 accuracy of 0.78 and an AUC of 0.91. These outcomes confirm the system's potential to improve the effectiveness of chemical analysis in both laboratory and industrial applications. The proposed methodology not only accelerates the identification process but also enhances its reliability by reducing the influence of measurement noise and overlapping spectral characteristics. The study offers a foundation for future development of scalable and automated chemical recognition systems using advanced artificial intelligence techniques.

Keywords: Optical tomography, FTIR spectroscopy, residual neural network, ResNet, chemical compound classification, machine learning, deep learning, spectral analysis, AI in chemistry.

PHYSICS-INFORMED NEURAL NETWORK FOR IDENTIFYING THE HYSTERESIS MODEL OF THE VACUUM-PACKED PARTICLES TORSIONAL DAMPER

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Abstract: The Vacuum-Packed Particles Torsional Damper (VPPTD) is a novel adaptive device for vibration mitigation in rotating mechanical systems. It consists of elastic silicone membranes and rigid rings forming a hermetically sealed chamber filled with granular material. The relative rotation between the rings, constrained by the membranes' elasticity, results in a hysteretic torque-twist response, which becomes stiffer with increasing underpressure due to enhanced intergranular friction. Experimental investigations confirmed that the VPPTD behavior can be represented by a symmetric hysteresis loop, with torque increasing as a function of twist angle and underpressure. A theoretical model was proposed incorporating viscous damping, linear and nonlinear stiffness, and frictional components, with all parameters assumed to depend on the level of underpressure. Given the complexity of parameter identification, a Physics-Informed Neural Network (PINN) approach was developed. Using experimental data (torque, twist angle, and twist direction), the PINN predicted four key model parameters without access to direct target values. The loss function minimized the difference between model-generated and experimental torque curves. A sensitivity analysis evaluated the influence of hyperparameters, training conditions, and initialization strategies on prediction accuracy and convergence. The final model showed effective comparison with experimental results across different underpressure levels and enabled the derivation of functional relationships between model parameters and underpressure. This study demonstrates the effectiveness of PINNs in identifying hysteresis model parameters and provides a base for future papers on active control of VPPTD systems and modeling of more complex hysteresis behaviors.

Keywords: Vacuum-packed particles torsional damper, adaptive damping, hysteresis loop, model parameters identification, physics - informed neural network, unsupervised learning.

EVOLUTIONARY TRAINING OF RECURRENT NEURAL NETWORKS FOR INDUSTRIAL DATA ANALYSIS AND ENGINE LOAD FORECASTING

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Abstract: This paper presents an innovative approach to industrial data analysis using evolutionary algorithms for training recurrent neural networks (RNNs). The research focuses on quality monitoring and process control in manufacturing lines, emphasizing the classification of products and prediction of the Engine Load parameter based on time-series sensor data. A hierarchical evolutionary algorithm (H-ESP) was adapted and extended to train both the hidden recurrent layers and dense layers of neural networks, enabling robust optimization and improved generalization. Additionally, a custom feature selection and recombination mechanism at the network level was introduced to enhance convergence and performance. A novel compression technique utilizing autoencoders was employed to reduce the dimensionality of sensor inputs for time-series modeling. Two predictive models were evaluated: an evolutionary-trained classifier for parcel categorization and a GRU-based regressor for Engine Load forecasting. Results demonstrated high model accuracy (94.04% classification and 5.49% RMSE in regression), validating the effectiveness of the proposed methodology in real-world industrial environments. The solution offers a scalable framework applicable to various sectors, including energy systems and smart manufacturing.

Keywords: Recurrent neural networks, evolutionary algorithms, industrial automation, time-series prediction, engine load forecasting, GRU, autoencoder, neural network training, process control, smart manufacturing.

NEURAL IMAGE RECONSTRUCTION IN A HYBRID ELECTRICAL TOMOGRAPHY SYSTEM FOR REAL-TIME INDUSTRIAL MONITORING

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Abstract: This paper presents the design and implementation of a novel hybrid electrical tomography system incorporating advanced microcontroller and FPGA architectures with neural image reconstruction algorithms for industrial applications. The system was developed to support non-invasive, real-time monitoring of technological processes with enhanced image precision and processing efficiency. The tomography setup included a dedicated measurement tank with a 32-electrode array in a 2×16 configuration, enabling quasi-3D (2.5D) data acquisition. The core of the system utilized dynamically reconfigurable FPGA components to facilitate high-speed data collection, processing, and remote system configuration through a UART communication interface. Central to the innovation was the integration of neural network-based reconstruction algorithms capable of processing complex impedance data, significantly improving the spatial resolution and fidelity of tomographic imaging. Experimental tests demonstrated the system’s capability to detect subtle material changes, indicating strong potential for implementation in diagnostics, industrial process control, and quality assurance systems. This research highlights the synergistic potential of combining hardware-accelerated computation with artificial intelligence in the field of process tomography.

Keywords: Electrical impedance tomography, neural networks, FPGA, industrial monitoring, image reconstruction, real-time systems, signal processing, machine learning, hybrid systems, process control.

MACHINE LEARNING METHODS FOR IMPROVED POSITIONING ACCURACY IN BLUETOOTH LOW ENERGY ASSET TRACKING SYSTEMS

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Abstract: This paper presents an analysis of indoor positioning systems based on Bluetooth Low Energy (BLE) beacons. BLE-based systems are commonly used in asset tracking solutions due to their low power consumption, cost-effectiveness, and ability to provide real-time location data within indoor environments. The research investigates the accuracy and reliability of trilateral positioning methods under various environmental conditions, focusing on electromagnetic interference impacts. Five distinct testing scenarios were conducted with controlled placement of beacons across diverse environments: server rooms with high interference, corridors with moderate infrastructure interference, and open spaces with minimal interference. Testing was performed using multiple mobile devices to ensure consistency of results. An ensemble learning approach combining transformer architectures with specialized positioning networks was implemented, achieving a prediction confidence of 0.974 while maintaining an acceptable error rate. The findings indicate that the primary factors affecting accuracy are not merely physical obstacles but rather the predictability and stability of the signal propagation environment. The proposed methodology offers significant improvements for indoor positioning in environments where traditional GPS signals are unavailable or unreliable.

Keywords: indoor positioning, RSSI, bluetooth low energy, beacon, wireless localization, trilateration, asset tracking, real-time location system.

COMPUTER-AIDED SYSTEM WITH MACHINE LEARNING COMPONENTS FOR GENERATING MEDICAL RECOMMENDATIONS FOR TYPE 1 DIABETES PATIENTS

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Abstract: The paper presents an original method for processing medical data derived from a type 1 diabetes patient, aimed at generating therapeutic recommendations to improve the quality of the patient's treatment. This problem is characterized by high complexity, the need to tailor the method to the available data, and the inability to conduct experiments other than computer simulations. The proposed approach introduces novel solutions, including the development of a computer model of a person with diabetes, the adaptation of a genetic algorithm to the specific problem, and the use of a time series similarity criterion for blood glucose concentration. The method was designed for patients using an insulin pump and a continuous glucose monitoring system. In the research section, data from five real patients were analyzed using the developed method, and the results indicated that it may be effective in supporting real-world therapy.

Keywords: Computer-aided therapy, type 1 diabetes, genetic algorithm, Type 1 Diabetes Direct Simulator, computer simulations.

VISUAL INSPECTION OF SYMMETRIC MACHINE COMPONENTS USING ARTIFICIAL INTELLIGENCE ALGORITHMS AND POLAR TRANSFORMATION

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Abstract: Modern manufacturing facilities, especially in mass production environments, place increasing demands on automation and the effectiveness of quality control systems. In response to these needs, artificial intelligence (AI) methods—particularly in the field of visual inspection—are gaining growing attention. Special focus is given to rotationally symmetric components such as shafts, bearings, and pistons, where defects can lead to serious failures and production downtime. A review of the scientific literature indicates that machine vision techniques, deep learning, and neural networks are increasingly supporting diagnostic processes, enabling precise detection of surface defects. This paper presents an innovative approach to quality control of rotationally symmetric components using neural networks and image transformation into polar coordinate systems. Converting image data from two-dimensional to one-dimensional formats not only leverages the inherent symmetry of components but also significantly reduces the memory and computational demands of the system. The proposed method is compared with YOLO and RT-DETR algorithms operating on standard 2D images, demonstrating higher effectiveness and faster performance in the context of repetitive data typical for mass production. The implementation of such solutions substantially enhances the reliability of diagnostic systems and enables faster, more precise decision-making in industrial environments, positioning AI as a key component of the future of intelligent maintenance systems.

Keywords: Machine diagnostics, quality control, neural networks, symmetric elements, defect detection.

A CNN-DRIVEN MODEL WITH ADAPTIVE FEATURE FUSION FOR POLISH NATIONAL DANCE MUSIC RECOGNITION

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Abstract: Mel spectrograms have been widely applied in music identification, often yielding successful results when combined with well-known pre-trained classification methods such as VGG16, DenseNet121, or ResNet50. However, the acquired performance may still be improved by employing fusion techniques and proposing a dataset consisting of more samples, which generally demonstrate superior results. Thus, a novel approach employing these methods with the formerly pre-trained classifiers has been introduced. The core innovation of our study is feature fusion utilizing Mel spectrograms, spectrograms, scalograms, and Mel-Frequency Cepstral Coefficients plots, created based on audio recordings from the created dataset encompassing Polish national dance music. The adaptive model is suggested as a mechanism adjusting the highly relevant features for Polish national dance music identification. Furthermore, the use of SHapley Additive exPlanations makes it possible to visualize which parts of the input feature maps are crucial to the model fusion decisions. Subsequently, the most prevalent classification metrics were employed including accuracy, precision, recall, and F1-score to compare the obtained results with state-of-the-art. Hence, the present method yields highly satisfactory results, exceeding 94% accuracy. Consequently, this study not only sets a new benchmark for Polish national dance recognition but also underscores the broader potential of multi-representation fusion as a general blueprint for next-generation audio classification systems.

Keywords: Machine learning, convolutional neural networks, Polish national dance music identification, SHapley Additive exPlanations, feature fusion.

K4F-NET: LIGHTWEIGHT MULTI-VIEW SPEECH EMOTION RECOGNITION WITH KRONECKER CONVOLUTION AND CROSS-LANGUAGE ROBUSTNESS

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Abstract: Speech emotion recognition has been gaining importance for years, but most of the existing models are based on a single signal representation or conventional convolutional layers with a large number of parameters. In this studies, we propose a compact, multi-representation architecture that combines four images of the speech signal: spectrogram, MFCC features, wavelet scalogram and fuzzy-transform maps. Moreover, the application of Kronecker convolution for efficient feature extraction with an extended receptive field is shown. Another novelty is cross-fusion, a mechanism that models interactions between branches without a significant increase in complexity. The core of the network is complemented by a transformer-based block and language-independent adversarial learning. The model is evaluated in a scenario of five-fold cross-linguistic tests covering four data corpora for four languages: English, German, Polish and Danish. It is trained on three languages and tested on the fourth, achieving a weighted accuracy of 96.3%, Additionally, the impact of selected activation functions on the classification quality is investigated. Ablation analysis shows that eliminating Kronecker convolution reduces the efficiency by 5.6%, and removing the fuzzy transformation representation by 4.7%. The achieved results indicate that combining Kronecker convolution, multi-channel fusion and adversarial learning is a promising direction in building universal, language-independent emotion recognition systems.

Keywords: Features fusion, speech emotion recognition, Kronecker convolution, speech signal processing.

PULMONARY DISEASES IDENTIFICATION: DEEP LEARNING MODELS AND ENSEMBLE LEARNING

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Abstract: Deep learning models provide enormous support for medical imaging by understanding lungs conditions and indicating the multi lung diseases. Due to the global burden of respiratory illnesses, their prevention and control is of great importance. Thus, this study focuses on the effectiveness of various deep learning architectures in diagnosing pulmonary diseases from chest X-ray images. Five deep convolutional neural networks are involved: VGG16, DenseNet-121, ResNet-50, MobileNet, and Vision Transformers. They are pre-trained using the ImageNet dataset. Both transfer learning as well as developing custom models based on the above-mentioned architectures are applied. The study addresses the determination of the most effective single model for lung diseases identification. The Gradient-weighted Class Activation Map are utilized to highlight the key regions influencing model decisions. Moreover, the soft voting ensemble learning methods are used to enhance the performance of lung illness detection. Commonly used metrics are applied to evaluate all models. The lung diseases identification exceeded 89% accuracy results for single models. The ensemble learning further improved the performance. These findings demonstrate the high potential of deep learning and ensemble approaches for supporting accurate and efficient lung disease diagnosis utilizing chest X-ray images. The deep learning models provide promising decision-support tools for this type of healthcare diagnosis.

Keywords: Lung diseases detection, deep learning, VGG16, DenseNet-121, ResNet-50, MobileNet, ViT, Grad-CAM, ensemble learning, chest X-ray imaging.

PRELIMINARY EEG-BASED ASSESSMENT OF ANXIETY USING MACHINE LEARNING

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Abstract: My doctoral research is centered on evaluating the occurrence of anxiety states in individuals using the cognitive load paradigm. The project is deeply interdisciplinary, combining elements of neuroinformatics, machine learning, and biomedical signal processing. The primary aim is to apply advanced machine learning methods to the prediction and identification of biological features in human neural networks, which are modeled using EEG data. Electroencephalography (EEG) serves as the core method for data collection in this study. EEG is a non-invasive technique for recording brain activity via electrodes placed on the scalp, offering high temporal resolution and making it suitable for real-time brain activity analysis. The presentation will showcase the results of experimental research using electroencephalography (EEG), aimed at identifying brain activity patterns characteristic of anxiety states. The study was conducted on a group of 30 participants – young adults aged 18–26, all students – who were subjected to cognitive tasks designed to induce cognitive load. The recorded EEG signals underwent preliminary preprocessing to eliminate noise and artifacts, and were subsequently analyzed in terms of synchronization between different brain regions. The results indicate the potential for effective identification of anxiety states based on EEG data and confirm the usefulness of computational methods in neuropsychiatric diagnostics. The presented approach combines modern data analysis tools with clinical practice and may be applicable in the development of tools supporting the early detection of anxiety disorders.

Keywords: Electroencephalography; brain imaging; brain-computer interface; EEG analysis; neural networks; machine learning.

APPLICATION OF YOLO ALGORITHMS TO CROP PRODUCTION MANAGEMENT USING UNMANNED AERIAL VEHICLES (UAVS) AND COMPUTER VISION SYSTEMS

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Abstract: Iraq, the country where the date palm originated and which was once the global leader in date production, has experienced a significant decline in both production and genetic diversity over the past three decades due to various factors. In an effort to revitalize the date palm sector, Iraqi authorities and researchers have adopted innovative approaches, including the use of (UAVs) unmanned aerial vehicles for aerial imaging. These images, collected by the Department of Computer Techniques Engineering at Al-Salam University in Baghdad, support improved orchard management, palm tree counting, and yield estimation. Additionally, they facilitate processes such as pesticide spraying and pollination with greater accuracy, speed, and reduced cost. The proposed methodology involves processing the captured images and applying three versions of the You Only Look Once (YOLO) object detection algorithm—v11, v12, and YOLO-NAS to determine the most effective model. The YOLOv12 model achieved the highest mAP@50 at 99.12%, demonstrating the algorithm's effectiveness. This approach holds potential for further development into a mobile application for identifying and counting palm trees in the field.

Keywords: Aerial imaging, Deep Learning, Palm trees, UAVs, YOLO, Yield estimation.

DUFFING SYSTEM PARAMETER ESTIMATION BY INVERSE PHYSICS-INFORMED NEURAL NETWORKS WITH SINE ACTIVATION FUNCTION

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Abstract: This work presents the application of the inverse Physics-Informed Neural Networks (PINNs) algorithm for the estimation of parameters of the nonlinear dynamic Duffing system. To achieve fast convergence and accuracy during the neural network training with the smallest possible set of training data, a sine activation function was used. The research provides a comprehensive comparison of the capabilities of inverse PINNs in reproducing the parameters of the studied system using classical activation functions such as sigmoid, tanh, GELU, and the proposed sine function. The issue of training data resources (dense vs. sparse data) is also discussed. This research demonstrates the advantage of the model with the sine activation function when analyzing very sparse data across a wide time domain of the Duffing system's solution. However, these studies also indicate the difficulty of estimating the frequency of the periodic driving force in the studied system using a sparse dataset for training. As an example, for a time domain of a chaotic solution of the Duffing equation t=100s, with a training set containing only 50 measurement points, PINNs with sine activation can easily reproduce the damping parameter and the oscillator potential, as well as the attractor in phase space, while models with the sigmoid, tanh, or GELU activation function are not even able to converge. Additionally, an attempt was made to reproduce the system's parameters, as well as the time series and the attractor, for noisy data.

Keywords: Physics-informed neural networks (PINNs), chaotic dynamical systems, automatic differentiation, Duffing equation, parameter estimation, sine activation function.

KERATOCONUS DIAGNOSIS BASED ON DYNAMIC CORNEAL IMAGING USING 3D CONVOLUTIONAL NEURAL NETWORKS

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Abstract: Keratoconus is a progressive disease that requires precise and rapid diagnosis, as well as the initiation of treatment, to prevent serious and permanent visual impairment. This article presents a comparison of 3D convolutional neural network models for the diagnosis of keratoconus based on dynamic corneal imaging results obtained with the CORVIS device. The article describes the data preprocessing and compares models of varying complexity in terms of accuracy, inference time, number of parameters, and GPU memory usage. To ensure adequate generalization capability during algorithm training, 5-fold stratified cross-validation was used, and the average metrics from all splits were compared. The best model achieved an average keratoconus detection accuracy exceeding 88%, confirming that deep neural networks can be a promising tool to support physicians in diagnosing corneal diseases such as keratoconus. Future work includes plans to gather a larger patient database and apply more advanced preprocessing methods for the video data.

Keywords: Keratoconus, cornea, deep learning, convolutional neural network, medical imaging.

ARTIFICIAL NEURAL NETWORKS IN PREDICTION OF MECHANICAL BEHAVIOR OF COMPOSITE AT DIFFERENT TEMPERATURE – PRELIMINARY STUDY

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Abstract: This paper discusses the results of experimental tests conducted to estimate the influence of temperature on the tensile and compressive strength of composite samples, as well as on changes in the mechanical properties of the tested material. The experiments were carried out at ambient temperature and at elevated temperatures of 40°C, 60°C, and 80°C, during which the specimens were subjected to tensile and compressive loading until failure.

The obtained experimental data were then used to train and validate artificial neural network (ANN) models aimed at predicting the temperature-dependent mechanical behavior of the composite. The input parameters included the test temperature and selected material characteristics, while the outputs targeted the prediction of temperature-dependent properties at unseen intermediate temperatures. Several network architectures were evaluated to determine the optimal configuration providing the best correlation between predicted and measured data.

The preliminary results confirmed the high potential of ANN-based approaches in capturing complex, nonlinear relationships between temperature and the mechanical response of composites. The developed models demonstrated satisfactory predictive capability even for temperatures not included in the training dataset and can serve as a foundation for future intelligent tools supporting the design and optimization of composite structures operating under variable thermal conditions.

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Keywords: Composite material, temperature, material parameters, ANN.

JERK LIMITED FEEDRATE PROFILE OPTIMIZATION FOR NURBS TOOLPATHS IN CNC MACHINES WITH H-BOT KINEMATICS

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Abstract: This paper presents an algorithm for generating the feedrate profile for Computerized Numerically Controlled (CNC) machines with non-cartesian H-Bot kinematics. Feedrate profile defines the relationship between the end-effector or tool velocity tangent to the toolpath and time or the toolpath's parameter. To maximize machining effectiveness the feedrate should be as high as possible. However the feedrate, accleration, jerk of the end-effector and inividual machine axes should be within their respective limits. The toolpath is defined as a Non-Uniform Rational B-Spline (NURBS) polynomial curve to ensure smooth motion. This problem is more difficult for non-cartesian machines due to their non-linear dependencies between kinematic parameters of the end effector and the machine's axes. In this paper Particle Swarm Optimization (PSO) gradient free algorithm is used to determine the optimal shape of the feedrate profile to achieve shortest travel time within the velocity, acceleration and jerk constraints imposed by the machine's axes. Compared to more common approaches the profile is initialized with a near-optimal shape determined by a feedrate limit curve and then optimized to the final shape. The method is experimentally verified on an actual H-Bot gantry plotter. Presented results show that the proposed method effectively generates a feedrate profile within the imposed limits.

Keywords: Feedrate profile, optimization, H-Bot, particle swarm optimization, CNC.

AGGREGATING EVALUATION METRICS FOR ANOMALY DETECTION: A UNIFIED SCORING APPROACH

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Abstract: This paper introduces a procedure that transforms multiple evaluation metrics into a single aggregated score, providing a comprehensive and interpretable summary of machine learning performance. The approach is demonstrated on a set of metrics obtained from various anomaly detection algorithms based primarily on Isolation Forests. Seven relevant performance metrics were selected and aggregated using diverse techniques, including the arithmetic mean, weighted mean, Choquet integral, the OWA operator, and several Smooth OWA variants based on different interpolation Newton-Cotes quadratures. For methods requiring them, two distinct sets of weights were prepared. The results show that, especially in anomaly detection tasks where individual metrics may lead to inconsistent evaluations, the aggregated score effectively reflects metric preferences and enables quick identification of the best-performing algorithm for a given dataset.

Keywords: Multi-Criteria Decision Making , Model Ranking, Metric Aggregation, Evaluation Metrics, OWA Operator, Choquet Integral.

SMOOTH OWA IN FEDERATED LEARNING: A NEWTON-COTES QUADRATURE-INSPIRED AGGREGATION FRAMEWORK

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Abstract: This paper presents a novel approach to federated learning based on the Smooth Ordered Weighted Averaging (OWA) operator, which enables flexible and context-sensitive weighting of local models during the aggregation process. To enhance the precision of the aggregated weight computations, we incorporate numerical quadrature-inspired techniques, allowing for a more accurate representation of individual client contributions to the global model. Specifically, the approach utilizes classical OWA and several smoothed variants derived from Newton-Cotes quadratures, including the 3/8 rule, trapezoidal rule, and ONC4 (4-point open Newton-Cotes) formula. The study compares federated learning models using standard weight averaging against those incorporating both classical and smoothed OWA operators. This evaluation provides insight into how the smoothing mechanisms influence aggregation quality and final model accuracy. A neural network comprising several dense layers served as the classification model in the Federated Learning framework. Two experimental scenarios were considered: one where data was evenly distributed across local clients, and another with non-uniform data distribution to reflect real-world heterogeneity. Various strategies for extracting the OWA weights were explored, including performance-based weighting determined by the accuracy of local models during preliminary training rounds The proposed methodology was tested on small-scale image datasets, such as MNIST, and demonstrated improved classification accuracy value compared to traditional Federated Learning approaches using simple averaging.

Keywords: Federated Learning, Neural Network, OWA operator, smooth OWA, weight aggregation.

ROBUST FAULT DETECTION IN WASTEWATER TREATMENT USING LSTM AUTOENCODERS UNDER SENSOR AGING AND DAMAGE CONDITIONS

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Abstract: Wastewater treatment processes rely on continuous monitoring supported by sensor systems, which are prone to gradual aging as well as sudden failures such as electrical short circuits. These phenomena degrade signal quality and can affect the performance of anomaly detection models. This study investigates the resilience of LSTM autoencoders in detecting faults in sequencing batch reactor (SBR) systems, even when the reliability of the monitoring sensors is compromised.

The research focuses on evaluating the impact of sensor aging and abrupt malfunctions, such as burnout caused by electrical faults, on the reconstruction error of the LSTM autoencoder. Experimental results show that although both factors moderately increase reconstruction errors, the model consistently maintains its ability to distinguish abnormal process behavior from normal operating conditions. This confirms the robustness of the LSTM approach in realistic monitoring scenarios.

The findings highlight that LSTM autoencoders provide effective fault detection despite inevitable sensor degradation over time. Their robustness to measurement imperfections makes them a valuable tool for real-world wastewater treatment monitoring, where sensor wear and occasional breakdowns are unavoidable. By ensuring reliable anomaly detection, the proposed approach enhances process stability, reduces operational downtime, and supports sustainable water management practices.

Keywords: Autoencoders, anomaly detection, long-short term memory.

COMPUTATIONAL FLUID DYNAMICS (CFD)

ASSESSMENT OF AERODYNAMIC INTERFERENCE BETWEEN AN AIRCRAFT WING AND AGRICULTURAL SPRAYERS - NUMERICAL AND EXPERIMENTAL INVESTIGATIONS

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Abstract: The contemporary advancement of unmanned aerial vehicle technology is increasingly intensifying their implementation across diverse economic sectors, with agriculture demonstrating significant application potential. Traditionally, multirotor platforms have been dominant in tasks related to precision crop spraying. Fixed-wing platforms offer an alternative to these designs. In conventional solutions for agricultural aircraft, the spraying system is typically integrated with a boom suspended beneath the wing. An innovative concept involves the direct integration of sprayers onto the lower surface of the wing. Nevertheless, such a configuration implies a potential modification of the airfoil's aerodynamic characteristics due to flow interference induced by the presence and geometry of the sprayers. To quantify this phenomenon, interdisciplinary investigations were conducted, encompassing numerical and experimental analyses. Numerical simulations of the aerodynamic interference were performed using Computational Fluid Dynamics method within the Ansys Fluent software environment. The simulation results were verified through comparison with experimental data obtained in a closed-circuit wind tunnel. A detailed analysis was conducted on the aerodynamic characteristics of a wing segment, including the lift coefficient, drag coefficient, and pitching moment coefficient as a function of the angle of attack. The conducted studies revealed a relatively minor impact of the integrated spraying system on the global aerodynamic performance of the analyzed wing configurations, suggesting potential for further development and research in this design approach.

Keywords: Aerodynamics, airfoil, CFD, sprayer, wing, wind tunnel.

CFD ANALYSIS OF HEAT TRANSFER IN MODIFIED SHORT CHANNEL STRUCTURES

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Abstract: In situations where developed laminar flow of fluid occurs, the values of heat and mass transport coefficients reach a constant limiting value dependent on the cross-sectional shape of the channel. Increasing the flow velocity of the fluid, as long as it remains a layered flow, does not affect the change in these coefficients. In this case, only the flow resistance changes with velocity. The only way to intensify heat and mass transfer in the laminar flow regime is to shift the working area to a developing laminar flow. This shift can be achieved by reducing the channel length to a length corresponding to a maximum of a few diameters of the channel being considered. Reducing the length over which heat or mass transfer occurs allows for transport coefficients to be several or even a dozen times greater than the limiting values. Due to the lack of published correlations for calculating transport coefficients in the developing laminar flow regime in channels of atypical shapes, it is necessary to conduct laboratory measurements or utilize computational fluid dynamics (CFD) tools. The work involved a series of CFD analyses for channels with modified geometry. The starting point was a channel in a classic monolith (with a square cross-sectional area) and a channel with a streamlined inlet edge based on the profile of an aircraft wing. As a result of the simulations conducted, it was found that each of the modified channels exhibits greater flow resistance compared to channels in a classical monolith while simultaneously enhancing heat transport. The conducted studies allowed for a deeper understanding of the transport phenomena in the area of the inlet and outlet edges of the channels in structures characterized by a channel length not exceeding five diameters of the channel.

Keywords: CFD, heat transfer, short channel structure.

NUMERICAL ANALYSIS OF ICING EFFECTS ON THE AERODYNAMICS OF THE WORTMANN FX 63-137 AIRFOIL

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Abstract: This study presents a detailed numerical analysis of the effects of ice accretion on the aerodynamic performance of the WORTMANN FX 63-137 airfoil, widely used in light aviation and unmanned aerial systems. The phenomenon of icing, which leads to the accumulation of ice layers on lifting surfaces, can significantly alter the flow structure, reduce lift, and increase drag, thereby compromising flight safety and efficiency. Computational Fluid Dynamics (CFD) simulations were carried out for both a clean (non-iced) airfoil and several iced configurations representing different stages of the icing process. The corresponding geometries were generated by modifying the leading-edge profile to reflect increasing ice thicknesses obtained from empirical icing models. The simulations were performed using the SST k-ω turbulence model under steady-state flow conditions for a range of angles of attack typical of cruise flight regimes. The study includes a comparative evaluation of aerodynamic characteristics such as lift and drag coefficients, pressure distribution, and velocity fields. The results clearly demonstrate a progressive degradation of aerodynamic performance with increasing ice accretion. Pressure and velocity contour plots reveal significant flow separation and distortion near the leading edge, confirming the disruptive impact of ice formation on boundary layer stability. The findings emphasize the high sensitivity of the WORTMANN FX 63-137 airfoil to icing and highlight the necessity of incorporating ice-induced aerodynamic degradation into design optimization and performance prediction for small aircraft and UAVs operating in adverse weather conditions.

Keywords: ICING, CDF, airfoil, WORTMANN, Ansys FENSAP-ICE.

CONCEPTUAL DESIGN AND AERODYNAMIC AND HYDRODYNAMIC ANALYSIS OF AN UNMANNED PLATFORM FOR AIR AND WATER OPERATIONS

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Abstract: This study presents the conceptual design and numerical analysis of a hybrid unmanned platform capable of operating both in the air and water environments. The research aims to develop a dual-mode vehicle that integrates aerodynamic and hydrodynamic performance requirements within a single, structurally optimized configuration. Such a design approach addresses the increasing demand for multi-environment unmanned systems that can perform surveillance, environmental monitoring, or search and rescue missions across different domains without the need for vehicle replacement or recovery. Computational Fluid Dynamics (CFD) simulations were performed to investigate the aerodynamic behavior of the platform under various flight regimes, including takeoff, steady-level flight, and transition phases. Complementary hydrodynamic analyses were conducted to evaluate buoyancy, stability, and drag characteristics during submerged operation. The geometric configuration of the platform, including fuselage shape, wing profile, and fin arrangement, was iteratively optimized using CFD-based parametric studies to balance the conflicting aerodynamic and hydrodynamic constraints. The obtained results indicate that achieving satisfactory performance in both media requires a compromise between aerodynamic efficiency and hydrodynamic stability. Pressure and velocity contour visualizations reveal distinct flow patterns in air and water, emphasizing the critical role of smooth transition surfaces and reduced wetted area. The presented findings provide valuable insights into the design trade-offs inherent in hybrid aerial–aquatic platforms and lay the groundwork for further prototyping, control system integration, and experimental validation under real operational conditions.

Keywords: Hybrid unmanned platform, Dual-mode vehicle, Aerial-aquatic operation, Aerodynamic and hydrodynamic analysis, CFD simulation, Conceptual design.

NUMERICAL ANALYSIS OF FLUID FLOW AND HEAT TRANSFER IN PERIODIC OPEN CELLULAR STRUCTURES

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Abstract: Recently, 3D-printed periodic open cellular structures (POCS) have gained popularity as catalyst supports due to the ease and speed of their design and manufacturing. These materials are porous and composed of cells formed by struts, similar to open-cell solid foams, but arranged in a regular pattern like monoliths. Consequently, they combine the advantages of these two internal structure types: intensive mass transport of reactants to the catalytic phase (large contact surface area) and low flow resistance, which reduces the cost of fluid pumping through the reactor (high porosity). They are designed by duplicating a representative unit cell (RUC) in three principal spatial directions. Their main benefit is their geometrical flexibility, allowing changes in the shape and size of the unit cell, and the struts to enhance their hydraulic and transport properties. The most frequently analyzed POCS are cubic, Kelvin, and diamond lattices with circular or square struts. Porosity and cell density have the biggest effects on the pressure drop, whereas surface area, which is closely linked to cell morphology, has a significant impact on the thermal convective coefficient. Therefore, this work aimed to numerically investigate the geometrical impact on POCS's heat transfer and flow resistance. Different strut shapes (including circle, square, hexagon, triangle, and star) were considered. Cell dimensions and strut thicknesses were varied within the ranges of 2.5-10 mm and 0.25-2 mm, respectively. Computational simulations were performed using ANSYS Fluent software. The numerical model was verified experimentally on manufactured POCS.

Keywords: Periodic open cellular structures; heat transfer; pressure drop; CFD modeling.

CFD STUDY OF STRUCTURED CATALYTIC CARRIER BASED ON FISH GILLS

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Abstract: The quality of the air often does not satisfy established standards, which is a significant problem for the natural environment. One of possibilities to reduce dangerous gas emissions is the use of structured catalytic converters. These devices consist of catalytic active phase responsible for neutralisation of the pollutants. This phase is applied on the surface of a carrier which shape is designed to facilitate access of the pollutants molecules to the active centers. The conducted research focuses on developing new catalytic carriers that will promote this process. It is important that the support geometry is characterized by large specific surface area and does not generate high flow resistance. One of the structures of very large specific surface area and excellent heat and mass transport properties are fish gills, through which 80 – 90% of the heat generated in the fish organism is exchanged (Don Stevens E., Sutterlin AM.; J. Exp. Biol., 1976; 65:131-45). Therefore, fish gills were inspiration for developing new structures - the GSCs - "gill-like structured carriers". First step of the research was to analyze the flow pattern through the gills and based on this, CAD models were developed. Then, flow resistance and heat transfer coefficient of created GSCs were studied with the use of CFD simulation. Streamlines and temperature maps of the carriers and flowing fluid were determined and thoroughly analyzed. The GSCs display favorable transport and flow properties, which indicates their high potential for use as catalytic supports.

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Keywords: Catalytic carriers, gill-like structured carriers, CFD, heat transfer, flow resistance.

ACHIEVING LOW ENERGY CONSUMPTION THROUGH HYDRODYNAMIC MIXING OF NON-NEWTONIAN FLUIDS IN COMPACT CHAOTIC MICROMIXERS

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Abstract: This study investigates the mixing performance of compact chaotic microdevices for Newtonian and non-Newtonian fluids in microfluidic applications. Building upon the notable mixing characteristics of the Two-Layer Crossing Channels Micromixer (TLCCM-X) with Newtonian fluids, we developed modified designs (TLCCM-KX and TLCCM-O) to enhance mixing efficiency. Numerical simulations were conducted using CFD code to solve Navier-Stokes, mass conservation, and species transport equations. The species transport model was implemented to analyze the mixing process of pseudoplastic carboxymethyl cellulose (CMC) solutions, characterized by the power-law model with flow behavior indices ranging from 0.49 to 1 and generalized Reynolds numbers from 0.2 to 70. Mixing effectiveness was evaluated through hydrodynamic mixing degree calculated across various cross-sectional areas, where a value of 1 represents perfect mixing. Our comprehensive analysis included mass fraction contours, streamlines, shear rate curves, pressure drops, Poiseuille number to hydrodynamic mixing degree (Po/HMD) ratios, and mixing energy costs. Results demonstrate that the TLCCM- O micromixer exhibits the most energy-efficient device among those studied, requiring significantly lower mixing energy costs. This makes the TLCCM-O particularly promising for applications where energy efficiency is a critical consideration, representing advancement in micromixer technology for both Newtonian and non- Newtonian fluid applications.

Keywords: Microdevices, chaotic mixing, hydrodynamic mixing degree, shear-thinning fluids, Low Reynolds numbers, TLCCM, mixing energy costs.

EFFECT OF OBSTACLE SHAPES ON MIXING PERFORMANCE IN SHORT TLCCM MICROMIXERS WITH CIRCULAR CROSSING CHAMBERS

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Abstract: Passive micromixers play a crucial role in industrial and energy applications due to their ability to enhance fluid mixing without external energy input. Their efficiency, simplicity, and scalability make them ideal for processes such as chemical synthesis, fuel cell technology, and heat exchangers. This study presents a comparative numerical investigation of mixing performance in four short two-layer crossing channel micromixers (TLCCMs): TLCCM 1 (baseline) and three geometrically modified designs (TLCCM 2, TLCCM 3, and TLCCM 4). The simulations were carried out using computational fluid dynamics (CFD) at Reynolds numbers ranging from 0.2 to 80. Mixing performance was evaluated based on the mixing index, mass fraction distributions, and mixing energy cost (MEC). Results show that geometric modifications significantly enhance fluid mixing through induced chaotic advection, especially at moderate to high Reynolds numbers. TLCCM 4, in particular, demonstrated superior mixing efficiency, achieving a mixing index of up to 0.972 at the outlet and outperforming other configurations in terms of energy efficiency. The influence of aspect ratio was also examined, revealing that designs with $d/W = 0.5$ and $d/W = 1$ provided optimal performance at higher Reynolds number. This work confirms that targeted geometrical optimization of crossing elongations in micromixers can significantly improve mixing quality while minimizing energy consumption.

Keywords: Passive micromixers, TLCCM, circular crossing, cixing index, chaotic advection, Reynolds number, mixing energy cost.

NUMERICAL ANALYSIS OF THE INFLUENCE OF THE VERTICAL POSITION OF TUBES IN LATENT HEAT THERMAL STORAGE ON THE CHARGING AND DISCHARGING PROCESSES

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Abstract: The aim of this study is to perform a numerical analysis of the influence of the position of the tubes carrying the heat transfer fluid on the charging and discharging processes of a thermal energy storage system with a phase change material (PCM). The investigation was based on a three-dimensional numerical model of a repetitive section of the storage unit, consisting of four copper tubes and an aluminium fin acting as a heat exchanger. The model was implemented in the ANSYS Fluent environment using the built-in Solidification and Melting Model, which accounts for heat conduction, natural convection in the liquid phase, and the phase change of the PCM. Several configurations of tube placement were analysed with respect to the vertical position within the storage unit. The study evaluated their impact on the charging and discharging time, the resulting heat fluxes, temperature distribution, and the evolution of the liquid phase fraction over time. In the simulations, a PCM with a relatively high phase change temperature of approximately 78°C was used, allowing the results to be applicable in the design of thermal storage systems integrated with conventional central heating installations. The results indicate that tube placement significantly affects the efficiency of the charging process. Lowering the tubes toward the bottom of the storage tank reduced the melting time of the PCM by 23.2%, mainly due to the enhancement of natural convection. In contrast, during the discharging process, the tube arrangement had a significantly smaller impact on the solidification time. The findings of this analysis may serve as a basis for designing more efficient stationary and mobile PCM-based thermal energy storage systems, especially in applications where compactness and fast thermal response are essential.

Keywords: Phase change material, PCM, pipe position optimization, thermal energy storage, TES, LHTES, charging and discharging processes.

COMPUTER SIMULATIONS OF PROCESSES AND PHENOMENA

COMPARISON OF MACHINE LEARNING METHODS IN PREDICTIVE MAINTENANCE OF MACHINES

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Abstract: The objective of this study is to identify the most effective machine learning algorithm for predictive maintenance of industrial machinery using three input variables: temperature, vibration, and machine condition. Considering the balance between predictive accuracy and computational efficiency, as well as the practicality of implementation in resource-constrained environments. This study evaluated the effectiveness of six machine learning algorithms for predictive maintenance in industrial environments using three input variables. A dataset of 90,000 training instances and 10,000 test instances was analyzed, with models including decision trees, neural networks, support vector machines (SVMs), k- nearest neighbor (KNN), naive Bayes, and logistic regression. Performance was evaluated based on accuracy, F1 score, AUC, training time, prediction speed, and model size. The results showed that the coarse decision tree achieved the highest accuracy (98.24%), the lowest error rate (1.76%) and the highest prediction speed (>420,000 observations/second) with the smallest model size (4.7 KB). The results underscore that simpler, easy-to-interpret models, such as decision trees, offer excellent practicality for real-time industrial applications without compromising predictive power. This work highlights the importance of balancing model complexity with computational efficiency in predictive maintenance systems.

Keywords: Machine learning, industrial applications, decision trees, predictive maintenance, neural networks, computational efficiency, model accuracy.

ADVANCED TRILATERATION STRATEGIES WITH UWB TAGS FOR HIGH-PRECISION INDOOR LOCALIZATION IN WMS ENVIRONMENTS

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Abstract: This paper presents a high-precision indoor localization system based on Ultra-Wideband (UWB) technology, designed for Warehouse Management System (WMS) applications. The developed solution integrates miniaturized and multifunctional UWB tags with environmental sensing capabilities and a robust power management system. A combination of two computational methods, the matrix-based trilateration algorithm and a non-linear optimization method using least squares minimization – is implemented to estimate the tag's 3D position using distance measurements from multiple anchors. The influence of anchor placement on localization accuracy is systematically analyzed using simulated datasets with realistic noise profiles. Results indicate a significantly improved accuracy and stability when anchors are distributed across varied vertical levels compared to coplanar configurations. Experimental evaluation demonstrates that even with a moderate number of anchors, sub-decimeter accuracy is achievable. The proprietary hardware platform, comprising DWM1000 and STM32 F7 microcontrollers, ensures long operational autonomy and full maintenance-free functionality via PoE support. This study confirms the efficacy of combining advanced geometric methods with optimized hardware configurations to support reliable real-time tracking in industrial indoor environments.

Keywords: Ultra-wideband, indoor localization, trilateration, optimization algorithms, IoT, warehouse management, RTLS, matrix method, power management, anchor configuration.

APPLICATION OF COMPLEX DECISION STRUCTURES IN THE ANALYSIS AND DESIGN OF HYDRAULIC SYSTEMS SUBJECTED TO WATER HAMMER

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Abstract: The phenomenon of water hammer in metal pipeline systems poses a serious threat to their reliability and durability. Traditional analytical models, primarily based on the method of characteristics, capture basic physical dependencies but lack sufficient flexibility under complex and uncertain structural and operational conditions. This paper proposes the use of complex decision structures—including selected classification trees and dependency graphs—as tools for supporting the design and optimization of hydraulic systems. These structures enable not only the identification of key parameters affecting unsteady flow characteristics but also variant analysis and adaptive system optimization in the presence of variable and incomplete data. The results indicate significant advantages of integrating classification- and graph-based methods with classical physical models, offering new perspectives for designing more robust and energy-efficient hydraulic installations.

Keywords: Water hammer, method of characteristics, decision structures, classification trees, dependency graphs.

AN INTEGRATED SYSTEM FOR NON-INVASIVE MONITORING OF BLOOD GLUCOSE, OXYGEN SATURATION, AND HEART RATE USING SPECTRAL IMPEDANCE AND OPTICAL SENSORS

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Abstract: Effective, continuous, and non-invasive monitoring of key physiological parameters such as blood glucose levels, oxygen saturation (SpO_2), and heart rate is a critical challenge in contemporary biomedical engineering. This paper presents a custom-designed hardware solution that integrates spectral impedance technology with optical sensing modules based on photoplethysmography (PPG), enabling real time and non-invasive health monitoring without the need for blood sampling. The system utilizes frequency-dependent electrical impedance variations in body tissues to estimate glucose concentration and employs optical methods to measure blood oxygenation and pulse rate. A microcontroller unit (MCU) coordinates signal acquisition processes the data using embedded algorithms and communicates with a host device via USB. The presented prototype demonstrates the feasibility of combining these two sensing modalities into a compact and user-friendly system. The proposed solution offers a promising direction for future development of diagnostic tools for chronic disease management, particularly for diabetes and cardiovascular conditions.

Keywords: Non-invasive glucose measurement, spectral impedance, optical sensors, photoplethysmography (PPG), oxygen saturation (SpO_2), heart rate, biosensors, physiological monitoring systems, microcontroller-based device, biomedical engineering.

ENERGY HARVESTING FROM A VERTICAL CANTILEVER PIEZOELECTRIC HARVESTER WITH A BLUFF-BODY UNDER WIND FLOW EXCITATION

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Abstract: Nowadays, technological and social progress imposes a very high demand for energy in all forms. This in turn determines scientists to work hard on more efficient use of current energy resources as well as searching for new sources and energy systems. This development can be seen in many economic and technical areas. In this article, we focus on systems for efficient energy acquisition from the environment to power low-energy measurement systems. The growing demand for distributed, self-sufficient sensors stimulates research on energy acquisition from the environment. One of the promising methods is the use of wind energy using piezoelectric transducers. We present the concept and preliminary research on energy recovery from vibrations of coupled bodies mounted on metal beams, set in motion by the wind flow. Experimental studies will be carried out in a wind tunnel with a closed air circulation, in the laboratory of the Department of Automation of the Lublin University of Technology. Piezo elements mounted on the beams generate a voltage dependent on the degree of their deflection with a frequency dependent on the beam vibration frequency. The experiments assume the use of solid bodies of various shapes and beams that are most optimal for the shapes tested. The main goal of this work is to develop an efficient energy harvesting system that can withstand variable wind conditions. Experimental tests use a laser deflection sensor to measure mechanical vibrations and piezoelectric transducers to evaluate the generated electrical energy. The presented results are a step towards designing autonomous power systems for distributed sensor applications.

Keywords: Energy harvesting, piezoelectric, energy systems, wind tunnel, CFD.

COMPARISON OF MACHINE LEARNING MODELS FOR PREDICTING THE COMPRESSIVE STRENGTH OF CEMENT MIXTURES WITH ZEOLITE

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Abstract: This study investigates the applicability of machine learning algorithms for predicting the compressive strength of cement mixtures with zeolite. The research compares the performance of four predictive models - Elastic Net regression, Support Vector Machines (SVM), Multilayer Perceptron (MLP) neural networks, and Decision Trees - trained on experimentally obtained data describing mix composition and curing conditions. The input features included zeolite percentage, water-to-cementitious-material ratio, curing time, cement mass, and zeolite content. The output variable was compressive strength. Among the evaluated models, the SVM algorithm exhibited the optimal generalization capability, attaining the minimal prediction error on the validation set while sustaining elevated correlation between actual and predicted values. The MLP neural network demonstrated the optimal fit to the training data, however, this was achieved at the expense of heightened sensitivity to overfitting. Decision trees demonstrated robust training efficacy but exhibited diminished generalization capabilities, while the linear elastic net model encountered challenges in replicating the nonlinear characteristics of the material system. The study corroborates the viability of nonlinear machine learning models in facilitating the design and optimization of zeolite-enhanced cementitious mixtures. These findings signify a significant stride towards data-driven modeling in the field of construction materials engineering, thereby facilitating enhanced prediction of mechanical performance with minimized experimental effort. The study also underscores avenues for future exploration, encompassing model hybridization, multi-output prediction frameworks, and integration with optimization algorithms for automated mix design.

Keywords: Neural network, compressive strength, SVM, machine learning, sustainable materials, predictive modeling, mix design, cement mixtures with zeolite.

NUMERICAL MODELLING OF HEAT TRANSFER IN AN EPOXY RESIN MATRIX DISPERSIVE COMPOSITE WITH POLIMERIC INCLUSIONS

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Abstract: Dispersive epoxy resin composites are a subject of intensive research due to their applications in materials engineering and industry. The thermal properties and the course of thermal processes in these materials depend on their microstructure and this in turn is characterized both by the filling content and by the geometric distribution of inclusions. It is important whether the arrangement of particles and their size distribution is regular or stochastic. When modeling heat transfer processes in such structures, an additional problem arises of determining a representative unit cell for which reliable resultant (i.e. effective) values of thermophysical properties can be determined. Understanding the influence of these parameters is important for understanding the differences between steady and transient heat transfer, which in turn influences the determination of design assumptions for this type of structures. This paper presents a numerical analysis of how the distribution, volume fraction of inclusions, and the elemental cell size ratio influence steady-state and transient heat transfer in geometrically inhomogeneous media with complex spatial structure. The study focuses on a composite model structure consisting of an epoxy resin matrix with a dispersed phase of spherical polymer microcapsules. Both regularly distributed inclusions and randomly distributed inclusions were included in the study, as well as configuration with variable size inclusions. In order to reduce the energy cost of calculations models with simplified geometry reproducing a representative elementary cell of the composite were used. The obtained numerical results were then compared with experimental data collected within the typical operational temperature range of epoxy matrix composites.

Keywords: Heat transfer in composites, numerical modeling, epoxy resin matrix, dispersed polymeric filler, stochastic filling parameters, effective heat transfer parameters.

APPLICATION OF ELECTRICAL IMPEDANCE TOMOGRAPHY FOR REAL-TIME MONITORING AND CONTROL OF FERMENTATION PROCESSES

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Abstract: This paper presents an innovative approach to monitoring and controlling fermentation processes using electrical impedance tomography (EIT). Fermentation, a critical biochemical process in bioenergy, pharmaceutical, and food industries, requires precise regulation to ensure process efficiency and microbial stability. Traditional monitoring systems often fail to capture spatial heterogeneities and dynamic changes occurring within bioreactors. The proposed method utilizes a modular EIT platform with a multi-electrode sensor array, enabling real-time imaging of conductivity distributions that correlate with biochemical transformations throughout hydrolysis, acidogenesis, acetogenesis, and methanogenesis phases. The study evaluates several reconstruction algorithms including LARS, Tikhonov regularization, Elastic Net, Support Vector Machine (SVM), and ResNet, assessing their performance using RMSE and Pearson correlation coefficients. Among these, ResNet demonstrates superior accuracy in image reconstruction, enhancing the capacity to detect process anomalies and improve control responses. The integration of EIT with intelligent analytical algorithms offers a significant advancement in fermentation diagnostics, enabling spatial and temporal insight into process dynamics and contributing to improved efficiency, reduced downtime, and optimized bioreactor operation.

Keywords: Electrical impedance tomography, fermentation, bioreactor monitoring, process control, image reconstruction, deep learning, ResNet, industrial biotechnology.

FULLY AUTOMATIC SIMULATION OF CRACK PROPAGATION IN PLANE STRUCTURES

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Abstract: Fracture mechanics is an important tasks in real industrial applications. The optimization of structures to conserve natural resources may lead to smaller dimensions. Therefore, the investigation of initial cracks can not always guarantee the safety of the structures during the whole life cycle and crack propagation has to be considered. Since experimental determinations can be very expensive the numerical simulation of the crack propagation is a very important task. The defect assessment methods play an important role in industrial regulations and standards. For real applications a fully automatic simulation to analyze the corresponding crack growth and the plastic limit load at each crack propagation step is required. In this work, advanced fully automatic computations of curved crack paths in combination with the analysis of the plastic limit load by the lower bound theorem of plasticity are presented. For this purpose a program based on the FEM has been developed. A Coffin-Manson-model is implemented to include additionally initiated cracks into the model during the crack growth simulation process. To show the accuracy of the simulation program several numerical results of multiple crack growth under proportional loading configurations are presented and compared with experimental data.

Keywords: Crack growth, plastic limit load, failure assessment diagram, Coffin-Manson-model.

SELECTED ASPECTS OF SPINAL MODELING

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Abstract: The spine is a fundamental component of the human musculoskeletal system, responsible for stabilization, mobility and protection of nerve structures. Its complex anatomy, consisting of vertebrae, intervertebral discs, ligaments and surrounding muscles, enables it to perform multiple functions under various physiological loads. Understanding the biomechanics of the spine is crucial not only for diagnosing and treating spinal disorders, but also for designing implants, rehabilitation procedures and ergonomic solutions. This paper presents a multivariate modeling process of the human spine, which is a key tool for analyzing its biomechanics. The goal of the study was to create an accurate model of the spine in the AnyBody Modeling System environment, using the geometry of the patient's entire spine reconstructed from the resulting CT imaging, experimental data and the biomechanics of the structures interacting with the spine. The paper presents the successive stages of model construction, from image data processing, to reconstruction of anatomical geometry, to implementation of biomechanical properties of individual structures. Preliminary simulations are also presented, illustrating the possibilities of analyzing dynamic interactions within the spine. The combination of medical imaging, modeling methods and computer simulation has provided a tool for a more accurate assessment of the influence of various factors on the mechanics of the spine and a deeper understanding of its functionality. The developed model can be further expanded and refined to simulate various pathological conditions or surgical interventions, offering new opportunities for both clinical and research applications. In the future, this approach may contribute to the improvement of personalized treatment strategies and the optimization of therapeutic outcomes for patients suffering from spinal disorders.

Keywords: Spine biomechanics, Spine modeling, AnyBody Modeling System.

STENT SHAPE OPTIMIZATION USING FEA

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Abstract: Stents are mechanical vascular prostheses inserted into anatomic vessels for various medical purposes. They are mainly, but not only, used to unclog closed veins (stenosis). From a mechanical point of view, stents are structures to which— because of the method of their implantation - non-trivial requirements are placed. They are openwork cylinders, which in the first phase of implantation must reduce their initial diameter by about 40%-60% and then are expanded to about 200%- 400% of this diameter. In this form, they are to remain in the vessel for an extended period of time. Besides the durability, the key parameters in stent design are the specified diameter at crimping and the radial force in the operating state. The only way to achieve this effect is to select the appropriate geometric proportions of the stent mesh and to consciously plan appropriate zones of permanent deformation. This paper presents the author's algorithm for optimising the stent shape. Using a pre-processor script, finite elements models are generated by changing the main geometric parameters of the stent. As a result, a population of models is created. These models are then analysed for radial force, post-implantation diameter, maximum stress and crimping profile. Finally, the optimal solution is selected.

Keywords: Optimization, FEA, stent.

FULL-COLOR DIGITAL IMAGING TECHNOLOGIES FOR PRINT QUALITY ASSURANCE

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Abstract: The paper considers the problem of high-quality reproduction of full-color images with low resolution. Currently, for this purpose various amplsampling algorithms are used, which automatically increase the clarity and contrast of photos. However, not all of them can be applied to all types of images. Therefore, a study was conducted to investigate various software tools to increase the resolution of images. Increasing the resolution of an image is not a simple matter. To begin with, one need to increase the number of pixels, but that's not all. It is also important to get some meaningful details or the illusion of beauty. Special post-processing programs can help to achieve this goal, but the image may not look very good without applying various filters and manipulations. To solve the task at hand, we used a tool software that copes well with different types of images. The free online editor Photo Enlarger proved to be the best, although it is least suitable for complex tasks. However, the Photoshop Preserve Details 2.0 algorithm turned out to be the most optimal for the task at hand; it surpasses the others in terms of quality indicators.

Keywords: Upsampling, image, post-processing, reproduction quality, color models, metrics.

FINITE ELEMENT METHOD (FEM)

STRENGTH ANALYSIS OF THE MAIN ROTOR HEAD FOR THE X-GYRO UNMANNED AERIAL VEHICLE

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Abstract: This paper presents an analysis of gyroplane configuration types, including an examination of main rotor systems and their aerodynamics. Based on the state of the art, a conceptual design of the main rotor head adapted to the rotor system of the X-Gyro unmanned aerial vehicle has been developed. The design process involved 3D modeling of individual rotor head components in accordance with structural and technical requirements. The designed main rotor head assembly was subjected to a strength analysis using the Finite Element Method. The processes of computational model preparation, simulation execution and analysis of the obtained results are described in detail. The final stage includes the manufacturing of the main rotor head components using additive manufacturing technology, as well as the final assembly process. Overall, the results obtained at each stage of the work confirm the feasibility and practicality of the designed main rotor head concept for the X-Gyro unmanned aerial vehicle.

Keywords: UAV, Unmanned Aerial Vehicle, CAD, Computer Aided Design, FEM, Finite Element Method, strength analysis, main rotor, main rotor head, gyroplane, X-Gyro.

DETERMINATION OF THE JOHNSON-COOK MODEL OF AUSTENITIC STEEL FOR FEM SIMULATIONS OF FAST-CHANGING PROCESSES

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Abstract: The aim of this study was to develop a characterization of austenitic steel under elevated strain rates using the Johnson-Cook model, intended for numerical simulations of fast-changing processes. This objective was achieved based on results obtained from static tensile tests conducted on an MTS testing machine and dynamic tests performed using a rotary hammer, within a strain rate range of 0 to 2500 s^{-1}. The experimental results were analyzed and verified, and subsequently used to determine the coefficients of the Johnson-Cook constitutive equation. The data were presented in graphical form. The numerical validation of the developed material model was performed using a CAE environment, through simulations of dynamic tensile under high strain rate conditions replicating those of the rotary hammer testing, as well as simulations of quasi-static tensile tests. Finally, the numerical simulation results were compared with corresponding experimental data.

Keywords: Austenitic steel, static tensile test, dynamic tensile test, rotary hammer, plastic characteristics, strain rate, material model in terms of FEM, CAE.

COMPARISON OF STRESS PREDICTIONS FOR SHIP ONBOARD EQUIPMENT SHOCK RESPONSE USING DDAM AND TRANSIENT FEM METHODS

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Abstract: Modeling structural responses to underwater explosions (UNDEX) remains a significant challenge in simulation engineering due to the limited availability of experimental validation data. This study presents a comparative evaluation of two methods for assessing the shock resistance of shipboard equipment: fully nonlinear transient Finite Element Method (FEM) simulations and the Dynamic Design Analysis Method (DDAM), an empirical approach derived from U.S. Navy experiments. To ensure consistency, DDAM formulations were converted into SI units, allowing a direct comparison with FEM results. The findings reveal a good correlation between the two methods, with DDAM producing slightly conservative yet reliable predictions. This suggests DDAM's potential as a rapid assessment tool during the early design stages, before engaging in resource-intensive UNDEX simulations. The research focuses on evaluating stress distributions and load-bearing capacities of structural components such as frames and supports, providing valuable insights into shock attenuation and damper design—areas often insufficiently addressed by classification society guidelines. While advanced Fluid-Structure Interaction (FSI) techniques offer high fidelity in modeling shock phenomena, their computational demands limit their practicality for fast, iterative workflows. Classical FEM remains widely used but becomes inefficient in 3D solid configurations involving contact and material nonlinearity. Substituting shell elements can mitigate this, albeit with increased modeling complexity. Although DDAM is historically well-established and implemented in commercial solvers, it remains underutilized due to its conceptual complexity. This work demonstrates its practical value and highlights its effectiveness when validated against high-fidelity FEM simulations. Ultimately, the study proposes a balanced methodology for shock analysis, combining computational efficiency with sufficient accuracy for engineering decision-making in naval applications.

Keywords: UNDEX, underwater explosion, ship, shock response, FEM, simulation, ANSYS LS-DYNA.

NUMERICAL ANALYSIS OF FUNCTIONALLY GRADED POROUS TI-BASED HIP JOINT ENDOPROSTHESIS

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Abstract: Titanium and its alloys belong to a group of materials with outstanding properties such as high specific strength and corrosion resistance, which makes them particularly suitable for aerospace or automotive applications. They are also highly biocompatible and have been successfully used in medicine as dental or endoprosthesis implants. However, their high stiffness modulus (~120 GPa) compared to bone tissue (~20GPa) can result in stress shielding. It can lead to implant loosening. Therefore, the appropriate solution appears to be the modeling and production of functionally graded materials (FGM). They are composite materials in which the chemical composition or structure varies in one or more directions. In addition, porosity in gradient materials has the effect of reducing their density and stiffness in certain zones, which could be particularly welcome for such applications. Therefore, the aim of this study was to model and numerically analyse a hip joint endoprosthesis made of porous graded Ti-based material, and to evaluate the strength properties of the bone-implant system. The FGM material was modeled with different porosity distributions throughout the volume, including both even and uneven porosity. The obtained model was subjected to numerical analysis considering different boundary conditions. The effect of the endoprosthesis surface roughness on the mechanical response of the implant-bone interface was also studied. The numerical analyses confirmed that porous gradient structures effectively reduce stress shielding and can promote bone healing.

Keywords: Functionally graded material; porous gradient material; hip joint endoprosthesis; numerical analysis; finite element method.

QUASI-STATIC STUDY OF THE ENERGY ABSORPTION OF ARMADILLO BIO-INSPIRED TUBES UNDER AXIAL AND OBLIQUE LOADS

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Abstract: Today the implementation of biomimetic elements during the design of thin-walled structures (BTWS) is relevant among engineers and designers since bionic solutions are the result of successful evolution and adaptation processes. The current article presents the design and evaluation of five BTWS based on the nine-banded armadillo armor. The BTWS were designed considering the pectoral and pelvic patterns of the armadillo's carapace. In all cases, the tubes were made of aluminum alloy 6061. The evaluation of the BTWS was through a numerical oblique compression test with loading angles of 0°, 5°, 10° and 15°. Oblique loading conditions are used since in practice most car crashes occur under these conditions. The numerical results revealed a decrease in the Pmax and Pm as the load angle (θ) increased. Likewise, it confirmed the superior performance of BTWS respect to conventional tube regardless of θ value. Specifically, an improvement in crash force efficiency (CFE) and energy absorption (Ea) of 86% and 78% was computed. Despite a decrease in Ea was observed as the loading angle increased, BTWS exhibited an enhancement of this parameter regard to conventional tube named HX-00. Regardless of the load angle, the best energy absorption performance was calculated for BTWS HX-04, where an average of 0.85 kJ was calculated. Lastly, comparing the bionic thin-walled structures for each loading angle, the largest crush force efficiency (CFE) of 0.74 was obtained on a structure with a main circle surrounded by smaller irregular pentagons (HX-04).

Keywords: Crashworthiness, Finite element analysis, oblique load, armadillo-bioinspired tubes.

THE INFLUENCE OF MECHANICAL COUPLING ON THE BUCKLING BEHAVIOUR OF CFRP COLUMN PROFILES

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Abstract: The study focuses on the analysis of three recently identified classes of mechanically coupled laminates exhibiting matching Extension–Twisting (B_{16}/B_{26}) couplings. The considered stacking sequence configurations fulfill the Hygro-Thermally Curvature Stable (HTCS) condition, ensuring immunity to thermal warping deformations resulting from the high-temperature curing process. The investigation was performed on thin-walled carbon fibre reinforced plastic (CFRP) profiles subjected to axial compression, with the aim of quantifying how selected types of mechanical coupling influence both the buckling and postbuckling response.

The research methodology included algorithm development for synthesis of laminates with precisely matched orthotropic ABD stiffness properties in order to quantify the effects of adding specific mechanical coupling properties through stacking sequence tailoring. The baseline design represents a fully isotropic material onto which Extension-Twisting coupling is then added. Further mechanical couplings are then introduced to assess the influence of Extension-Shearing and/or Bending-Twisting.

Analytical and Numerical (finite element) analyses were conducted to assess the influence of the coupling terms on the critical buckling load and mode shape interaction. Experimental validation tests were performed on selected profile sections using a universal testing machine with bespoke support fixtures. The results demonstrate that the presence of Extension–Twisting coupling modifies the stability characteristics of composite profiles, leading to interesting changes in the critical load and buckling mode development. The findings highlight the potential of controlled mechanical couplings in the design of advanced, tailored-stiffness composite thin walled structures.

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Keywords: Buckling, Mechanical Coupling, Extension-Twisting, Extension-Shearing, Bending-Twisting.

ANALYSIS OF THE IMPACT OF DRIVER WEIGHT DISTRIBUTION ON CHEST LOADS

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Abstract: During typical frontal crash tests, the driver dummy is placed in the vehicle in the correct body position. The hands are placed on the steering wheel, the legs on the footrest and brake or floor. During the collision, the dummy moves forward, hitting the vehicle components or knee airbag with its knees. The hands, in turn, resist contact with the steering wheel before detaching from it. The torso and head, in turn, strike the steering wheel airbag. This means that only part of the driver's inertial force acts on the seat belts. The resulting load is distributed between the lap belt and the shoulder belt. The reaction force between the shoulder belt and the torso causes deformation of the chest. Chest injury severity scores are calculated on this basis. In the case of people with special needs, the conditions of the above-mentioned tests may not always be met. Firstly, drivers very often use additional equipment placed, for example, on the steering wheel and in the center tunnel of the vehicle, which changes the conditions of support for the upper body. Secondly, the driver may be a person who has had one or more limbs amputated. When the driver has no legs, the distribution of loads acting on the arms, torso, and head changes. This paper presents the impact of the driver's body weight distribution, e.g. as a result of amputation, on the loads acting on the chest.

Keywords: FEM, crash, dummy, chest deformation.

POSSIBILITY OF USING FEM TESTING OF BUS STRUCTURES IN THE VEHICLE APPROVAL PROCESS

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Abstract: In recent years, numerical analysis methods have been dynamic in the context of vehicle design and type approval, including buses. In light of the UNECE (United Nations Economic Commission for Europe) regulations, using numerical calculations equivalent to traditional physical tests in the type approval process is becoming increasingly important. The article presents an overview of the current UNECE requirements for bus safety, with particular emphasis on Regulation No. 66 (the integrity of the load-bearing structure during rollover) and Regulation No. 107 (functional requirements for vehicle structure), as well as Regulations No. 93 and 29. The possibilities of using finite element methods (FEM) in the simulation of emergency scenarios, structural strength assessment and optimisation of bus structures were analysed. We presented examples of practical applications of numerical analyses as tools supporting the certification process and discussed the conditions that must be met for them to be considered equivalent methods. The article emphasizes the importance of validating numerical models and complying with procedures agreed upon with approval authorities. The study aims to identify computer analysis's potential and limitations in light of contemporary approval and regulatory challenges.

Keywords: FEM, vehicle design, validating numerical models.

MATERIAL PROPERTIES AND STRUCTURE RESEARCH METHODS

AN EXAMPLE OF USING FRACTAL ANALYSIS TO MODEL THE DYNAMICS OF MECHANICAL SYSTEMS

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Abstract: The dynamic interactions of mechanical systems are traditionally described using a second-order ordinary linear differential equation. This same type of equation, but non-homogeneous, incorporates an additional generalized exciting force. The Runge-Kutta method can be used to solve this equation, which involves reducing a second-order equation to a system of two first-order equations. For multi-member objects, instead of a single equation, one must write down as many relations as the number of these terms or use matrix notation. A new method for describing dynamics involves the use of positive fractional differential operators and the gamma function. This has characteristics of fractal analysis. The mathematical interpretation of fractional differential operators, like the differential or integral operator, is only possible when we have a specific function in mind. The gamma function, on the other hand, can be calculated by the factorial of a number smaller by one. Therefore, it has an easy-to-calculate value for an integer argument, but a challenging one if the argument is fractional. Using the R programming language syntax, this function can be calculated as: function(s) {integrate(function(t) exp(-t) * t^(s - 1), 0, Inf) }. The new, modified equation of motion dynamics includes the Grunwald-Letnikov (order close to 2) and Caputo (order close to 1) fractional differential operators. The simulation results using the presented procedure are consistent with the results of experimental studies of a system with six and nine degrees of freedom and with simulations conducted using the traditional method. The advantage of the new fractal simulation method is the ability to implement excitation not only through the system parameters but also through the order of the fractional derivative. This allows for the representation of small-scale imperfections, such as local wear of kinematic pairs.

Keywords: Fractal analysis, fractional differential operators, mechanical system, dynamics, gamma function.

AI TECHNIQUES TO OPTIMISE THE PROCESS PARAMETERS OF THE STEEL COMPONENTS RESISTANCE PROJECTION WELDING

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Abstract: The study employed applied computer modelling to identify the optimal process parameters for resistance projection welding. The influence of technological parameters (welding power, welding time, electrode pressure) on the quality of 186 joints obtained through resistance projection welding of steel nuts and S235JR steel plates was examined utilising computer modelling methods, notably a combination of machine learning and evolutionary algorithms. A model based on a random forest structure was used to determine relationships between signals, while a genetic algorithm facilitated multi-criteria optimisation. The prepared joints were analysed to assess the effects of welding parameters on microstructure, Vickers hardness, and tensile strength. It was observed that joints exhibited superior tensile strength when short welding times and high power were employed. Additionally, a limited welding time effectively restricted the heat-affected zone and reduced the hardness of welds, thereby enhancing joint plasticity. The developed modelling procedure enables the minimisation of energy consumption (welding current) while maximising joint strength, which constituted the primary objective of this research. The set of optimised welding parameters, as determined by artificial intelligence, was verified through experimental procedures, including sample welding and strength testing, and these findings were positively confirmed by final tensile strength assessments.

Keywords: Projection welding, machine learning, genetic algorithm, joint strength.

COMPARATIVE ANALYSIS OF EXTRUSION ALUMINIUM ALLOY COMPONENTS QUALITY

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Abstract: This study presents a comparative assessment of the quality of drawn aluminium alloy components, focusing on microstructure, surface condition, and mechanical properties. Metallographic investigations were carried out using light optical microscopy (LOM) and scanning electron microscopy (SEM), revealing differences in grain morphology, phase distribution, and deformation patterns resulting from the drawing process. Surface roughness was evaluated using profilometric analysis, with parameters such as Ra and Rz used to quantify surface finish. The results showed that drawing conditions significantly influence surface quality, with optimized parameters reducing roughness and improving functional performance. Chemical composition was confirmed through spectroscopic analysis, ensuring alloy compliance with standard specifications and identifying trace elements that may affect corrosion resistance and strength. Vickers hardness testing demonstrated increased hardness in drawn components, attributed to strain hardening and microstructural refinement. The integration of microstructural analysis, surface characterization, and mechanical testing provides a comprehensive understanding of how drawing parameters affect final component quality. This comparative approach supports the optimization of manufacturing processes for aluminium alloys used in structural engineering applications.

Keywords: Microstructure, hardness, roughness, composition, metallography.

EVALUATION OF POWDER PLASMA TRANSFERRED ARC HARDFACINGS ' PARAMETERS ON RESISTANCE TO CAVITATION EROSION

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Abstract: This paper investigates the influence of powder plasma transferred arc welding (PPTAW) parameters on the microstructure and hardness of Stellite 6 and 316L overlays. Plasma welding is a widely adopted technique for surface enhancement, repair, and wear protection of machine components. A critical aspect of powder-based PTA welding is the precise selection of process parameters—such as current intensity and welding speed—tailored to the filler material, which directly affects the resulting microstructure and mechanical properties of the overlay. The study describes the preparation of test samples using Stellite 6 and 316L powders under varying process conditions. It outlines the laboratory procedures and presents results concerning overlay geometry, dilution ratio, microstructure, chemical composition, and hardness. To assess erosive resistance, cavitation erosion tests were conducted, supported by scanning electron microscopy (SEM) and profilometry to identify the erosion mechanisms. Additionally, artificial intelligence (AI) methods were applied to determine correlations between welding parameters and coating properties. The findings confirm that optimizing PPTAW parameters significantly enhances the structural integrity and functional performance of the resulting coatings.

Keywords: Hardfacing, coating, Stellite 6, 316L, cavitation erosion, microstructure.

DEVELOPMENT OF A JOHNSON–COOK CONSTITUTIVE MODEL FOR 316L STAINLESS STEEL MANUFACTURED BY WIRE LASER METAL DEPOSITION

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Abstract: The aim of this study is to analyze the mechanical properties of samples produced using the Wire-Laser Metal Deposition (WLDM) technology for numerical research applications. WLDM is an advanced additive manufacturing technique that enables precise fabrication of metallic components by melting a metal wire with a laser beam. Despite its growing industrial relevance, there is still a lack of reliable data regarding the mechanical properties and isotropy of materials manufactured using this method, which hinders their implementation in numerical simulations. The research involves the production of samples in three orientations relative to the loading direction, followed by static and dynamic tensile testing. The obtained results will be used to develop a rheological material model suitable for numerical analyses. This study serves as a foundation for further development of WLDM technology, including its potential use in mobile repair units for industrial applications.

Keywords: Wire-Laser Metal Deposition (WLDM), additive manufacturing, mechanical properties, tensile testing, rheological modeling, numerical simulations, anisotropy, metal 3D printing, dynamic testing, advanced manufacturing technologies.

STUDY OF THE EFFECT OF THE SURFACE MODIFICATION WITH METALLIC OR OXIDE PARTICLES ON THE TiO_2 SURFACE

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Abstract: It is crucial to develop modern technologies for large industrial concerns due to the increasing production of pollutants that have a devastating impact on the environment. Organic industrial dyes in particular, are hazardous pollutants that are chemically stable and do not biodegrade. The most promising solution to this problem is advanced oxidation processes, such as photocatalysis. Photocatalysis is an ecofriendly technology that plays a crucial role in water purification and environmental detoxification and is induced by visible light. Semiconductor photocatalysts are considered to be clean, safe and cost-effective. TiO_2 is a well-known photocatalyst used for energy production and environmental purification. The material's wide bandgap unfortunately limits its use due to low absorption of solar energy in the visible part of the light spectrum. To enhance its catalytic properties, it can be combined with another semiconductor material to create a composite with a greater ability to degrade organic pollutants under the influence of visible light. In this work we focus our attention on the modification of TiO_2 with metallic (i.e.Cu) and oxide coatings (i.e. CeO_2). The synthesized nanomaterials were subjected to comprehensive physicochemical characterization using a combination of analytical techniques, including X-ray diffraction (XRD), scanning and transmission electron microscopy (SEM and TEM), diffuse reflectance spectroscopy (DRS, UV–Vis), Raman spectroscopy, and Fourier-transform infrared spectroscopy (FTIR). Further, to check the utility of as-modified material the photocatalytic performances were evaluated through the degradation of Acid Orange 7 (AO7), a representative azo dye pollutant, under both UV and visible light irradiation. The results of these measurements will be presented at the Conference.

Keywords: Photocatalysis, water purification and environmental detoxification, semiconductor photocatalysts, modification of TiO_2.

INFLUENCE OF PRINT ORIENTATION AND TYPE OF LIGHT-CURING RESIN ON THE DYNAMIC MECHANICAL ANALYSIS PROPERTIES OF SAMPLES PRODUCED BY STEREOLITHOGRAPHY

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Abstract: The aim of this paper is to analyse the influence of the printing orientation and the type of photopolymer resin on the dynamic properties of the samples, using stereolithography (SLA) technology on a Prusa SL1S SPEED printer. The samples were divided into three series differing in the type of material used and the spatial orientation of the print (X-, Y- and Z-axis printing). Identical exposure and layering parameters were used in each series, allowing a direct comparison of the effects of design variables on the dynamic characteristics of the material. The properties were analysed using Dynamic Mechanical Analysis (DMA), measuring the storage modulus (E'), loss modulus (E'') and damping factor (tan δ) as a function of frequency and temperature. The results show significant differences between the series, especially in terms of damping and dynamic stiffness. These studies provide a basis for optimising the 3D printing process of UV resins for applications requiring specific dynamic properties, such as damping components, micro gear components or parts exposed to vibration. The results can contribute to a better understanding of the relationship between SLA printing parameters and the mechanical behaviour of materials under varying loads.

Keywords: DMA, UV resin, 3D print, SLA.

EFFECT OF CURING TEMPERATURE OF AERONAUTICAL EPOXY RESIN USED FOR ABLATIVE SHIELDING ON SOFTENING AND DEFLECTION TEMPERATURE

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Abstract: This paper presents the results of a study on the heat deflection temperature (HDT) and Vicat softening temperature (VST) of the LH285 MGS aerospace polymer resin, used as a matrix in ablative shielding composites. This topic is particularly relevant because, during ablative testing, the composite material undergoes partial combustion (ablative layer), while its remaining sections are exposed to elevated temperatures, leading to changes in viscoelastic properties that depend, among other factors, on VST and HDT. In this study, the authors examined aerospace resins cured under various conditions as recommended by the manufacturer. In addition to assessing changes in thermal properties due to material conditioning, the study also investigated the effects of heating rate and applied load magnitude, following the applicable standards for this type of material. The results indicate that resin heating influences HDT and VST values. Additionally, the indentation shape in the material varies with conditioning temperature. However, the choice of heating rate and load magnitude had a relatively minor impact on the results.

Keywords: Epoxy resin, vicat softening temperature (VST), heat deflection under temperature (HDT), surface profile examination.

SIMULATIONS OF THE ASYMMETRIC RESPONSE OF VACUUM PACKED PARTICLES USING THE DISCRETE ELEMENT METHOD

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Abstract: Vacuum Packed Particles (VPP) are structures that can be classified as smart materials due to their ability to exhibit controllable mechanical properties regulated by vacuum pressure. A VPP structure consists of a loosely packed granular medium enclosed in a sealed, thin, flexible, and elastic shell (typically made of silicone or plastomer) equipped with an external valve. By using a vacuum pump, the internal pressure can be reduced, significantly affecting the global physical and mechanical behavior of the structure. In this work, the authors propose a novel modeling approach for VPP structures and devices utilizing DEM. A reliable and representative simulation method is achieved through the use of the Discrete Element Method (DEM). This approach enables the creation of a discrete numerical twin of a VPP-based device at the design stage, allowing for comprehensive analyses aimed at optimizing its geometry, the quantity, granularity, and type of granular material, as well as the properties of the shell, based on selected performance criteria (e.g., maximizing the damping efficiency of VPP dampers). The proposed methodology includes fundamental material testing of the granular media (e.g., determination of Young's modulus), mechanical characterization of the shell (including adhesive layers), and the extrapolation of these results for numerical analysis of cylindrical VPP samples. Given the critical role of loading direction (tension vs. compression) in determining energy dissipation, the effectiveness of the proposed DEM-based approach is validated by comparing simulation results with experimental data from cyclic loading tests on VPP specimens under varying vacuum conditions. Although the proposed method requires significant computational resources, it offers a substantial advantage over traditional experimental approaches, paving the way for broader application of VPP structures in practical engineering contexts.

Keywords: VPP DEM.

THE EFFECT OF HYBRID PROCESS TREATMENT ON THE TRIBOLOGICAL PROPERTIES OF HIGH ALLOY TOOL STEEL

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Abstract: Advanced high-strength nanobainitic steels, in addition to high strength reaching the level of 2000 MPa, are also characterized by increased plastic properties. They owe this extremely advantageous combination of mechanical properties to a nanocrystalline structure consisting of carbide-free bainite plates separated by austenite bands. Such a structure is obtained in the process of hardening quenching with an isothermal transformation carried out at temperatures slightly above the Ms temperature. However, due to the relatively high content of austenite in the structure, these steels are characterized by hardness at the level of approx. 55 HRC which is relatively lower than in standard martensitic quenching. This limits the area of their potential applications operated in friction wear conditions usually requiring hardness of at least 60 HRC. Hardening the nanobainitic steel surface by final surface treatment, using in industrial practice gas nitriding in particular typically performed between 500 – 600°C encounters the barrier of low thermal stability of nanocrystalline structures, usually not exceeding c.a. 400°C, hence the need to seek for an unconventional solutions. In this paper, the influence of high-temperature gas nitriding of high-alloy tool steel type K360, carried out in the austenitic range above 1000°C in a new integrated hybrid process combining nitriding in a nitrogen atmosphere with subsequent nanobainitization of the core on tribological properties was investigated. The tests of resistance to frictional wear were carried out in sliding friction conditions using the three-roller-cone method. In order to assess the functional properties obtained in the hybrid process, comparative tests of tribological properties of K360 steel processed in a conventional way, i.e. heat-treated and then gas nitrided in an ammonia atmosphere in the ferritic range, at a temperature of 530°C were also carried out in the paper. The results of the work were finally discussed in terms of microstructure – properties correlation.

Keywords: Nanobainitic steels, hybrid process, gas nitriding, three-roller-cone method, tribological properties.

COMPUTING NANOMECHANICAL PARAMETERS FROM PF QNM AFM DATA: THEORY, MODELS, AND SOURCES OF ERROR

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Abstract: Atomic Force Microscopy (AFM), particularly when using the PeakForce Tapping technique, has revolutionized surface science by enabling simultaneous topographic, mechanical, and physicochemical properties analysis. Based on the interaction between a sharp probe and the sample surface, AFM provides nanometer-resolution visualization and quantification of surface morphology, as well as mechanical, electrical, and magnetic characteristics. During imaging, precisely controlled and repetitive contact cycles between the probe and the sample generate individual force–distance curves at each pixel, resulting in tens of thousands of curves per image. The mechanical interaction between the AFM tip and the sample is typically considered a quasi-static process, allowing interpretation of the force curves using classical contact mechanics theories. Commonly applied models include the Hertz, Derjaguin–Muller–Toporov (DMT), and Johnson–Kendall–Roberts (JKR) models, which mathematically describe the relationship between force and deformation based on material properties and probe geometry. However, the quantitative extraction of nanomechanical properties from raw force–distance data into physically meaningful parameters is far from straightforward. The accuracy of the results is highly sensitive to several critical factors, including calibration of the cantilever spring constant and deflection sensitivity, estimation of the tip radius, and correct identification of the contact point. Additional complications, such as model mismatch and surface-related artefacts (e.g., roughness, heterogeneity, or contamination) can further compromise measurement reliability. Therefore, without precise control over these key experimental parameters and theoretical assumptions, the resulting nanomechanical maps may reflect model-dependent artefacts rather than true surface material properties. The study will discuss in detail the procedures that enable quantitative analysis of the results and the avoidance of the aforementioned artefacts.

Keywords: Atomic Force Microscopy (AFM), Quantitative Nanomechanical Mapping (QNM).

IDENTIFICATION OF MARAGING STEEL FAILURE PROPERTIES FOR SIMULATING THE IMPACTS AND PERFORATION PROBLEMS

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Abstract: This study demonstrates the calibration and validation process of the Tabulated Johnson – Cook (TJC) constitutive model used to reproduce the failure behaviour of Maraging M300 steel (1.2709). First, the manufacturing process of specimens fabricated from Maraging M300 steel, including a basic characterization of its mechanical properties, is described. The specimens were produced using the Selective Laser Melting (SLM) technique with M300 steel powder. Next, basic tests were performed with experimental data acquisition, and then simulated numerically in equivalent conditions. Subsequently, the failure surface originally developed for the Armox 500T was adjusted based on the trial-and-error approach using a coupled experimental-numerical procedurę. For this purpose, an authorship experimental set-up to carry out quasi-static perforation tests with pointed, flat and hemispherical punches was used. The real-world laboratory tests were numerically replicated using the TJC constitutive model and appropriate boundary conditions. It was observed, that the proposed failure model reproduced very well the experimental outcomes from the qualitative and quantitative point of view. Finally, experimental impact tests were conducted against the additively manufactured targets from the M300 powder. In this stage, the model also provided a satisfactory response within the dynamic impacts regime. The results are promising in the scope of developing feasible constitutive models for the metallic powders used in additive technologies. Moreover, the paper provides a valuable guide for modelling and simulating impacts problems in explicit hydrocodes.

Keywords: FEA, Additive Manufacturing, SLM, LS-Dyna, M300 steel

ADVANCED MATERIALS IN THE STRUCTURE OF A HIGH-PERFORMANCE QUADCOPTER

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Abstract: Unmanned aerial vehicles (UAVs) are currently widely used in various fields. They are mainly manufactured from composite materials due to their low weight, but 3D printing technology also seems to be a technique worth considering in the manufacture of such structures. This article attempts to compare two materials that can be used in the construction of a small-sized high-performance drone. For the purpose of selecting the material for the frame of the device, samples for strength testing were made from carbon fiber reinforced polymer laminate and PETG Carbon filament, from which samples and frame elements were produced on a Prusa i3 MK3 printer. Basic strength tests were performed for strength analysis and comparative strength of selected materials to determine their properties: tensile test, three-point bending test, and impact test. The carbon composite had 16 times higher tensile strength and 10 times higher Young's modulus compared to PETG Carbon. In the Charpy impact test, the carbon composite showed 72% higher surface impact strength and 121% higher edge impact strength compared to PETG Carbon. However, the quadcopter frame was made of PETG Carbon filament due to the simpler manufacturing process and the filament's lower density than the composite by approximately 7.5%. These properties were given priority due to the intended use of the unmanned aerial vehicle under test. After testing the mechanical properties, the drone frame was assembled, the drive unit was installed, the control electronics were installed, programming and flight tests were carried out with performance analysis, which was compared with the performance of a similar commercially available system.

Keywords: Quadcopter, unmanned aerial vehicle, carbon composites, strength testing, performance analysis.

PRELIMINARY RESEARCH ON THE POSSIBILITY OF IDENTIFYING IMPACT LOADS OF A LAYERED COMPOSITE USING PIEZOELECTRIC SENSORS

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Abstract: Composite materials are exceptionally interesting materials due to their properties, which is why they are widely used in the aerospace, automotive, sport and many other industries. They are increasingly used as key components of complex structures. Many factors influence the properties of composites, therefore, it is crucial to monitor the condition of composite components and identify any potential damage. The most common cause of damage to such components is mechanical impact. Impact loads are particularly dangerous for layered composites, the effects of which are often invisible from the outside. Therefore, to perform a more effective assessment, it is crucial to determine whether such damage has occurred and to determine the extent of any potential damage. This article presents the research process for a nine-layer polymer composite reinforced with glass fabric, measuring 210 x 210 mm. Four LDT0-028K piezoelectric vibration sensors are mounted at the corners. By monitoring the electrical signals from the sensors, impact loads on any place of the composite surface can be detected. Furthermore, by comparing the recording times of the acquired signals, the area of probable damage can be determined for further investigation. This area can be narrowed down to 1/16 the size of the object being tested.

Keywords: Layered composite, piezoelectric sensor, impact load.

THE INFLUENCE OF TEMPERATURE OF THE MATRIX ON PROPERTIES OF GFRP MADE BY INFUSION METHOD

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Abstract: Layered composites are an important element of modern material technologies, widely used in many industries, including aviation, automotive, construction and marine. One of the most modern methods of composite production is the resin infusion process, which allows obtaining materials of high strength and low weight. Selection of appropriate infusion process parameters, such as resin temperature, is crucial for the quality of the final product. Epoxy resins are one of the most commonly used matrix materials in composites due to their excellent mechanical, chemical and thermal properties. Proper control of the resin mixture temperature in the composite creation process can affect the viscosity of the resin, its curing rate and the quality of the connection between the layers of reinforcing fibres. The aim of this work was to investigate the effect of the temperature of the epoxy resin and hardener mixture on the strength of layered composites produced by the infusion method. The conducted studies are aimed at identifying the optimal temperature conditions that allow obtaining composites with the highest strength parameters. The mechanisms influencing the formation of internal defects and their influence on the mechanical properties of composites were also analyzed. The main goal was to investigate how different temperatures of the resin composition (cooled to -10°C, at room temperature, and heated to +50°C) affect the mechanical strength of composites. A series of mechanical tests were performed, including three-support bending tests, impact tests and tensile tests. The temperature of the resin composition had a noticeable effect on Young's modulus and bending strength. The composite with the mixture heated to +50°C was characterized by the highest stiffness, however, the tests showed that the samples with the resin composition cooled to -10°C were characterized by higher bending strength. In the case of impact tests and tensile tests, the results were very similar.

Keywords: Layered composites, infusion method, GFRP (glass fiber reinforced polymer).

THE INFLUENCE OF ATMOSPHERIC CONDITIONS AND THERMAL SHOCKS ON THE SURFACE LAYER PROPERTIES OF EPOXY COMPOSITES WITH TIO_2 ADDITIVES

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Abstract: As part of the conducted research, the influence of atmospheric conditions and thermal shocks on the surface layer properties of epoxy composites produced from aerospace-grade epoxy resin modified with titanium dioxide (TiO_2) was investigated. The prepared composite samples were exposed to environmental factors simulating real operating conditions typical for composite materials used in aerospace applications. The aging process was carried out in a QUV/SPRAY/RP weathering chamber, which allows simulation of the destructive effects of weather conditions such as UV radiation, humidity, and elevated temperature. Changes in selected mechanical and physicochemical properties of the surface layer were analyzed, with particular emphasis on hardness and resistance to surface degradation. The obtained results indicate that exposure to atmospheric factors and cyclic temperature variations leads to noticeable changes in the structure and surface properties of the composite. In terms of hardness, localized material hardening was observed, which may result from additional cross-linking of the resin under the influence of thermal factors. The findings provide a basis for further research on the durability of epoxy composites with TiO_2 additives under complex operating conditions.

Keywords: Composite, epoxy resin, titanium oxide, profilometric test.

PRODUCTION ENGINEERING, MANAGEMENT AND QUALITY CONTROL

RAPID PROTOTYPING OF OPTICAL LENSES USING 3D PRINTING: SPECTRAL TRANSMISSION MEASUREMENT OF LENSES MADE FROM PHOTOPOLYMER RESINS

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Abstract: The article presents information on the application of 3D printing technology in the production of optical lenses, which are used in fields such as mechanical engineering, computer science, and precision optics. The aim of the study was to design, manufacture, and verify the properties of transparent optical lenses made from photopolymer resins. Optical lenses are a key component in many modern devices, ranging from optical systems to electronic equipment. The article analyzes the technological possibilities related to 3D printing of polymer lenses. The production process used a 3D printing method: SLA (Stereolithography). This technology was applied to produce optical lenses, and the article provides a detailed description of the entire manufacturing process, including the use of proprietary finishing tools. These tools were specifically designed for the purposes of this study to ensure precise processing of the lenses, which is crucial for their final optical properties. The article discusses various types of lenses, their applications, and potential defects that may occur during production. The most important part of the study was the analysis of post-processing methods in 3D printing, which are not commonly addressed in the literature. Based on this analysis, the most effective methods were selected and applied in the production of lenses using stereolithography. The optical properties of the lenses were examined in a professional laboratory at ProLight using specialized equipment—a monochromator. The test results were presented in the form of optical characteristics, allowing for an accurate assessment of the quality of the manufactured lenses. This type of analysis represents an important contribution to the development of 3D printing technology in the production of optical lenses. The research findings received positive feedback from professionals in the field of optics.

Keywords: 3D printing, optical lenses, rapid prototyping, photopolymer resins, spectral transmission.

ANALYSIS OF THE SELECTION OF MEASUREMENT TOOLS TAKING INTO ACCOUNT THE RISK OF MAKING ERRORS WHEN JUDGING COMPLIANCE

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Abstract: The article discusses practical aspects of selecting measuring tools for workshop measurements in the metal industry. The analyses take into account traditional principles of selecting measuring tools, issues related to the actual location of tolerance fields of the realized feature (more precisely, the probability density distribution), and the density distribution of the obtained measurement results. The results take into account the division of erroneous decisions when deciding on conformity, i.e. the occurrence of alpha and beta type errors and the risk of manufacturing and receiving nonconforming parts. The calculation results can be helpful in designing technological processes in conditions of high-quality requirements and limited manufacturing and measurement possibilities.

Keywords: Workshop measurement, manufacturing tolerance, measurement tolerance, measurement uncertainty.

THE PROCESS OF IDENTIFYING RISK FACTORS IN THE FMCG SECTOR – LIMITATIONS AND CHALLENGES

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Abstract: In the field of risk management in the FMCG warehouse sector, there is still a lack of targeted studies on the algorithmization of the risk factor identification process. Existing literature primarily focuses on general logistics approaches, neglecting the operational specifics of warehouses handling fast-moving consumer goods, characterized by high inventory variability, seasonal deliveries, and intense time pressure in storage and order-picking operations. Current research centers on risk classification at the level of the entire supply chain or general logistics processes, without providing a detailed analysis of the mechanisms underlying risk occurrence in the warehouse environment. Consequently, there is a noticeable research gap in developing a dedicated model or algorithm that would enable the identification and selection of key risk factors in FMCG warehousing, considering the actual operating conditions of high-turnover facilities. This article attempts to define these limitations and suggests potential research directions that could support the optimization of risk identification processes in the FMCG sector through the development of a dedicated algorithmic model.

Keywords: Risk management, FMCG sector, warehouse logistics, risk identification, algorithmic modeling, high-turnover facilities, supply chain risk, operational variability, seasonal deliveries, time pressure.

TECHNOLOGY MANAGEMENT IN ENERGY ACQUISITION PROCESSES

INTEGRATING EXPERIMENTAL DATA AND NEURAL COMPUTATION FOR EMISSION FORECASTING IN AUTOMOTIVE SYSTEMS

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Abstract: This work presents an integrated approach combining experimental testing and mathematical modelling to analyze fuel consumption and pollutant emissions in a spark-ignition engine vehicle. Experimental data were obtained from chassis dynamometer tests under the WLTP driving cycle, including time series of vehicle speed, energy consumption, and CO_2, CO, THC, NOx. Two classes of artificial neural networks were implemented to capture the complex, nonlinear relationships between driving dynamics and emission profiles: Multi-Layer Perceptrons (MLP) and Self-Associative Neural Networks (SANN). These models were trained on real-world time series data to predict vehicle speed and energy consumption as functions of emission parameters and vice versa. The models demonstrated high accuracy, especially in the validation phase, confirming their potential for forecasting and environmental performance assessment. The neural network models underwent training, validation, and testing processes, allowing for the assessment of their effectiveness in predicting energy consumption under various system operating scenarios. Additionally, the observed patterns in energy use were interpreted through a physical lens, considering the thermodynamics and chemical kinetics of combustion processes under different driving conditions. This hybrid methodology – combining data-driven AI with domain-specific physical insight – provides a robust framework for predicting the environmental impacts of internal combustion engines and optimizing their operation.

Keywords: Emission modelling, energy efficiency, combustion process optimization, sustainable development, energy consumption prediction, artificial neural networks.

STUDY OF A KINEMATICALLY DRIVEN SYSTEM WITH VISCOUS DAMPING AND STEP-VARIABLE HYSTERETIC STIFFNESS

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Abstract: One of the main challenges in harvesting energy from vibrations is the inherently low efficiency, which results from the small amplitude of excitation and the system's weak response to frequencies outside resonance. A potential way to improve the performance of electromagnetic harvesters involves introducing mechanical modifications, such as amplifiers or spring bumpers. This study focuses on modelling an oscillator mounted on two pre-compressed coil springs, additionally constrained by rigid bumpers that serve as motion limiters (Fig. 1a). The formulation accounts for viscous damping and the frictional interaction between the moving mass and the vibrating base, with excitation provided by the base displacement. Due to friction, the effective stiffness of the springs differs depending on whether the springs are loaded or unloaded, while the level of pre-compression influences the hysteresis loop of the force–displacement relation acting on the mass (Fig. 1b). The developed model represents the mechanical component of a vibration-based energy harvester. To validate the theoretical predictions, experimental tests were conducted using a laboratory prototype.

a) b)

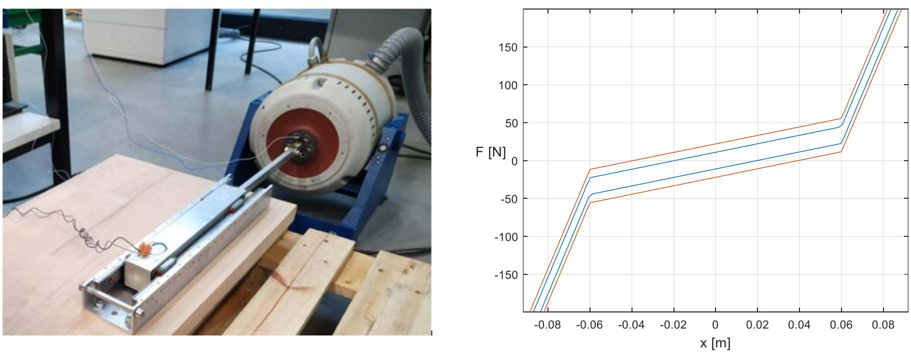

Fig. 1. The oscillator with pre-compressed springs (a) and corresponding force characteristic with hysteresis loop (b).

Keywords: Vibration energy harvesting, hysteretic stiffness, viscous damping, kinematic excitation.

ELECTRICITY GENERATION IN A SIMPLE CYCLE GAS TURBINE SYSTEM USING NATURAL GAS AND HYDROGEN (H_2-NG) MIXTURE

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Abstract: Recently, there has been a growing interest in hydrogen in the energy sector. Hydrogen has a high calorific value relative to its mass. It can be obtained by different methods. Depending on the method of hydrogen production, we have green, blue, grey, brown, and black hydrogen. Green hydrogen is the most environmentally friendly as it is produced by electrolysis using renewable energy sources. Hydrogen can be used as a means of storing the excess energy created when the amount of energy produced is greater than the supply. The use of surplus energy from renewable sources allows the energy system to be stabilised, making it possible to increase the proportion of energy from renewable sources. Hydrogen can also be used as a fuel in the energy sector. At present, it can be used as an admixture of up to 30% in natural gas. Work is underway to design turbines that can burn 100% hydrogen fuel. This article presents a system consisting of a power generation unit. Electricity is generated in a gas turbine in which hydrogen is co-fired with natural gas. Calculations have been carried out using the Python programming language. The results were compared with a model created in the Cycle Tempo software. The results were analysed for different fuel compositions.

Keywords: Hydrogen, gas turbine, hydrogen fired gas turbine, natural gas, power systems.

COMPUTER SIMULATIONS AND APPLICATIONS IN ELECTRICAL ENGINEERING

ADVANCED DIAGNOSTIC MODELING OF RESPIRATORY DISORDERS USING ELECTRICAL IMPEDANCE TOMOGRAPHY

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Abstract: This paper presents the development of an advanced medical diagnostic framework utilizing electrical impedance tomography (EIT) to enhance the detection and characterization of respiratory diseases. The research focuses on simulating and analyzing pathological and healthy respiratory conditions such as chronic obstructive pulmonary disease (COPD), acute respiratory distress syndrome (ARDS), pneumothorax (PTX), pneumonia (PNA), bronchospasm, and pulmonary hypertension (PHTN). Numerical models were constructed to emulate six patient-specific anatomical scenarios, incorporating up to eighteen components to reflect physiological variability. Each disease type was evaluated across multiple stages of clinical progression. Data acquisition was carried out through finite element simulations replicating EIT measurements over temporal sequences corresponding to inhalation and exhalation cycles. Comparative analyses of the resulting time series allowed for the assessment of signal divergence between diseased and reference healthy states. The study employed dimensionality reduction techniques and similarity metrics such as cosine and Euclidean distances to visualize inter-class variability. The findings underscore the potential of EIT as a non-invasive diagnostic modality capable of differentiating complex lung pathologies. The proposed framework lays a foundation for future integration of machine learning-based classification systems, enabling real-time diagnostics and supporting the development of precision medicine approaches in pulmonary healthcare.

Keywords: Electrical impedance tomography, respiratory diagnostics, COPD, ARDS, pneumothorax, pneumonia, pulmonary hypertension, bronchospasm, finite element method, time series analysis, medical imaging.

DEVELOPMENT OF A HYBRID LINEAR-ROTATIONAL ENERGY HARVESTER FOR MULTISOURCE MECHANICAL ENERGY CONVERSION

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Abstract: This paper presents research on maximizing energy output in a hybrid electromagnetic energy harvester utilizing a coil with a ferromagnetic core and two independently moving permanent magnets—one performing linear motion and the other rotational motion. The aim of the study was to develop and optimize a design capable of effectively converting mechanical energy from two distinct types of motion into electrical energy. The system was designed for environments with complex vibration dynamics, where various sources of mechanical energy may occur simultaneously. The rotational motion of the magnet was achieved using an independent electric motor with adjustable rotational speed, while the linear motion was driven by a vibration generator with precise frequency and displacement amplitude control. Detailed numerical modeling using the finite element method (FEM) was conducted to analyze the magnetic flux distribution and its time variation for different geometric configurations and operating parameters. Voltage and power measurements at the coil output confirmed the effectiveness of the approach, indicating that proper tuning of motion parameters—

particularly phase synchronization and amplitude modulation—can significantly enhance the generated energy compared to systems with a single motion source. The proposed harvester architecture provides a versatile solution for autonomous systems requiring energy harvesting in mechanically heterogeneous environments, such as industrial machinery, transport infrastructure, or intelligent monitoring systems.

Keywords: Hybrid energy harvesting, electromagnetic harvester, Finite Element Modeling (FEM), dual-motion system.

WEARABLE ULTRASOUND-IMPEDANCE DUAL TOMOGRAPHY SYSTEM FOR NON-INVASIVE BLADDER FUNCTION MONITORING

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Abstract: This paper presents the design and development of a portable diagnostic system that integrates ultrasound and electrical impedance tomography (EIT) technologies for the non-invasive monitoring of bladder function. The system features a wearable solution consisting of a multipurpose UST-EIT head embedded in a silicone socket, mounted in specially adapted medical underwear, and connected to a backpack-style measuring unit. The ultrasound module employs phased array transducers with synchronized control, while the EIT module utilizes textile electrodes and high-resolution ADCs for impedance data acquisition. A dedicated mainboard, equipped with an STM32H7 microcontroller, ensures data processing and wireless transmission via WiFi to external computation platforms. The device has been designed in compliance with electromagnetic compatibility standards and was validated at an accredited EMC laboratory. Its hybrid tomographic approach enables precise, real-time bladder imaging while maintaining patient mobility and comfort. The presented solution is expected to support advanced urological diagnostics and remote monitoring in both clinical and home care settings.

Keywords: Bladder monitoring, ultrasound tomography, electrical impedance tomography, wearable medical devices, UST-EIT system, non-invasive diagnostics, electromagnetic compatibility.

ROBUST EVALUATION OF PHASE ESTIMATION ALGORITHMS FOR DISCRETE-TIME SIGNALS IN ELECTRICAL IMPEDANCE TOMOGRAPHY

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Abstract: This paper presents a comparative analysis of six discrete-time signal phase estimation algorithms dedicated to Electrical Impedance Tomography (EIT) systems operating in dynamic and noisy environments. The examined methods include Discrete Fourier Transform (DFT), Curve Fitting, Least Squares, Hilbert Transform, Quadrature Demodulation, and Cross-Correlation. Each algorithm was implemented in a unified simulation environment allowing for generation of synthetic signals with defined parameters, systematic introduction of noise and harmonic interference, and precise evaluation of estimation error and execution time. The simulation results demonstrate that while all algorithms offer high accuracy under ideal conditions, their performance under distortions varies significantly. In particular, the Least Squares and Cross-Correlation methods exhibited superior resilience in the presence of broadband and harmonic noise. Conversely, the Quadrature Demodulation method, though computationally efficient, suffered from reduced accuracy in distorted scenarios. These findings underscore the necessity of algorithm selection based on specific operational requirements, balancing computational efficiency and robustness to signal degradation in real-time tomographic imaging systems.

Keywords: Electrical impedance tomography, phase estimation, discrete-time signal processing, noise robustness, cross-correlation, least squares, quadrature demodulation, simulation.

APPLICATION OF VARIOUS ANTENNA DESIGNS IN MOISTURE MEASUREMENTS OF POROUS MEDIA

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Abstract: Microwave technology employs a variety of antenna designs, and their proper selection is crucial for ensuring the quality and accuracy of acquired measurement data. Antenna structures can range from complex solutions requiring high manufacturing precision to simplified designs, which, despite reduced structural complexity, may still provide comparable performance parameters. Among the most frequently used antennas are horn antennas, Vivaldi antennas, and double-horn antennas, each characterized by specific radiation properties and operational bandwidth determined by their design. An important parameter in antenna analysis is the Voltage Standing Wave Ratio (VSWR), which serves as a measure of the quality of impedance matching between the transmission line and the load. A low VSWR indicates efficient energy transfer from the transmitter to the antenna, minimizing losses and improving the overall performance of the measurement system. Equally significant is antenna directivity, which describes the spatial distribution of radiated energy. High directivity enables energy to be concentrated in a specific direction, thereby increasing measurement sensitivity and reducing the influence of environmental noise. Through appropriate antenna selection, it is possible to precisely investigate the physical properties of a medium, including dielectric permittivity, which is closely related to the material's water content. The analysis of this parameter allows, among other applications, the evaluation of building moisture conditions, making microwave methods a versatile tool in engineering research.

Keywords: Microwave technology, horn antennas, Vivaldi antennas, Voltage Standing Wave Ratio (VSWR), impedance matching, antenna directivity, dielectric permittivity, building moisture detection, non-destructive testing.

RELATED TOPICS

THE USE OF ARTIFICIAL NEURAL NETWORKS FOR FORECASTING OF GREENHOUSE GASE EMISSIONS FROM AGRICULTURE

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Abstract: Greenhouse gas emissions from the agricultural sector constitute a significant component of the climate balance, and their accurate forecasting is crucial for shaping sustainable development policies and environmental protection. This article presents an approach based on artificial neural networks for modeling and forecasting greenhouse gas emissions (CO_2, N_2O, CH_4) resulting from the use of limestone, dolomite, urea, and fertilizers in Poland. Inventory data obtained from official UNFCCC reports included the amount of fertilizers used, emission factors, and emission volumes for the years 2010–2025. The data were processed, normalized, and analyzed using a multilayer perceptron neural network (MLP) and a sequential LSTM variant to capture temporal dependencies. The best artificial neural network model achieved a root mean square error (RMSE) of 0.063 for CO_2 emissions, while also reaching a mean absolute percentage error (MAPE) of 0.004. The results indicate that the application of machine learning methods allows for high prediction accuracy and additionally enables the simulation of emission reduction scenarios depending on changes in fertilization structure.

Keywords: Greenhouse gas emissions, Artificial neural networks (ANN), Multilayer Perceptron (MLP), Long Short-Term Memory (LSTM), emission forecasting

POLISH METROLOGICAL UNION AS AN INTEGRATOR OF METROLOGY IN POLAND

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Abstract: The Polish Metrology Union (PUM) was established on the initiative of the Ministry of Education and Science. On the basis of the Minister's order of 30.08.2021r. Lublin University of Technology undertook to carry out the task entitled: ‘Establishment and coordination of activities of the Polish Metrology Union (PUM)’. The main objective of its establishment was to network and position activities in the area of Polish metrology, set directions for research and development and promote innovation, support staff development, and organise forums, conferences and congresses. The first edition of the targeted task was planned for 2021-2023, with 40 affiliates joining PUM. The new edition of the PUM programme, scheduled for 2024-2026, is a continuation of the existing key assumptions and new projects responding to the needs of the metrology community. On the basis of a mandate from the Minister of Science, Lublin University of Technology has again committed itself to the task of ‘Strengthening and consolidating the activities of the Polish Metrology Union (PUM) in Poland’, consisting of increasing the level of activity of secondary schools, students, societies and associations, the socio-business community and entrepreneurs in the area of metrology. In line with the objectives of the new task, PUM aims through its activities to increase the availability of information on research facilities owned by scientific units and usable by all target groups by developing and implementing the Metrology Services Kiosk (KUM). This is a way of making research services available using the Metrology Infrastructure Base (BIM) created in the previous edition of the programme. The BIM will form the core of the new service system. This will ensure that the KUM system provides the most up-to-date key metrology infrastructure. PUM organises two international metrology conferences "New Trends of Metrology" (3 editions, 2022, 2024, 2026) and the Economic Congress "Metrology of the Future" (2025). The Congress will help to consolidate cooperation with industry, strengthen the operation of the Metrology Cluster and promote implementation PhDs, as well as create opportunities for PhD students to gain practical experience in companies, including using the laboratory potential of the Central Office of Metrology (GUM). Three editions of metrology workshops for young academics, students and secondary school students are planned, using the metrology infrastructure of the GUM and laboratories of leading scientific centres. PUM is committed to the promotion of metrology. PUM suppor the programme of the Minister of Science entitled Polish Metrology. PUM is co- author of a report entitled "Identification of long-term needs and directions for strategic activities in Polish metrology and its development". The presence of PUM representatives at various scientific picnics, events related to metrology and the co-organisation of a metrology knowledge competition for secondary school students are key to the achievement of the above objectives. The PUM also plans to organise mobile metrology laboratories (MLM) to improve access to modern teaching and research methods. The Mobile Metrology Laboratories will provide easily transportable measurement equipment and carry out demonstrations and exercises in schools and organisations involved in youth education. This will increase the level of education of young people with limited access to measurement and testing equipment, including but

not limited to those from rural areas and small towns, and will make it possible to stimulate young people's interest in metrology and to create metrological awareness and metrological literacy. Co-organisation of metrological knowledge competitions (e.g. METROLIGA competition) will be carried out, which will increase the level of metrological knowledge. The implementation of the above mentioned activities guarantees the increasing of the position of metrology in the public awareness, ensures a stronger integration of the metrology community and facilitates real and effective cooperation.

Keywords: Metrology, Polish Metrological Union, PMU, metrological infrastructure, promotion, knowledge transfer.

ADVANCED MANAGEMENT ALGORITHMS AND ONTOLOGICAL MODELING FOR INTERACTIVE VIRTUAL ENVIRONMENTS IN INDUSTRIAL DIGITAL TWIN SYSTEMS

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Abstract: This paper presents a comprehensive framework for managing virtual spaces in the context of industrial Digital Twin applications, focusing on the integration of ontological modeling, spatial algorithms, and interactive simulation environments. The developed architecture, implemented in the Tomoverse platform, supports dynamic scene management, user interaction personalization, and synchronization between virtual and real-world data. Key innovations include the concept of ethereal planes, unified information spaces, and spatial object positioning mechanisms designed for complex scenarios, such as ultrasonic tomography simulations. The system employs semantic and numerical modeling techniques, enabling advanced scenario editing and real-time visualization integrated with FEM-based physical modeling. Additionally, the platform addresses interoperability through the use of high-level ontological constructs like "Eidos" and "Hyle" to harmonize diverse data streams. The work highlights distinctions between simulation frameworks and game engines and outlines the requirements for interactive industrial Metaverse scenarios. The proposed solution supports co- working, co-creation, spatial audio, and avatar-based interaction, enhancing the fidelity and operational control within digital replicas of industrial processes.

Keywords: Digital Twin, Virtual Environment, ontology, metaverse, simulation, FEM, scenario management, ultrasound tomography, VR interaction, spatial algorithms.

WEARABLE ULTRASOUND SYSTEM USING BEAMFORMING AND NEURAL NETWORK-BASED IMAGE RECONSTRUCTION FOR BLADDER MONITORING

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Abstract: This paper presents a novel approach to the continuous monitoring of bladder function using a wearable ultrasound system based on beamforming techniques. The proposed system integrates a custom-designed ultrasonic transducer embedded in a wearable garment, enabling prolonged, non-invasive data acquisition. Central to the methodology is the implementation of a passive acoustic mapping (PAM)-based beamforming algorithm, which converts raw ultrasonic signals into high-resolution cross-sectional images. The system was evaluated using physical phantoms and synthetic data, successfully reconstructing internal structures with preserved geometry and dimension fidelity. Additionally, artificial neural networks were employed to refine the image quality, yielding significant improvements in the interpretation of diagnostic images. The integration of signal processing, wearable hardware, and deep learning presents a promising direction for real-time, patient-friendly urological diagnostics beyond the clinical setting.

Keywords: Beamforming, bladder monitoring, ultrasound imaging, passive acoustic mapping, wearable diagnostics, artificial neural networks, medical image reconstruction.

THREE-DIMENSIONAL BEAMFORMING TOMOGRAPHY FOR NON-INVASIVE INDUSTRIAL DEFECT DETECTION

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Abstract: This paper presents the design and validation of a novel beamforming based tomographic system developed for non-invasive detection and imaging of internal defects in various industrial materials. The proposed solution integrates high-frequency ultrasonic transducers and a configurable sensor matrix ranging from 32 to 128 elements, supported by dynamic apodization algorithms and advanced signal processing techniques. The system employs three-dimensional reconstruction algorithms that enhance the spatial accuracy of defect visualization while maintaining real-time imaging capabilities. The implemented digital beamforming architecture includes features such as adjustable gain control and signal filtering, contributing to high diagnostic precision under varying operational conditions. Experimental validation was conducted on test phantoms with artificial defects, demonstrating the superiority of the proposed approach over conventional techniques. Quantitative analysis indicates the system's robustness, although the standard deviation in comparative tests suggests complexity in defect-induced signal variation. This work emphasizes the potential of beamforming tomography in industrial applications, especially in sectors requiring reliable non- destructive evaluation such as aerospace, construction, and manufacturing.

Keywords: Beamforming tomography, ultrasonic imaging, non-invasive diagnostics, defect detection, industrial applications, 3D reconstruction, apodization, real-time imaging.

INTEGRATING SILICA SAND RECOVERY INTO WASTEWATER TREATMENT: CIRCULAR ECONOMY APPLICATIONS IN GRP PIPE MANUFACTURING

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Abstract: The growing worldwide sand crisis emphasises how urgent it is to identify substitute supplies of silica sand. This type of material, especially construction-grade sand, is the most extracted solid material globally after water, with annual consumption reaching unprecedented levels due to rapid urbanisation and infrastructure expansion (United States Geological Survey, 2021). The extraction of sand is directly linked to riverbed degradation, coastal erosion, and habitat destruction, causing extensive environmental damage. In line with the objectives of the circular economy, valorising wastes rich in quartz through industrial symbiosis lowers the cost of disposal and raw material acquisition. Beyond these environmental and economic motivations, silica's inherent material qualities also contribute to its value. In many industrial applications, including composites and building materials, silica (SiO_2) is valued for its mechanical strength, high thermal stability, and chemical inertness. These material qualities position silica as a functional contributor to product performance rather than a mere filler. The aim of this review is to present a comprehensive examination of the transitioning processes within WWTPs that make it possible to collect silica sand for the advancement of the circular economy. This analysis systematically explores the origins and pathways of silica sand within wastewater streams, recovery and purification technologies, characterisation methods, applications in GRP pipe production, policy frameworks facilitating circular resource flows, and prospective research directions. By synthesising the existing scientific literature and highlighting practical case studies, this article seeks to support the broader adoption of silica sand recovery practices and contribute to the development of truly circular urban material systems.

Keywords: GRP pipe, wastewater treatment, silica sand, circular economy.

APPLICATION OF ENTROPY BASED INDICES FOR ANALYSES OF ACTIVATED SLUDGE COMMUNITIES

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Abstract: Activated sludge is a complex ecosystem of microorganisms whose structure and diversity largely determine the efficiency of wastewater treatment processes. Traditional evaluation of activated sludge quality is based on microscopic flock evaluation and interpreting the data based on the presence of particular bio- indicative groups of organisms; however, there is a growing need for quantitative tools that provide objective and reproducible analyses. In this study, mathematical methods derived from information theory were applied, particularly entropy-based indices, to describe and compare the structure of microbial communities occurring in activated sludge. The research material consisted of the activated sludge samples collected at the “Hajdów” wastewater treatment plant in Lublin, Poland. The samples were obtained from different points of the technological line, with particular focus on two non-aerated chambers: the anaerobic chamber and the denitrification chamber. Observations were conducted using an optical microscope at 100x and 400x magnifications, followed by photographic documentation, which provided the basis for further analysis. On the basis of the data obtained from the observations, selected diversity indices, including Shannon entropy and related statistical measures, were calculated. The resulting values were then compared in order to assess the significance of differences between the investigated chambers. It is expected that the applied approach will make it possible to capture the subtle differences in microbial community structure arising from the distinct environmental conditions of the analyzed chambers, even though the technological process parameters remain largely unchanged. The results may serve as a basis for further development of mathematical tools for monitoring and controlling wastewater treatment processes, as well as for integrating quantitative methods with classical bio- indication approaches.

Keywords: Entropy based indices, biocenotic indices, structure of communities, bioindication, activated sludge.

CAPABILITIES AND ACTIVITIES OF THE STUDENT RESEARCH CLUB FOR AVIATION MATERIALS

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Abstract: The Student Research Club for Aviation Materials operates within the Faculty of Aviation at the Polish Air Force University. It brings together students passionate about materials engineering, aviation technology, and modern manufacturing methods. The club’s primary mission is to expand practical and scientific knowledge in the field of advanced materials used in aerospace structures. Its members conduct a wide range of research and design activities focused on the development, testing, and optimization of innovative composite and metallic materials. The projects often combine experimental work with numerical simulations and computer-aided design, allowing students to explore both the theoretical and applied aspects of aerospace materials science. Research topics include the characterization of mechanical and thermal properties of composites, analysis of additive manufacturing processes (3D printing), and the evaluation of structural integrity under operational loads. In addition to laboratory work, students gain experience in data analysis, visualization, and the preparation of research publications. The club actively participates in scientific conferences, workshops, and collaborative projects with research institutions and industrial partners, promoting knowledge exchange and innovation in the aerospace sector. The presented poster summarizes the club’s main areas of activity, highlights selected research achievements, and showcases the laboratory capabilities that support the ongoing development of modern aviation materials at the Polish Air Force University.

Keywords: Aerospace materials, composites, additive manufacturing, material characterization.