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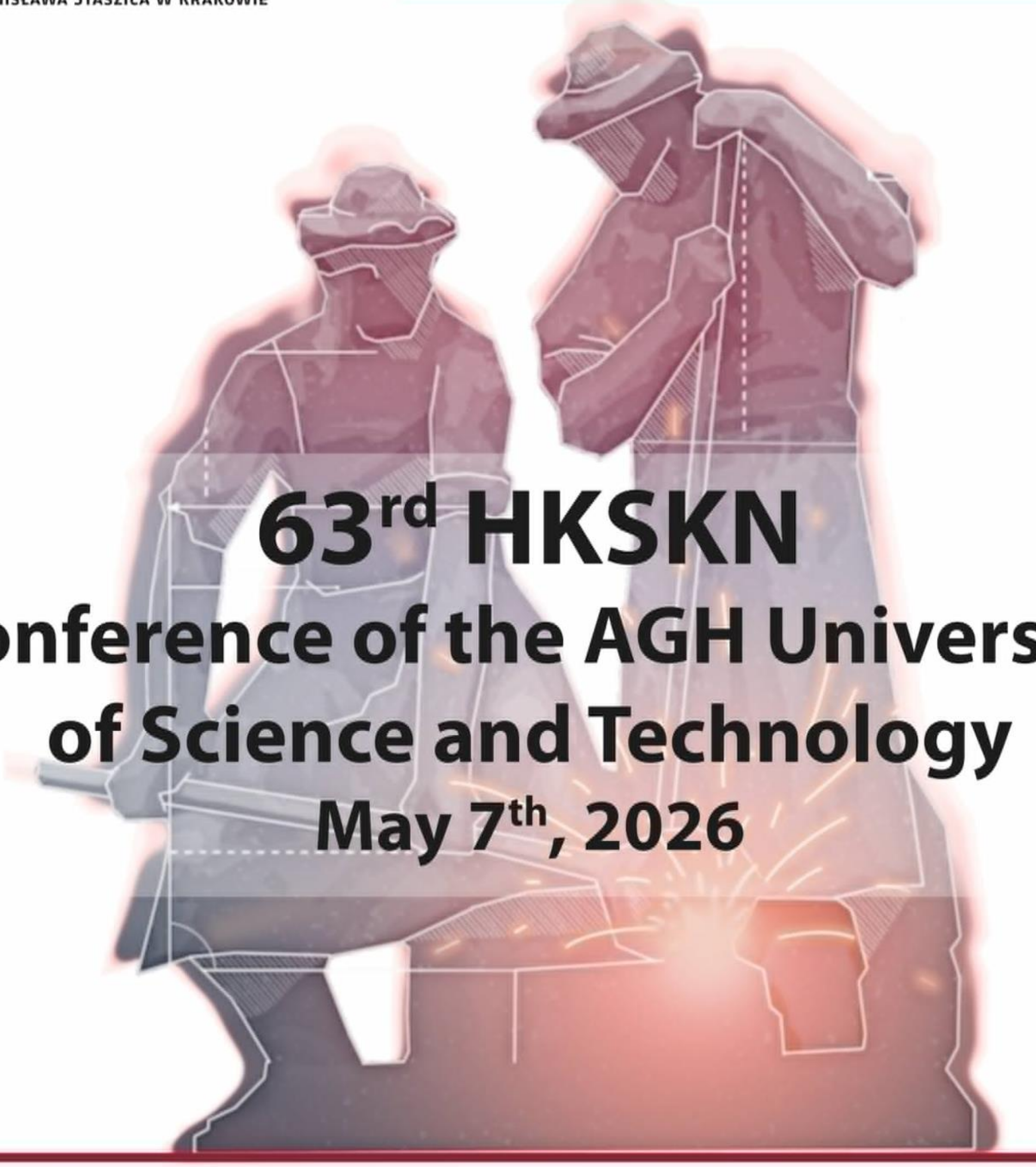
im. Stanisława Staszica w Krakowie

Studenckie Koła Naukowe AGH

Book of Abstracts



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Section Acoustics, Biomechanics and Bioengineering

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KN Komfort AGH

KOMFORT
AGH

Vibration transmission analysis from a sound source to the structure of coupled reverberation rooms

This thesis investigates the transmission of vibrations from an acoustic source to the structure of coupled reverberation chambers located in Building D-1 at the AGH University of Science and Technology in Krakow. The primary objective was to evaluate the efficacy of source vibration isolation in reducing vibration levels recorded on the floor of the receiving chamber. The experimental methodology involved measuring vibration acceleration amplitudes at four designated points for three distinct isolation variants and a reference configuration. Analysis was performed using three piezoelectric sensors across 15 harmonic excitation frequencies and the pink noise. The analysis was based on the resultant RMS values of vibration acceleration amplitudes and supplemented by amplitude-frequency characteristic evaluations. The results indicated no significant reduction in vibration levels in the receiving chamber for any tested isolation variant, suggesting the predominance of alternative transmission paths. Furthermore, the structural analysis revealed high susceptibility to harmonic excitations at frequencies below 500 Hz.

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KN Komfort AGH

Impact of sample location in the measurement opening on vibration transmission between coupled reverberation rooms

This project analyzes the impact of sample location within a measurement opening on structural vibration transmission between coupled reverberation chambers. The objective was to optimize mounting conditions for laser vibrometry, which requires an extremely low vibration background. Two configurations were compared: reference K1 (sample placed behind the expansion joint, rigidly supported) and test K2 (sample placed before the expansion joint, resiliently mounted using a sealing compound).

The study involved vibration acceleration measurements in three axes (X, Y, Z) for selected sine excitations (60–1200 Hz) and pink noise. Data were recorded at points P1, P2, and P3 on the receiving chamber floor and PKN1 on the source chamber wall. Results showed that configuration K2 degrades the system's vibroacoustic performance. Despite a local reduction in source chamber wall vibrations, increased levels were observed in the receiving chamber. The cause was identified as vibroacoustic bridging: energy transfer from the sample to the receiving chamber structure, bypassing the damping effect of the foundation expansion joint.

A change in ceiling vibration characteristics was also observed, including increased vertical Z-axis amplitudes and higher response impulsivity, which is unfavorable for the measurement requirements. The findings confirm the superiority of configuration K1 and provide a basis for further optimization of the test stand.

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KN Bio-Logika

CO_2 absorption in an algae photobioreactor with biomass production

A glass vessel equipped with a gas diffuser and a gas dosing device was adapted for a CO_2 absorption experiment in a biological system. The vessel (photobioreactor) was exposed to sunlight inside the laboratory, and thus maintained at approximately a constant temperature. The vessel was filled with water (1 dm^3) enriched with nutrients and seeded with a starter culture of Chlorella sp. algae. The CO_2 concentration in the gas above the liquid was checked daily, and a new portion was dosed to maintain a constant concentration of ~10%. The photobioreactor operated on a weekly cycle for 6 weeks under conditions of adequate sunlight. Every week, the liquid was transferred to a collection tank and replenished with a new batch (water + fertilizer + algae starter culture). The amount of CO2 absorbed was calculated. The biomass was filtered and dried, and its mass was determined. The ratio of absorbed CO_2 to the mass of algae produced is consistent with literature data; CO_2 /Algae = 1.81 g/g, and the mass of assimilated carbon was 0.494 g/g. A total of 13.52 g of CO_2 was absorbed, resulting in the production of 7.47 g of algae. The algal biomass can be used for the production of biocoal, cosmetics, or dietary supplements.

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SKN Nucleus

Surface Functionalization of Bioceramic Implants with Controlled Release of Ions and Anti-Inflammatory Drugs

The development of modern implants requires the design of biomaterials capable of actively interacting with the biological environment. In this project, porous β-tricalcium phosphate (β-TCP) scaffolds with functionalized surfaces were developed to enable the simultaneous release of copper ions and anti-inflammatory drugs. The obtained materials exhibited an open and interconnected pore network, favorable for vascularization and bone tissue regeneration. The compressive strength (~3.91 MPa) falls within the range characteristic of alveolar bone, while a low coefficient of variation confirms good reproducibility of the fabrication process. Importantly, the applied surface modification did not adversely affect the structural integrity of the scaffolds.

The scaffolds were fabricated using the polyurethane foam replication method. Surface functionalization was achieved by applying a chitosan coating containing diclofenac via a deep coating technique. Additionally, selected samples were enriched with hybrid granules containing copper ions, responsible for pro-angiogenic and antibacterial effects. Material characterization was performed using XRD, FTIR, SEM, and compressive strength testing. The developed scaffolds represent a promising platform for controlled therapeutic delivery in tissue engineering applications.

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KN Mat4Future

A non-invasive system for the analysis of psychomotor fatigue based on biomeasurements

In an era of increasingly fast-paced living, psychomotor fatigue significantly impacts human performance and safety (e.g., in drivers and machine operators). It accounts for approximately 20–30% of road accidents, with an even higher proportion in fatal cases, as reported by the European Transport Safety Council. Traditional survey-based assessment methods are subjective and not suitable for real-time evaluation. The aim of this project is to objectively assess the body's response to a demanding stimulus using signal analysis to extract features of psychomotor fatigue.

A research protocol was developed consisting of two stages: a resting phase and a fatigue-inducing phase. The Digit Symbol Substitution Test (DSST), combined with an additional auditory distractor, was used to induce fatigue. Cyclic voice sampling (reading a vowel-rich sentence) was performed.

The main focus of the analysis was the comparison of acoustic voice parameters. Signal features such as fundamental frequency and phonation instability indices (jitter and shimmer) were analyzed.

The collected data were analyzed using Python. A database was developed for training machine learning models. These approaches enable the development of non-invasive systems based on voice analysis and smartwatches, supporting occupational health and accident prevention. Additionally, continuous monitoring of electrodermal activity (EDA) and heart rate (HR) is possible.

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SKNFM Kerma

Quantitative Segmentation of Focal Adhesions Using HSV Color Space in Studies on the Effects of Micro- and Nanoplastics on Reproductive Cells

Environmental pollution with micro- and nanoplastics (MNP) is an important scientific concern, particularly due to their potential impact on human reproductive health. A project conducted by SKNFM KERMA within the IDUB AGH program examines how MNP affect reproductive cells, focusing on cytoskeletal organization and gene expression. A key aspect is the analysis of focal adhesions, which are crucial for cell adhesion, migration, and signaling. Current evaluation methods are largely qualitative, limiting objective comparison and statistical analysis.

This work presents a MATLAB-based tool for semi-automated quantitative analysis of cellular structures. The method uses image segmentation in the HSV color space, chosen due to staining characteristics, with special emphasis on the cyclic Hue component, which improves signal detection. It enables measurement of structure size and spatial distribution, with results exportable to MS Excel for further analysis. The approach supports objective and reproducible assessment of focal adhesion changes in MNP-exposed cells.

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KN Mat4Future

Porous silicone structures as a platform for controlled collagen release in the knee joint

Knee joint dysfunction associated with cartilage degradation and impaired lubrication leads to reduced mobility and decreased quality of life. There is a growing need for material-based solutions that can improve joint function through the sustained release of lubricating agents, without the need for frequent medical interventions.

The aim of this study was to design and fabricate porous silicone structures with a sponge-like architecture capable of acting as carriers for collagen or hyaluronic acid, and to determine the optimal porosity and morphology of the material for further investigation.

The samples were prepared using the solvent casting and particulate leaching method, with sodium chloride of varying particle sizes (125–841 μm) used as a porogen. The resulting materials were subjected to macroscopic evaluation, microstructural characterization using optical microscopy, quantitative porosity analysis, and optical profilometry.

Based on the obtained results, a porosity range and processing parameters were identified that provide the most favorable balance between structural integrity and a highly developed internal surface area, which is essential for subsequent collagen functionalization. The selected structures represent a promising basis for further studies on controlled release of bioactive substances, as well as for optimizing implantation strategies within the joint.

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KN Mat4Future

3D-Printed Anatomical Models as an Educational Tool: Evaluation of Measurement Accuracy and Didactic Value

The study of anatomy, particularly osteology, requires access to bone specimens, which are not always readily available. Advances in 3D printing technology enable the fabrication of high-quality anatomical models that can serve as an alternative to traditional teaching materials.

The aim of this study was to evaluate the usefulness of 3D-printed bone models as a tool supporting the learning of human anatomy.

The study involved anatomical models (rib, vertebra, clavicle, skull, and temporal bone) prepared based on original 3D scans and printed using ABS material. A group of medical students performed measurements of selected anatomical parameters on both real bones and their 3D-printed counterparts. Faculty members from the Department of Anatomy at the Jagiellonian University Medical College compared measurement accuracy and evaluated the educational value of the models.

3D-printed anatomical models represent a valuable complement to traditional osteology teaching methods. Their use may enhance the accessibility of teaching materials and improve learning outcomes.

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Koło Naukowe Akustyki Architektonicznej

Analysis of the Impact of Low-Cost Modifications on Acoustic Insulation of Internal Doors.

Internal doors constitute one of the key, yet typically weakest, elements of building partitions in terms of acoustic insulation. Despite their important role in shaping acoustic comfort, there are no simple solutions that allow for effective improvement of this parameter.

The aim of this study is to evaluate the effectiveness of low-cost modifications of internal doors, including both the door leaf and the frame, using readily available materials and simple installation methods. The study analyzes the influence of additional mass-loading and sound-absorbing layers, as well as sealing elements, on the resulting acoustic insulation.

Measurements were carried out in situ in accordance with ISO 16283-1. The study was performed for various material configurations, taking into account differences in mass and thickness of the applied modification materials.

An additional extension of the study is the investigation of the influence of door frame insulation, which may constitute a dominant sound transmission path.

The obtained results allowed for the evaluation of the effectiveness of individual solutions in terms of cost–benefit performance and for the identification of practical methods for improving door insulation under real conditions. The study has an applied character and may provide practical guidelines for improving acoustic comfort in residential buildings.

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Koło Naukowe Akustyki Architektonicznej

Analysis of the feasibility of acquiring phytoacoustic data using MEMS microphones

Phytoacoustics is a rapidly developing research field focused on the analysis of the emission and reception of acoustic signals by plants, as well as their relationship with physiological processes and responses to stress conditions such as drought. Contemporary scientific studies suggest that plants exposed to adverse environmental conditions may generate ultrasonic impulses that could potentially serve an informational function. However, conducting such research requires long-term measurements using advanced equipment, which significantly increases costs and limits the accessibility of experiments.
This study presents an analysis of the feasibility of using MEMS microphones as an alternative to traditional bioacoustic microphones. A measurement system concept based on MEMS sensors is proposed, capable of recording low-amplitude acoustic signals, including those in the ultrasonic range, while reducing equipment costs. The proposed research methodology, planned experiments, and the potential application of multi-microphone arrays for spatial analysis of plant sound emissions are discussed. The presented approach may contribute to the development of scalable and cost-effective systems for monitoring plant health.

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SKN Nucleus

BioVolt - the Impact of Variable Gravity on Microbial Fuel Cells (MFCs) During Parabolic Flight

BioVolt investigates the performance of microbial fuel cells (MFCs) under conditions of varying gravity. The project evaluates MFC operation across a broad gravitational spectrum from 0 to 5 g, with the objective of understanding how different levels of acceleration and microgravity influence bioelectrochemical systems. MFCs employ electroactive microbial biofilms that transfer electrons to the anode, establishing a biological electrical circuit at the microscopic level. The system will be monitored using a microelectrode array (MEA) for localized current measurements and electrochemical impedance spectroscopy (EIS) for resistance analysis. An inertial measurement unit (IMU) will accurately record acceleration data, with all signals synchronized through an integrated recording system. A compact, vibration-isolated module containing multiple micro-MFCs will be utilized to generate comprehensive data during testing. The ultimate goal is to evaluate the potential of MFCs as reliable and sustainable energy sources for space applications, supporting the development of biological power generation and energy recycling systems for future space missions and extraterrestrial environments.

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KN BioMetr

Pelvic bones segmentation in X-ray images using neural networks

The pelvic bones are central to the musculoskeletal system. With aging and bone disease, fractures become more frequent. Mortality rates reach 28.3% within a year, and injury counts are projected to double by 2050. Automated X-ray segmentation via neural networks can enhance clinical diagnostics and pelvic bone analysis.

The PENGWIN 2024 challenge focused on pelvic bone segmentation using synthetic data. However, such models often underperform on real-world images due to varied patient positioning and wider framing. This study conducted a SOTA analysis of competition methods to assess their clinical suitability.

To verify these solutions, the MedIG team's Unet++ method was reproduced and tested on the UNIFESP clinical dataset. Results showed decreased quality, indicating overfitting to synthetic data. To address this, a two-stage approach was proposed, combining YOLOv8s region-of-interest detection with Unet++ segmentation. This method improved results in 62% of cases, demonstrating robustness across different imaging areas and patient positions, particularly for the sacrum bone. This approach offers more stable, reliable results for clinical applications.

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KN BioMetr

Synergistic Fusion of Multimodal Data for Automated and Accurate Diagnosis of Parkinson's Disease

We present a mixed-reality (MR) protocol on HoloLens 2 that standardizes multimodal acquisition across 17 brief, self-guided tasks probing speech/voice, ocular motor control (IR eye tracking), head/upper-limb motor function (IMU, RGB), and gait/posture. After quality control, datasets with ≥70% completeness from 137 participants (66 Parkinson’s disease (PD), 71 heathy-control (HC)) were analyzed. Signals underwent domain-specific processing and feature extraction, enabling a comparison of data-fusion strategies. Early fusion with L1-regularized logistic regression achieved AUC 0.995, Accuracy 0.964, F1 0.963 (stratified 5-fold cross-validation). Late-fusion stacking reached AUC 0.985, while decision-level soft voting yielded AUC 0.982. Ablation and meta-model analyses identified head-IMU dynamics and speech/voice as the dominant contributors, with hand-motor and gait/posture providing complementary signal. The results indicate that MR-standardized acquisition combined with principled fusion delivers robust, interpretable PD/HC discrimination and offers a practical foundation for longitudinal and multi-site validation.

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AGH Marines

Passive Sonar – Hydroacoustic path modeling and sound source direction estimation

The project focuses on modeling the hydroacoustic path and the algorithm for estimating the direction of an acoustic wave reaching an underwater robot. The goal of this work is the initial validation of the model and the sound source localization method for the robot developed by the "AGH Marines" Student Research Club.

A model was developed in MATLAB/Simulink to simulate real underwater conditions and the measurement path. It includes ambient water noise, electronic system noise, and the effects of signal filtering and quantization. To estimate the direction of the sound source, a method based on Time Difference of Arrival (TDOA) was used, implemented by calculating the cross-correlation function of the signals reaching the hydrophones.

The conducted simulations confirmed that the applied algorithm correctly identifies the direction of the sound source, which provides a foundation for further tests in real-world conditions.

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SKN Nucleus

Bridging Biology and Electronics: Conductive Hydrogels for Nerve Regeneration

Nerve tissue injuries represent a significant clinical problem due to limited regenerative capacity. A key challenge is recreating the neural tissue microenvironment, characterized by low stiffness, high porosity, and electrical conductivity.
The aim is to develop an electroconductive hydrogel scaffold supporting peripheral nerve regeneration, enabling integration of biological and electrical functions and promoting neural cell growth.
Hydrogels, defined as hydrated polymer networks mimicking soft tissues, are developed using GelMA, SilMA, alginate, pectin, chitosan, and PVA. Depending on the material, different crosslinking mechanisms are applied. Synthesis protocols and a design of experiments (DoE) plan have been prepared to optimize composition and properties. Selected formulations are modified with conductive additives (PEDOT:PSS, PPy).
The project is currently focused on optimizing formulations and synthesis parameters. At this stage, the aim is to obtain materials with appropriate physicochemical properties. Further work will include detailed characterization and biocompatibility studies.
It is expected that combining suitable mechanical properties, porosity, and electrical conductivity will enable development of materials supporting nerve regeneration.

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SKN Nucleus

From Healing to Sensing: Intelligent Nanocellulose Dressings for Advanced Wound Care

A wound is a disruption of the anatomical continuity of the skin or mucous membranes, and its healing is a complex, multi-stage process involving hemostasis, inflammation, proliferation and tissue remodeling. Factors such as infection, hypoxia, and chronic inflammation can impair regeneration, particularly in hard-to-heal wounds. Conventional dressings often fail to provide optimal healing conditions, driving the search for advanced biomaterials.
The aim of this project is to develop an intelligent wound dressing based on bacterial nanocellulose (BNC) obtained from SCOBY cultures. After purification, BNC exhibits high biocompatibility, mechanical strength, and the ability to maintain a moist wound environment. The material is functionalized with chitosan, providing antibacterial properties, and red cabbage extract rich in anthocyanins, which act as a natural pH indicator. Color changes enable real-time monitoring of wound condition and early infection detection without removing the dressing.
The fabrication process includes BNC biosynthesis, purification, preparation of chitosan and anthocyanin solutions, impregnation, and freeze-drying to preserve the porous structure. The functionality of the dressing will be evaluated by pH-responsive color analysis and antibacterial testing.
The developed biomaterial combines barrier, therapeutic, and diagnostic functions, offering a promising approach for improving the treatment of chronic and burn wounds while reducing infection risks.

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KN BioMotion

Analysis and development of an sEMG signal acquisition system for bionic model control

The subject of this paper is a multi-faceted analysis of surface electromyography (sEMG) signal acquisition systems designed for the control of bionic models. The study includes a discussion on the selection of sEMG as a control method, comparing it with solutions based on electroencephalography (EEG), computer vision, and inertial measurement units (IMU).

The paper presents the logic behind selecting measurement path components and provides a comparative analysis of analog-to-digital converter architectures regarding latency and its impact on the naturalness of the system response. A comparison of commercially available sensor solutions is provided, analyzing the advantages of raw signal acquisition (RAW) compared to envelope signals (Envelope) in the process of advanced gesture classification.

The software design process on the Raspberry Pi 5 platform is discussed, considering the use of Python with C++-optimized libraries and the potential necessity for low-level implementation to ensure temporal determinism. The work also includes a comparison between dry and gel electrodes, analyzing their impact on ergonomics and signal stability in exoskeleton systems

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KN mHealth SpaceMed

Evaluation of the accuracy of heart rate and respiratory rate estimation using a contactless measurement method based on mmWave FMCW radar

The aim of this study was to estimate respiratory rate (RR) and heart rate (HR) using a contactless measurement method based on mmWave FMCW radar and a publicly available dataset. Chest displacement was reconstructed from the phase of the radar signal, followed by automatic selection of the optimal range bin. RR and HR values were determined using spectral analysis within a sliding time window, and the obtained results were compared with reference measurements. The results indicate high stability and strong agreement for RR estimation, while HR estimation shows greater sensitivity to acquisition conditions and the quality of the recorded signal.

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SKNFM Kerma

Molecular analysis of oils and fats by Raman spectroscopy in the context of dietary disinformation in the media

Recently, in the media there has been a growing number of online content promoting extreme, restrictive diets. This content is often framed in opposition to plant-based diets and often demonizes them. Both statements by individuals without formal education in biology, chemistry, medicine, or dietetics and controversial opinions presented by individuals categorized as experts are gaining popularity. Content often claims that animal fats are superior to vegetable oils, or vice versa. Raman spectroscopy is one of the most popular vibrational spectroscopic techniques. It allows for the qualitative and quantitative characterization of the chemical composition of tested preparations. For this reason, it is particularly useful in research on biological samples. Due to its high sensitivity and non-invasive nature, it can be used in food science, assessing food quality and safety, particularly oils and fats.
The aim of this study is to demonstrate the effectiveness of Raman spectroscopy in the qualitative analysis of oils, fats, and lipid-rich food products. Particular attention was paid to identifying differences between lipids of plant and animal origin, including differences in the content of individual functional groups and the degree of fatty acid unsaturation. Additionally, changes at the molecular level dependent on the origin of the tested samples and their potential thermal processing were determined.

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KN BioMotion

Assessment of the quality of paramedics' activities

The objective of this study was to develop a training methodology for emergency procedures and to define quantitative metrics for assessing the quality of cardiopulmonary resuscitation (CPR) under various ergonomic conditions.
Based on a literature review, a research experiment was designed utilizing a hybrid measurement system that integrates inertial sensors with video analysis. A comparative analysis was conducted on the biomechanical parameters of a rescuer performing chest compressions on a stable surface versus within an ambulance, taking into account different variations of the rescuer's body positioning relative to the patient.
The results indicate that the specific nature of the ambulance environment forces the rescuer into rapid dynamic adaptation, characterized by a drastic increase in compression rate and impact force in order to compensate for surface characteristics and maintain correct compression depth. A degradation of the movement pattern was identified in forced positions, manifested by the dominance of shoulder girdle engagement and a loss of postural stability.
The study demonstrates that performing CPR under simulated ambulance conditions is associated with a high physiological cost and a risk of musculoskeletal overload. The developed quantitative metrics provide an objective tool for assessing the ergonomics and effectiveness of rescue operations.

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AGH AIOTA

Vehicle X-ray Anomaly Detection System

This project presents an automated anomaly detection system for vehicle X-ray images, combining YOLOv8-based object detection with comparative image analysis. The system was implemented as a web application with a Python (Flask) backend and a React frontend. The first method employs a YOLOv8 model trained on annotated vehicle X-ray images for defect localization and classification. Data augmentation including geometric transformations, HSV augmentation, and mosaic and mixup techniques was applied to improve generalization with a limited training dataset. The second method compares the examined image with reference images of defect-free vehicles. The process involves automatic reference image selection based on histogram and gradient analysis, geometric alignment using ECC or ORB, and difference detection using SSIM and pixel-level analysis. Detected anomalies are filtered by area, aspect ratio, and contour solidity. The system generates visual reports with heatmaps, anomaly annotations, and JSON metadata. The interface supports drag-and-drop image upload and interactive result visualization. Experiments demonstrated that the comparison-based method provides effective detection even without training data, while YOLOv8 enables anomaly type classification given sufficient annotations. The combination of both approaches creates a flexible tool for vehicle quality control and security inspection.

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KN Glider

Skin Disease Detection and Monitoring App

The project is a mobile application for the detection and monitoring of skin diseases. It integrates machine learning models for monitoring moles and acne-related conditions.
The mole monitoring model is based on machine learning and analyzes visual differences between consecutive images of the same mole, enabling detection of potentially significant changes in appearance.
For acne lesion monitoring, the system uses a YOLO-based model to detect and classify skin lesions. It distinguishes three categories: active lesions, scars and post-acne marks, and comedones. The model identifies affected areas, labels them, and assigns appropriate classes. Users take facial photos from the front and side profiles, allowing both quantitative and surface-based assessment of skin condition.
The project follows a client-server architecture. The frontend is developed in Java for Android, while the backend is built using Spring Boot. Data storage and file management are handled by Supabase.
After taking a photo, the model processes the image, generates results, and saves them to the database. The application also allows users to annotate skin problems on images by marking their exact location and provides access to previously saved photos. Additionally, it provides health-related articles and includes three tests: skin phototype classification, skin cancer risk assessment, and skin type analysis.

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AGH Eko-Energia

Architecture and implementation of a custom error handling system in the distributed control system of the "Perła" solar vehicle.

This presentation outlines a custom Error Handling system for a distributed network of STM32 microcontrollers, implemented in the 4-passenger solar vehicle "Perła".
Due to the integration of multiple dedicated ECUs via a CAN bus, a centralized node state reporting mechanism was developed. The software architecture decouples the error severity across informational, warning, critical, and safe state levels from the operational halt decision, which remains dependent on the local logic of each controller.
The system employs a Heartbeat communication protocol broadcasting a fault-free status every 1000 ms, and an active error reporting mode with a 300 ms interval. This approach ensures reliable diagnostics of critical systems and prevents failures, fulfilling the vehicle's structural safety requirements.

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AGH Code Industry

Project of web application for managing the Metallurgical Conference SKN AGH

The goal of this project was to design and build a web application to help organize the Metallurgical Conference SKN AGH. The main reason for creating this system was to solve common problems, such as manual registration, lack of centralized data, and the slow process of communicating with participants and generating documents. The system was built using a modern T3 Stack. It includes Next.js, TypeScript, React, a PostgreSQL database with Prisma ORM, and a MinIO server for file storage. The client and server communicate using the tRPC library. The platform consists of three main parts: a public page, a participant panel, and an admin dashboard. The key features include: online registration with multi-language forms, a secure login system, a tool for organizers to verify and evaluate submissions, and a module that automatically generates personalized documents (like diplomas and certificates) and the book of abstracts using templates.

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KN Creative

Design and implementation of a defect detection system in a rolled metal coil using artificial intelligence methods.

The dynamic development of industry necessitates the use of modern quality control methods. In processes based on rolled materials, such as steel strips or coiled sheets, early detection of surface defects is particularly important, as they may affect the durability and safety of final products.
The designed system enables real-time analysis of images acquired from cameras, detection and classification of defects, and estimation of their approximate position along the material. This approach allows for fast removal of defective sections and reduction of material losses.
As part of the work, a training dataset consisting of synthetic images and real industrial data was prepared and used to train a YOLO-based object detection model. The trained model was then implemented in a system analyzing live video streams from cameras, enabling visualization of detection results and recording information about detected defects.
In addition, a prototype inspection line was designed and manufactured using 3D printing technology. The test stand enabled controlled material movement and system evaluation under conditions similar to real industrial processes. The conducted tests confirmed the effectiveness of the proposed solution and allowed its limitations to be identified. The results indicate that the developed system can serve as a basis for further development of vision-based systems used in automatic quality control in industry.

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City Run Quest: AR quest creation between different locations

When selecting an excursion, tourists accounts for many variables: season, available groups and guides, schedule constraints, etc. However, conventional itineraries frequently overlook lesser-known locations. Furthermore, large-scale enterprises often face a deficit of personnel required to facilitate the navigation of new employees between offices. To address the demand for guides and excursion planning, students from Lviv Gaming Club are developing a dual-application ecosystem designed for the creation and execution of AR quests between specific locations. This technological solution enables enthusiasts and locals to implement gamified strategies for audience engagement. The product grants users the opportunity for autonomous exploration at any time. The system possesses the potential to enhance educational and tourist initiatives. The applications are engineered to execute AR quests with optimized computational overhead, thereby ensuring compatibility with a broader range of mobile devices. The prototype is being developed for Lviv Polytechnic to facilitate the orientation of first-year students within campuses.

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KN Creative

Development of a road barrier model generation script and deflection analysis in Abaqus software

The project is devoted to the development of a parametric model of a road safety barrier and the analysis of the influence of selected geometric parameters of posts on the structural behaviour during impact. The model was developed in the Abaqus environment using a Python script that automates the process of generating structural variants and performing analyses under identical loading conditions. The script covers geometry generation, definition of connections and boundary conditions, model discretisation, and preparation of the input file for computations, while a graphical user interface allows parameter input without modification of the source code. A series of numerical simulations was carried out for configurations differing in the number of posts and their geometric parameters, aiming to evaluate barrier deflection, distribution of plastic strains, and the ability of the structure to absorb impact energy. The obtained results enabled comparison of the analysed variants and assessment of the significance of post design parameters and barrier length for the overall structural performance.

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KN Creative

Development of an Application for 2D Transient Heat Conduction Simulation Using the Finite Element Method

The developed application performs simulations of transient heat conduction in a 2D domain using the finite element method. It enables user-defined specification of geometry, material properties, as well as initial and boundary conditions. The primary motivation was to create a user-friendly program incorporating all essential components required to conduct time-dependent heat transfer simulations. The application provides automatic mesh generation for user-defined geometry and allows for importing meshes created in the commercial software ABAQUS. The solution of the system of linear equations is carried out using the Eigen library and its built-in Cholesky decomposition. The simulation results are visualized as temperature distribution maps at successive time steps. The obtained numerical results showed consistency with the results obtained in the SolidWorks environment for an identically defined problem.

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Koło Naukowe BIT

KOŁO NAUKOWE

Squat Coach, A Real-Time Squat Technique Analysis System Using 3D Pose Estimation and Sequential Models

Squat Coach is a real-time squat technique analysis system based on webcam or video input. The solution combines 3D pose estimation with biomechanical feature extraction and sequential models, including TCN and GRU, to recognize movement phases, detect technical errors, and assess exercise quality. The system supports both side-view and front-view analysis, automatically identifies the camera perspective during calibration, and generates a movement quality score on a 0–100 scale together with feedback on the most relevant issues, such as insufficient depth, excessive forward torso lean, back rounding, trunk instability, or improper foot positioning. The proposed approach can be applied in sports training, movement education, and self-guided exercise correction systems. The project aims to combine low-latency processing with clear and actionable user feedback, while also enabling future integration with voice-based coaching interfaces built on structured repetition-level data.

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Koło Naukowe BIT

KOŁO NAUKOWE

lonkit: Python package for visualization and analysis of Fitness Landscapes via Local Optima Networks

Fitness landscapes constitute a useful abstraction of optimization problems and are representation of the space of all possible solutions. However, in the case of high-dimensional problems, their direct analysis is usually infeasible or provides limited insight due to complexity.

Local Optima Networks (LONs) are the model of representing the fitness landscapes, meant to simplify their analysis by compressing the search space into a graph, whose nodes correspond to local optima and edges represent possible transitions between them. Originally proposed for combinatorial domains, LONs have been extended to continuous landscapes, where their properties have been found to be useful in estimating the performance of heuristic search algorithms.

This work presents a survey and technical overview of the lonkit library, an open-source Python toolkit for analyzing fitness landscapes using the LON framework. It first reviews established methods for visualizing fitness landscapes and introduces the theoretical foundations of the LON model as well as its variants. It then presents the architecture, functionality, and implementation details of the lonkit package, alongside practical usage scenarios and illustrative real-world applications.

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KN Creative

Development and performance analysis of cellular automata model components for the simulation of globularization phenomena in two-phase alloys

This work presents a cellular automata model for simulating microstructural globularization in two-phase alloys, with a focus on computational performance. The study investigates how model parameters and algorithmic choices affect simulation stability, result quality, and computational cost.
The impact of grid resolution, seed density, free-particle fraction, and neighborhood definition on microstructure evolution was analyzed. These factors significantly influence grain growth kinetics, fluctuations of average grain size, and overall stability. Neighborhood definition was found to be particularly important, affecting both morphology and performance.
Performance analysis shows that the dominant cost arises from lattice iteration and memory organization, while phase distribution has negligible impact. Improved memory locality was observed at high filling fractions. The results enable informed parameter selection balancing stability, accuracy, and efficiency.

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KN Creative

Project of lightweight 2D graphics library in C language for personal computers and microcontrollers

This project focuses on implementing a lightweight 2D graphics library in the C language, designed for use on both personal computers and microcontrollers from the ESP32 family.
The proposed solution is based on software rendering techniques and does not require the use of hardware graphics acceleration, which makes it suitable for platforms with limited hardware resources.
As part of the project, selected optimization techniques used by C compilers, example manual optimizations, and several software rendering algorithms are discussed. This is followed by an analysis of existing graphics libraries - SDL3 for PC-class devices and TFT_eSPI for microcontrollers, including the ESP32. Within these libraries, some of the applied rendering and optimization techniques are identified and compared.
Based on the theoretical introduction and the analysis, functional requirements were defined, the architecture of the custom library was designed, and components responsible for rendering, image buffering, memory management, and integration with target platforms were implemented. Selected optimizations and rendering techniques were then applied, and their integration into the project is described.
The final stage of the project involved conducting performance tests on a personal computer and an ESP32 microcontroller, comparing the results with pre-optimization variants, and analyzing the obtained outcomes.

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AGH Solar Boat

Automatic control system for the autonomous boat Barka

This work involved designing an automatic control system and a dynamic model of the autonomous research vessel Barka. The control system's operation was then tested during tests on the Bagry Reservoir in Krakow. The project involved simulating the operation of the Embedded code and estimating the force characteristics of thrusters. The influence of the drives on the vessel's behavior was then analyzed, and hydrodynamic equations representing the vessel's drag in linear and rotational motion were introduced. The resulting forces and torques were then converted to accelerations, velocities, coordinate position, and heading angle. The dynamics model was calibrated against the measured data, and a controller controlling the vessel within the simulation was built and tuned. From the controller model, C code was then generated and currently loaded onto the Barka's on-board computer. The work presents a detailed approach to modeling the control system based on the dynamics and physics of boat motion in the coordinate system.

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Koło Naukowe BIT

Finite Element Ion Recombination Simulations for Ultra-High Dose-Rate (FLASH) Dosimetry on PLGrid

Ionization chambers are primary reference detectors in clinical dosimetry, but ion recombination reduces the collected charge and may lead to dose underestimation. This effect becomes especially important for ultra-high dose-rate FLASH beams, where classical analytical correction methods can operate outside their valid range. We present a 3D finite element approach that solves coupled transport-recombination equations with electric fields and electrode boundary conditions, avoiding simplified analytical assumptions and enabling realistic chamber geometries and non-uniform ionization patterns. The model is implemented in IonTracks-FEniCSx using FEniCSx/DOLFINx, PETSc and MPI parallelization. Because realistic meshes, time stepping and multi-scenario studies are computationally expensive, a typical production case used for experimental comparison requires 1-5 GB of storage and, on a single PLGrid Ares node with 40 MPI ranks, may take from 30 minutes to several dozen hours. To support systematic parameter scans, the workflow uses SLURM job arrays, multiple YAML-based configurations and RAM-backed scratch storage for reliable I/O, while remote development is supported through VS Code Remote over an SSH tunnel. These results show that HPC infrastructure is not just convenient but necessary for practical, reproducible 3D FEM ion recombination studies and validation workflows relevant to FLASH dosimetry.

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SKNF Bozon

Investigating Financial Market Dynamics Through the Prism of Complex Systems Theory: Analysis of Fractal Structures in Stock Price Time Series Using Detrending Algorithms.

The main objective of this study is to analyse the complex nature of stock price time series using the Detrended Fluctuation Analysis (DFA) algorithm. Unlike classical statistical methods, DFA allows for the precise determination of long-range correlations and signal self-similarity, effectively eliminating the distorting influence of local trends and data nonstationary. The study analyses key stock market indices by calculating the Hurst exponent, which serves as a measure of market "memory" and its efficiency. The results indicate the presence of hidden dependencies describing the nature of fluctuations, which go beyond the standard random walk model. An essential element of the research is the attempt to link the obtained fractal parameters with external factors, such as macroeconomic volatility or sudden geopolitical events.

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KN Ekonometryk

EKONOMETRYK

A Comparative Analysis of eXplainable Artificial Intelligence Methods Applied to Black-Box Algorithms

The opacity of "black-box" AI models in critical sectors, such as healthcare, hinders their widespread adoption. This study evaluates the interpretability of complex classifiers (e.g., Random Forest, XGBoost) using the SHAP and LIME frameworks. The analysis focuses on explanation stability, feature importance, and algorithmic bias detection. Findings reveal significant discrepancies between XAI methods when interpreting identical instances, questioning the reliability of automated explanations. The paper contributes to the Trustworthy AI discourse by providing practical guidelines for selecting interpretability tools based on model architecture and data specificity.

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KN Ekonometryk

Application of Machine Learning Methods in Predicting Football Match Outcomes: The Case of La Liga

Football match outcomes constitute an interesting yet challenging area for the application of machine learning, due to the large number of random factors and complex sporting relationships. The aim of the study is to examine the possibility of using selected machine learning algorithms to predict the outcome of a football match in a binary setting: a home team victory or its absence.

The study is based on an original dataset, independently developed from raw match statistics of the Spanish Primera División (La Liga) from the 2019/2020–2024/2025 seasons. The data include offensive and defensive team statistics, historical information on league positions, and newcomer status. At the data preparation stage, feature engineering was applied based on differences in average statistics from the five previous matches, taking into account temporal splitting and the elimination of inter-seasonal dependencies.

As part of the study, selected machine learning algorithms were compared using cross-validation based on league seasons. Subsequently, the model with the highest classification performance metrics was interpreted using PDP, PCP plots, and SHAP values.

The proposed approach has potential applications in sports analytics as support for forecasting and decision-making processes, enabling a quantitative assessment of probable scenarios and the identification of factors with the greatest impact on match outcomes.

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AGH Eko-Energia

Real-time telemetry system architecture for the PERŁA solar car with automated CAN bus decoding and data streaming

Effective data collection and analysis are essential in complex engineering systems, enabling diagnostics, system development, and informed decision-making. In the PERŁA solar car project, telemetry data from the CAN bus plays a key role by integrating information from multiple electronic control units and vehicle components.

Due to system complexity, even minor faults may lead to significant operational issues. At the same time, collected data supports predictive analysis, optimization of driving parameters and identification of components requiring improvement. During competitions, real-time access to telemetry allows the engineering team to make strategic decisions, such as route optimization and energy management.

This work presents the architecture of a real-time telemetry system developed for the PERŁA solar car, designed with a focus on reliability, low computational overhead, and deployment flexibility. The system includes mechanisms for CAN bus data acquisition, automatic decoding based on DBC files, and real-time data streaming to clients using the WebSocket protocol.

Additionally, the work introduces a cross-platform open-source library written in Rust for efficient and safe CAN frame decoding. The solution is hardware-independent, supporting both USB-CAN adapters and socketcan-compatible interfaces. It abstracts low-level binary parsing, simplifies interaction with the CAN bus, and enables both data reception and transmission within a controlled access model.

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KN Creative

Analysis of the impact of algorithm parameters for generating the digital representation model of a fuel cell microstructure on the complexity of its internal structure

This paper presents the generation of digital representations of porous microstructures for various types of fuel cells, with particular focus on SOFC and PEMFC. The introduction section outlines the fundamental principles of fuel cell operation and the morphological characteristics of its primary layers, namely the anode, cathode, and electrolyte, with particular emphasis on open porosity and phase composition as key parameters governing performance.

After that, a microstructure generator implemented in C++ that enables parametric configuration of both individual cell layers and the transition zones between them is presented, including the target phase ratio, desired porosity, neighborhood type, number of grains, or simulation steps. Porous structures are generated using discrete computational methods: a grain-growth algorithm based on cellular automata and the Monte Carlo method. The resulting microstructures are subsequently subjected to controlled modifications to achieve a prescribed pore volume fraction.

A crucial aspect of this work is the analysis of the influence of generative model parameters on the geometric complexity of the resulting microstructures, evaluated using selected morphological descriptors, such as pore size distribution, transport path tortuosity, surface roughness, and three-phase boundary density. The obtained characteristics are employed to calibrate the developed generator against real fuel cell microstructures.

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AGH Solar Boat

Development of metamodel for optimizing the shape of hydrofoil for a solar racing boat

The development of low-emission water transport technologies is of critical importance for achieving sustainable development goals. Hydrofoil vessels that lift the hull above the water surface using underwater foils enable a significant reduction in drag and an increase in the overall energy efficiency of the craft. This paper aims to develop a metamodel describing hydrofoil efficiency based on 3D CFD simulations of the crafts hydrofoils, designed and built by the AGH Solar Boat student research group. The scope of the work includes defining optimization parameters, preparing a parametric CAD model, and automating the generation of computational domains, meshing, and simulation execution in an HPC environment. Based on the results, a five-dimensional metamodel was created, enabling optimization and the identification of new correlations between hydrofoil geometry and efficiency. The developed solutions were directly implemented in the design process of the actual hydrofoils for the Delta solar boat.

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KOŁO NAUKOWE

Koło Naukowe BIT

Integration of LLM Models in HPC Environments

A project aimed at the integration and optimization of Large Language Models (LLMs) within an HPC cluster. The work focuses on performance-related issues and the practical utilization of computational resources for generative AI tasks.

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Koło Naukowe BIT

KOŁO NAUKOWE

Task Evaluation and Ranking System for HPC Environments

Development of a system for monitoring and evaluating the performance of tasks executed within HPC infrastructure. The tool automatically generates a computational efficiency ranking, which is provided in real-time, enabling users to optimize their scripts and computational processes.

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AGH Code Industry

Effective Techniques for Procedural Level Replication in Client-Server Architecture Using the Unity Engine

The synchronization of procedurally generated environments in multiplayer mode poses a significant technical challenge, stemming from the need to maintain full game-world consistency among all participants in real time. Direct transmission of complete room structures as ready-made network objects proves to be an unreliable approach, susceptible to replication errors and diminished gameplay stability.

This paper presents methods for the efficient transmission of server-side generated spatial data by decomposing information into smaller, precisely defined units. Furthermore, the most common problems encountered during the implementation of such systems are discussed, and the possibilities of adapting solutions developed within the Unity environment to other engines and network architectures are identified.

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Koło Naukowe BIT

Data Processing in the MS Azure Environment Using SaaS Solutions

This project involves the implementation of an automated data processing pipeline using Microsoft Azure SaaS solutions, integrated with university infrastructure. The primary objective is to ensure a secure environment that enables communication with university interfaces while maintaining rigorous data protection standards.

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Koło Naukowe BIT

Automated Information Extraction System from Resumes (CVs)

Development of a tool that automates the acquisition of structured data from job application documents (CVs). The system leverages Natural Language Processing (NLP) techniques to extract key candidate attributes, thereby streamlining data selection in recruitment processes.

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AGH Code Industry

Management of a Student Organization as a Research Process: The Use of Qualitative and Quantitative Methods in Improving the Activities of the AGH Code Industry Student Club

For a student research group to operate efficiently and for its projects to achieve success, it is essential to provide members with adequate development opportunities and a supportive working environment. The presentation will showcase the approach of the AGH Code Industry student organization's board, in which supervision of project teams and event organization take the form of an iterative process resembling a research process, incorporating elements of both qualitative and quantitative research.

The process of creating and developing teams working on game projects within the organization will be presented, along with methods for identifying areas requiring improvement. Approaches to analyzing data from qualitative and quantitative research will be discussed, based on direct conversations with members as well as evaluation surveys (including the identification of recurring issues and pain points). The obtained results form the basis for drawing conclusions and improving the organization's activities. The presentation will also address the influence of the game development industry on project goals, as well as on the events and development opportunities offered to members.

The aim of the presentation is to demonstrate that effective management of a student organization based on qualitative and quantitative research methods, can be treated as a full-fledged research process, resulting in increased efficiency of project teams and higher quality of implemented initiatives.

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KN "Groznawcze"

The Language of Games: A Computational Tool for Automated Linguistic Complexity Analysis of Video Game Dialogues for Language Acquisition

Modern video games are characterized by linguistic complexity and diversity, offering significant glottodidactic potential for English learners. According to Stephen Krashen's Monitor Theory, language acquisition is most effective when a relaxed learner consumes content slightly above their current proficiency level (i+1). Video games, as a medium rich in vocabulary embedded in audiovisual contexts, align with this theoretical framework. However, utilizing this potential is hindered by the lack of IT tools for automated linguistic profiling of games.

The aim of this study is to design and implement a dedicated IT system for the analysis and visualization of video game dialogues. The analytical layer utilizes scripts to process the "Video Game Dialogue Corpus," which consolidates dialogues from over 50 popular titles. The process involved token extraction and lemmatization, CEFR-based vocabulary evaluation, and the calculation of linguistic complexity metrics (e.g., Dale-Chall, SMOG) alongside lexical diversity indices (MLTD).

The final result is a fully functional software solution that transforms raw text data into interactive visualizations of vocabulary distribution. The tool identifies titles that provide an optimal language development environment for specific players and establishes a framework for video game accessibility audits.

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KN Promat

Design and Implementation of an Adaptive Control Algorithm for an Industrial Robot in Open-Die Forging Using a Virtual Controller and FEM Simulation

The project involved the development of a control system for a robotic open-die forging cell, integrating a Kawasaki manipulator with a hydraulic press. The manufacturing process was programmed in the AS language (KIDE environment), with an emphasis on code modularity. This allows for rapid system reconfiguration and adaptation to new production variants without the need for deep modifications to the program's logic. A key algorithmic problem was compensating for the dynamically changing dimensions of the forged element during successive process phases. The applied active compliance mechanism (Soft Absorber) acts not only as a feedback loop protecting the equipment from overloads, but primarily allows the robot to adapt its tool position to the new billet geometry in real time. The input parameters of the algorithm, such as material flow, were determined through numerical simulation in QForm UK software, making it possible to define the robot's trajectory. Final code verification and collision tests were conducted in the K-Roset environment, which served as the digital twin of the workstation. This approach enabled full offline programming and optimization of the control logic prior to physical deployment.

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AGH Code Industry

Beyond gaming - leveraging shaders for general-purpose computing

While graphics processing units are synonymous with the gaming industry, their massive parallel processing power remains an underutilized resource for general-purpose computing. This paper explores the potential of using standard graphics shaders (GLSL/HLSL) as a cross-platform, hardware-agnostic alternative to proprietary frameworks like CUDA. Motivated by the optimization of a computationally intensive pheromone diffusion simulation, this research demonstrates how GPU pipelines can be repurposed for non-graphical tasks to achieve significant performance improvements. The study outlines the methodology for leveraging shader-based acceleration, while critically evaluating the technical challenges involved, such as communication overhead and memory format constraints. The paper provides an overview of this approach, offering insights into the efficiency gains, limitations, and strategic considerations for developers aiming to harness GPU resources outside of traditional graphics rendering.

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AGH Racing

A Comparison of Automatic Tuning Techniques for MPC-Based Control of an Autonomous Race Car

This paper presents a comparison of different automatic tuning methods for MPC controllers applied to autonomous racing. Three controller variants were analyzed: decoupled LTI MPC, decoupled LTV MPC, and coupled NMPC. The aim of the study was to investigate to what extent the choice of tuning algorithm and tuning pipeline influences the final control performance in comparison with the structure of the controller itself. The tuning methods considered were Random Search, GP-BO, TPE, and CMA-ES, tested in both an unstaged pipeline and a staged pipeline inspired by the curriculum learning approach. Parameter evaluation was performed in a closed-loop setting using a custom-built simulator on sets of randomly generated training and testing tracks. The objective function was defined as a metric incorporating average speed, slip, track violations, and . The results showed that the controller structure had a greater impact than the tuning method itself: the difference between LTI and LTV was significant, while the advantage of NMPC over LTV turned out to be smaller. In all controller families, automatic tuning yielded better results than manual tuning. The staged approach generally led to more aggressive parameter settings, while GP-BO provided the most consistent balance between high speed and low track-violation rates.

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KN Sensor

Dual-axis solar tracker mount

The objective of this project is to design and construct a prototype of a dual-axis solar tracker base, controlled in both manual and automatic modes. The primary research hypothesis is to verify the potential for optimizing electricity yield through precise, automated positioning of the panel relative to the sun. Experimental studies, conducted at a fixed location at various times of the day, will allow for the optimal placement of solar radiation sensors and the calibration of control algorithms. An integral part of the system is a weather station that monitors real-time parameters such as solar irradiance, temperature, and air humidity. The project includes a comparative analysis of the energy and cost efficiency of the tracking system versus a stationary setup and manual control.

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AGH Eko-Energia

Design and implementation of a cooling system in an electric vehicle

This paper presents the design and implementation of an active cooling system for an electric vehicle, based on a custom PCB controller. The system supports heat dissipation from the battery, motors, and cabin, especially during parking and charging conditions. It uses air cooling with 12V fans and servo-controlled airflow channels.

Control is implemented using a PID controller, which adjusts system operation based on temperature and humidity sensor data (I2C). The architecture consists of four identical modules with CAN communication and SAFE STATE capability.

The paper discusses power management, PWM control, and the issue of BLDC fan back-driving, solved using galvanic isolation and MOSFET switching. Functional tests were conducted, including battery tests and airflow analysis through filters. Results confirm the effectiveness and correctness of the system.

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KN Transpeed AGH

Design and Operating Principle of a Linear Synchronous Motor (LSM) and its Control Based on a Simulink Model

Linear Synchronous Motors (LSMs) are becoming a technological standard by eliminating the need for inefficient and failure-prone mechanical transmissions. This project outlines the architecture and operating principles of these types of drives. Due to their specific design, electromagnetic interactions between the traveling magnetic field and the permanent magnet array generate a thrust force that translates directly into linear motion, without lossy intermediary components. As part of the work within the Transpeed research group, following an analysis of the machine's design, appropriate motor parameters were selected, and necessary system components were specified. Precise control is managed by an STM32 microcontroller operating with Hall-effect current sensors. Accurate position tracking is achieved through the sensor fusion of data from encoders and laser distance sensors. The subsequent step demonstrates how the machine's actual electromechanical parameters were implemented in the MATLAB/Simulink environment. The developed model serves as a starting point for analyzing control principles based on the Field-Oriented Control (FOC) algorithm. The successive control stages are discussed, including Clarke and Park transformations, and the application of PID controllers with feedback loops. Particular attention is given to the development of individual subsystems within the block diagram, utilizing MathWorks models and the Simscape library.

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AGH Drone Engineering

Real-Time Telemetry System for UAVs: Data Acquisition and Transmission

An autonomous telemetry system intended for use in unmanned platforms has been developed, designed as a module independent of the flight controller. The main component of the system is the ESP32 microcontroller, responsible for data acquisition, processing, and transmission from barometric and inertial sensors communicating via the I2C bus. The device operates in WiFi access point mode, enabling direct user connection from a computer or mobile device. Data are presented in a web browser via an HTTP interface, while their real-time update is implemented using WebSocket technology, eliminating the need for page refresh. To improve transmission quality, an external 2.4 GHz antenna was used to increase system range. Telemetry data are filtered and transmitted in JSON format, then archived and made available for offline analysis. The proposed solution is characterized by simplicity, mobility, and ease of integration, making it suitable for experimental and diagnostic applications.

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KN Sensor

Autonomous control algorithms for an AGV

As part of the activities of the Sensor Student Research Group, a project is being developed focusing on the design and implementation of autonomous control algorithms for AGV-type vehicles. The primary goal of the work is to create decision-making logic that allows for the optimization of internal warehouse transport processes by determining the most efficient travel routes in real time.
To verify and test the developed algorithms under real-world conditions, an autonomous vehicle prototype was designed to serve as a mobile research platform. Thanks to the continuous analysis of signals from the drive system, the algorithm automatically adjusts the robot's trajectory. As a supplement to the project, the Digital Twin concept was also developed, which supports the process of monitoring unit parameters and allows for simulation-based verification of the algorithms before their physical deployment on the platform. The developed solution provides a basis for conducting a detailed verification of algorithm effectiveness in a dynamic environment. The project fits into the Industry 4.0 trend, representing a significant step toward building intelligent logistics systems and work on a collaborative fleet of vehicles.

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AGH Marines

Electronic System Verification of an AUV Acoustic Signal Processing Device

Autonomous Underwater Vehicles (AUVs) enable researchers to access locations that are inaccessible to humans. Due to underwater conditions, it is impossible to use radio waves to determine the location of target objects. Instead, acoustic signals received by hydrophone arrays can be employed for this purpose. Owing to the requirement for a high sampling rate, a custom measurement system based on an FPGA was designed. The objective of the project was the assembly of the system and the verification of this process through visual inspection and electrical measurements. Additionally, the performance of the measurement path was tested by preparing an FPGA code template, which will facilitate the future implementation of selected sound-wave-based localization algorithms.

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KN Sensor

Comparative Analysis of Remaining Useful Life (RUL) Estimation Methods for Mechatronic Systems Under Variable Stochastic Degradation Conditions.

This study presents a comprehensive approach to the prognostic health management of electromechanical systems, focusing on door drive actuators utilized in critical transport infrastructure. The primary objective of the research is to evaluate the effectiveness of diverse Remaining Useful Life (RUL) estimation methodologies under dynamically varying operating conditions and stochastic degradation patterns.
The paper details a robust diagnostic feature extraction process derived from current, voltage, and positional feedback signals, utilizing advanced time-domain statistical indicators. A comparative performance analysis was conducted between trajectory similarity-based approaches and deep recurrent neural network (RNN) models. The experimental framework accounts for variability in velocity, acceleration, and the intensity of random shocks affecting end-of-travel position drift. The research findings emphasize the critical role of model fusion in enhancing prognostic horizon stability and prediction accuracy within high-uncertainty environments, providing a strategic foundation for advanced Predictive Maintenance frameworks in industrial automation.

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KN Sensor

A predictive system for diagnostics, control, and energy conversion in hybrid polygeneration systems

Within the activities of the Sensor Student Research Group, a concept of a predictive energy management and conversion system for hybrid polygeneration systems has been developed, integrating artificial intelligence methods, predictive diagnostics, and adaptive control algorithms. The objective of the project was to design an architecture enabling operational decision-making under conditions of variable renewable energy generation, dynamic load, and measurement uncertainty, while accounting for the technical condition of system components. The proposed approach is based on the integration of multimodal data, including energy, environmental, and diagnostic signals. Models based on deep neural networks enable forecasting of energy generation and demand, as well as early detection of component degradation. The control layer employs Reinforcement Learning algorithms, allowing for adaptive optimization of energy flows. The developed solution integrates prediction, diagnostics, and control within a unified "predict-and-act" framework. Experimental validation confirmed the effectiveness of the system under dynamic operating conditions. The project provides a foundation for further development of intelligent energy management systems in distributed energy systems and Industry 4.0 applications.

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KN Sensor

Design and development of an integrated experimental platform for hybrid polygeneration systems.

An open control architecture for hybrid prosumer microgrids was developed and experimentally verified. The proprietary energy management system integrates reliable industrial automation with an information technology layer, solving the limited scalability of commercial inverters. This architecture enables the safe, simultaneous operation of renewable energy sources (wind, solar) and storage systems under variable load conditions.

The setup is based on a centralized hardware infrastructure with a two-level control model. In the executive and safety layer, a programmable logic controller (PLC) guarantees autonomous protection of components in real time. The analytical and communication layer, based on embedded systems, uses dedicated object-oriented software for multithreaded data aggregation. The system supports industrial protocols, ensuring full observability and data archiving while maintaining interoperability.

The proposed solution provides a fully functional physical test environment. Hardware verification confirms the stability of data acquisition and the effectiveness of control loop separation mechanisms. The constructed research setup creates the necessary infrastructure for the future implementation and validation of predictive algorithms, responding to the challenges of the energy transition, Smart Grid development, and the Industry 4.0 concept.

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AGH Space Systems

Stability and optimisation of model predictive control for apogee control of sounding rocket flight

A Model Predictive Control (MPC) scheme for airbrakes of a sounding rocket was developed to enable precise apogee targeting. The controller's performance was evaluated under external disturbances, including atmospheric variability and non-nominal system behaviour. A Monte Carlo analysis based on a six-degree-of-freedom (6-DOF) flight simulation demonstrated high effectiveness and robustness of the proposed predictive control approach.

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AGH Drone Engineering

37 grams of autonomy – a modular onboard computing platform for intelligent UAVs

This work presents an ultralight, high-performance computing platform dedicated to unmanned aerial vehicle (UAV) applications, developed within a student research group. The system, based on the CM5 module, combines high computational power with a compact and lightweight design – the total mass of the solution is only 37 g. Despite its small form factor, the module is capable of running advanced computer vision algorithms and neural networks directly onboard the drone.

The system architecture is divided into a baseboard and interchangeable HAT modules. The main board integrates the power supply and high-speed components, designed with controlled impedance, while additional functions – radio communication, a real-time microcontroller, and a safety system (killswitch) – are implemented on a separate expansion module. A high-quality LoRa module with an external antenna significantly improves communication range and reliability.

Compared to solutions previously used within the group, the new design achieves a substantial reduction in weight and eliminates issues such as unstable power, electromagnetic interference, unreliable communication, and vibration-prone mechanical connections The inclusion of a PCIe interface enables direct integration of AI accelerators. Combined with the ability to easily upgrade to newer generations of CM modules, this makes the platform a future-proof solution for the development of next-generation autonomous UAV systems.

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KN Sensor

Bearing Fault Diagnosis in Edge AI Architecture: Implementation Trade-offs and Model Optimization

Deploying vibration-based bearing fault diagnosis models on edge platforms requires balancing diagnostic accuracy with strict hardware constraints. This study investigates this trade-off using the CWRU dataset in a realistic cross-sensor scenario (training on the Drive-End sensor and testing on the Fan-End sensor), which introduces a significant domain shift. Classical machine learning methods (SVM, XGBoost) are compared with deep learning models (1D and 2D CNN) operating on raw signals, as well as FFT and STFT representations. The models were deployed on an NVIDIA Jetson Orin Nano platform using TensorRT optimization in FP32, FP16, and INT8 precisions.

The results demonstrate that time-frequency representations (STFT) offer the highest robustness to changes in sensor location. However, the deployment analysis revealed a critical constraint: while the 1D CNN operating on raw signals allows for full GPU acceleration as a single inference engine, spectral operations (FFT/STFT) require preprocessing outside the TensorRT engine, thereby increasing system complexity. While classical methods remain the most lightweight, the optimized 1D CNN offers the best latency-to-accuracy trade-off. This work proves that model selection for industrial Edge AI systems must be based on an evaluation of the entire end-to-end processing pipeline rather than classification accuracy alone.

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AGH AVADER

Autonomous Threat Detection in Urban Environments Using a UAV Swarm – System Development for the ICUAS'26 Competition

This paper presents an advanced autonomous Unmanned Aerial Vehicle (UAV) swarm system, developed as an evolution of the solution designed for the ICUAS'26 UAV Competition. The system is engineered to operate within complex urban infrastructure, with the primary objective of locating and identifying an unknown number of targets or threats. The software architecture was implemented using the ROS 2 framework. Algorithm validation was conducted in the Gazebo simulator, utilizing Bitcraze Crazyflie drones operating in Software-In-The-Loop (SITL) mode. A core component of the proposed solution is a proprietary implementation of the heuristic Artificial Potential Fields (APF) method, which is employed for dynamic path planning and collision-free swarm navigation. The paper also provides a detailed discussion on the challenges of maintaining communication network stability. It introduces mechanisms for ensuring Line-of-Sight (LoS) connectivity between agents and a strategy for continuous synchronization with the operational base and a moving Automated Ground Vehicle (AGV). Furthermore, the paper describes an autonomous energy management system that monitors battery levels and manages the rotational return of units to the docking station. This approach ensures uninterrupted mission execution despite the inherent physical limitations of the hardware platforms.

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AGH AVADER

A heterogeneous CPU–FPGA system for accelerating State Space Models in mobile robotics

This paper presents a computational acceleration system for mobile robotics, addressing the issues of high latency and energy consumption in CPU-based systems. Computational efficiency and low latency are crucial in localization, perception, and autonomous control tasks, where delays may lead to decision-making errors, loss of control, and reduced system safety. The research was carried out using a heterogeneous Zynq UltraScale+ MPSoC platform, enabling task partitioning between the CPU and FPGA. The processor is responsible for running the ROS framework, which serves as the basis for communication and data transfer. The FPGA performs parallel arithmetic operations, reducing data processing time and offloading the processor.

An FPGA-based matrix multiplication algorithm, which forms the basis of the State Space Model architecture, was implemented in a parametric form. This makes it possible to adapt the solution to different matrix sizes and degrees of computational parallelism. Based on this implementation, the relationship between performance and hardware resource utilization was investigated. The development of a Hardware-in-the-Loop environment, integrated with the ARM processor, enables performance analysis and comparison with alternative software-based approaches. The proposed solution accelerates computational tasks in the control of autonomous mobile robots.

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AGH AVADER

Autonomous sample collection and in situ analysis of water from an unmanned aerial vehicle

This paper presents the development of an autonomous UAV platform for aquatic environment research, featuring a module for water sampling and in situ analysis. The solution is being developed as part of the AEROSENSE project, and builds on work carried out during the Droniada competitions.
The first iteration of the system enabled fully autonomous mission execution based on RTK GPS navigation and the ROS2 architecture, integrating the Pixhawk 6C flight controller with a Raspberry Pi 5 onboard computer. During the precise positioning phase, a vision system was used to detect the sampling location, and an ultrasonic sensor was used to detect the water surface level. The system acquired physicochemical data and transmitted it in real time via Wi-Fi to a server, where it was stored in a relational SQL database. The data was available to view during the flight on a website.
Based on preliminary tests, an improved version of the system was developed, in which the liquid sampling module was modified. The use of peristaltic pumps integrated into the platform reduced the impact of suspended components on flight stability, improved sample purity, and expanded sampling capabilities to include chemically contaminated or corrosive samples. Additionally, precise liquid dosing was achieved with a theoretical accuracy of ±0.015 ml.
The developed solution enables the execution of fully autonomous measurement missions in aquatic environments, including hard-to-reach areas.

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AGH AVADER

Real-Time Detection of Illegal Waste Dumping Using Causal Streaming Video Networks

This paper presents a system for automatic detection of illegal waste dumping in video streams from closed-circuit television (CCTV) cameras. This problem represents one of the more serious challenges facing both urban and rural ecosystems, carrying significant ecological and health consequences. The proposed method is based on the Mobile Video Networks (MoViNet) architecture, modified to operate in causal mode, which eliminates latency caused by buffering future video frames. The key contribution of this work is the development of a dedicated predictive module (the Temporal Action Head) enabling precise temporal localization of events with minimal computational overhead. Particular attention was paid to optimizing the training process in resource-constrained environments such as Google Colab, and the applied temporal data augmentation techniques effectively improve the model's generalization on small training datasets. Experimental results obtained on the MIVIA-IWDD dataset confirmed a high system sensitivity of 0.74 at an extremely low VRAM requirement of only 120 MB, ensuring stable operation on edge devices with constant memory complexity. The developed solution was submitted to the Illegal Waste Dumping Detection competition, where it achieved first place among all submitted entries in terms of Recall, F1-score, and memory efficiency metrics.

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AGH Solar Plane

Edge AI in the air, real-time object detection onboard an unmanned aerial vehicle with a Hailo8 accelerator.

This paper presents the application of Edge AI methods for real-time object detection under flight conditions onboard an unmanned aerial vehicle. With the increasing autonomy of UAVs, the ability to process visual data directly onboard, without relying on communication with a ground station, is becoming increasingly important. The subject of this work is an object detection system developed by the programming section of the AGH Solar Plane Student Research Group, operating entirely on a Raspberry Pi 5 platform supported by a Hailo8 accelerator. A complete pipeline is presented, starting from data preparation and augmentation, through fine-tuning of a YOLO-family model, to its compilation into the HEF format and deployment on the target device supported by a neural accelerator. The architecture of the entire system is discussed, along with engineering decisions driven, among others, by platform-specific constraints, limited onboard power budget, weight requirements, and the need for real-time operation.

Particular attention is given to challenges specific to airborne installations that are not present in typical ground-based applications, such as image quality degradation caused by vibrations or rapid changes in lighting conditions during flight. Benchmark results comparing inference performance on the Raspberry Pi CPU and on the dedicated Hailo8 NPU are presented, demonstrating the tangible benefits of hardware acceleration in a resource-constrained environment.

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63rd HKSKN Conference of the AGH University of Krakow
7th May 2026

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Adaptive Load-Balancing and Automated Deployment for High-Load Microservices in DigitalOcean

This project introduces a comprehensive architecture for microservices management, specifically targeted at dynamic, high-load cloud environments that require instant response to unpredictable traffic spikes. Through the profound integration of adaptive load-balancing algorithms with advanced automated deployment methodologies within the DigitalOcean, the developed system demonstrates exceptional elastic scalability. Unlike traditional approaches, our model makes the most of the principles of infrastructure as code and reliable continuous delivery pipelines to facilitate autonomous, seamless system reactivity. The proposed design successfully combines the engineering simplicity and cost-effectiveness of setting up a cloud infrastructure with its extremely high fault tolerance. By intelligently distributing incoming network requests, the architecture proactively circumvents the overloading of individual computational nodes, minimizes latency, and optimizes resource utilization. The result is a scalable and universal solution for stable processing of large datasets, which is guaranteed to support high performance of services regardless of their complexity or load level.

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Koło Naukowe Integra

Wheel-E, the One-Legged Riding Balancing Robot

Wheel-E is a unicycle-type balancing robot. This means it has only one drive wheel. This wheel is used both for movement and to help the robot maintain its balance along the front-to-back axis. To maintain balance along the left-right axis, the robot is equipped with a reaction wheel. Additionally, the upper part of the robot (reaction wheel, electronics, power supply) is connected to the lower part of the robot (drive wheel) via a linear connection (allowing the leg to extend and retract).

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Information System for Intelligent Resource Management and Automated Queueing in Student Dormitories based on IoT Integration

LaundryHelper is an intelligent information system designed to automate laundry resource management in student dormitories by integrating real-time hardware data. Students use a Vue 3 Progressive Web Application to book time slots and monitor live machine statuses, receiving Firebase push notifications for session alerts. Administrators utilize a dedicated dashboard to manage infrastructure, register IoT devices, and track maintenance requests. The technical core is the Tuya Cloud API integration, enabling real-time monitoring of electrical parameters. By analyzing power consumption data, the system autonomously transitions machine statuses (e.g., to "Washing" when consumption exceeds 5W), preventing "ghost" bookings and synchronizing the digital schedule with physical hardware utilization. Built with NestJS 11 and MongoDB, the infrastructure is hosted on AWS with GitHub Actions for CI/CD. This scalable solution provides professional automation for smart dormitory management.

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Koło Naukowe BIT

Parameter Reduction in Reinforcement Learning Using Liquid Neural Networks (LNNs)

This project investigates the potential of Liquid Neural Networks (LNNs) for the compression of Reinforcement Learning (RL) models. The objective is to develop an architecture that enables a significant reduction in the number of model parameters while maintaining high agent performance in operational environments.

Research supervisor of the paper:
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Koło Naukowe BIT

Modular Integration of Deep Learning Models via Bayesian Networks

Development of a cognitive architecture for a heterogeneous robot fleet for autonomous triage in dynamic environments. By utilizing a Bayesian network for multi-sensor data fusion, the system enables early detection and mitigation of isolated module errors while ensuring an inference time of less than 1 millisecond.

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AGH AVADER

Implementation of a contrast maximization algorithm on an FPGA for an event-based camera image

This paper presents a hardware architecture that implements a contrast maximisation algorithm within an FPGA for event-based vision systems. The algorithm estimates motion parameters by maximising the contrast of an image reconstructed from asynchronous event streams. Event-based vision sensors generate sparse data with high temporal resolution. As they record only the dynamics of the scene, eliminating the static background, they are ideally suited for hardware processing. The deterministic, massively parallel structure of FPGAs allows for the design of a deeply pipelined architecture that enables efficient and energy-efficient processing. This solution is suitable for real-time embedded applications. This paper describes the hardware modules responsible for event transformation, contrast calculation and iterative optimisation, discusses key implementation decisions, and presents the optimisation method used in the project, taking into account its hardware feasibility. It also includes experimental results demonstrating a significant improvement in processing speed compared to CPU- and GPU-based implementations. The project was verified using an event-based object tracking application. The architecture was implemented on an FPGA SoC (AMD Kria KV260).

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KN Sensor

Neural State-Space Model Application in Anti-Sway Control Tuning of a Multidimensional Crane.

This paper presents the construction of a multidimensional laboratory crane and the implementation of an advanced motion control system. The test stand is equipped with a DC motor-based drive system and an encoder system for precise measurement of the payload sway angle in space. The main objective of the project was the effective reduction of undesirable pendulum sway angle oscillations occurring during trolley movement and simultaneous rope length variation.

Given the complex, non-linear dynamics of the system, algorithm tuning was based on experimental data. Using Neural State-Space Models (NSSM), a precise model representing the machine's dynamics was developed. It served for the safe offline optimization of the parameters of an industrial cascade controller utilizing a trapezoidal velocity profile generator.

The research results confirmed the high effectiveness of the proposed solution. Compared to a direct step excitation, the optimized system effectively limits sway angle oscillations, consistently maintaining the maximum payload sway below the safe threshold of 5 degrees. At the same time, the system maintains stability and robustness to the varying mass of the hoisted payload. The obtained results constitute a foundation for further work on the direct implementation and verification of advanced control algorithms on the real object.

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AGH Eko-Energia

Design of the inverter control board for the air supply panel

The project involves the development of an advanced control system that serves as a key component of a test rig designed for evaluating the modern HALYNA turbine. The primary function of the system is the precise management of an air supply panel comprising nine three-phase induction (asynchronous) motors.

An STM32-family microcontroller acts as the central unit of the communication network. Rotational speed regulation and motor status monitoring are performed via a serial bus based on the RS-485 standard using the Modbus RTU protocol. The user interface utilizes an LCD display that provides real-time monitoring of key inverter parameters, such as current intensity, power, and output frequency. The desired rotational speed is set intuitively using an incremental encoder integrated directly onto the printed circuit board (PCB).

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AGH Eko-Energia

Dashboard Controller for the PERŁA Solar Vehicle

This paper presents the design and implementation of a proprietary, multifunctional dashboard controller for an electric vehicle. The developed PCB integrates the functionalities of several standard automotive modules, serving as a centralized Human-Machine Interface (HMI). The system is based on a high-performance STM32 microcontroller, which manages data acquisition processes and executive control.

The power supply section utilizes galvanic separation of paths: the logic circuitry is powered directly from the main battery pack, while the wiper actuator system operates on an independent 12V line, ensuring system stability under varying load conditions. The module processes a range of input signals, including the drive mode selector (PRND), vehicle operating parameters, as well as lighting and steering column stalk settings.

A key element of the project is the integration of advanced sensors: an optical rain sensor (UART interface) for adaptive wiper control and a steering angle encoder. Data from the encoder, transmitted via the RS485 bus, is converted into CAN protocol frames, which is essential for the proper operation of the Electric Power Steering (EPS). The implementation of a dual communication interface (CAN and RS485) ensures high noise immunity and full compatibility with the vehicle's central ECU. This project serves as an example of high-level electronic integration, enhancing reliability and simplifying the system architecture of a solar vehicle.

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AGH AVADER

Autonomous Cargo Delivery System with Vision-Based Object Detection for the Last Mile Logistics Task at Droniada Challenge 2026

The work presented here is being carried out in preparation for the Last Mile Logistics task at the Droniada Challenge 2026 competition and covers the development of vision-based perception and mission planning algorithms as well as their integration with an Unmanned Aerial Vehicle (UAV) platform. The mission requires fully autonomous pick-up of three tennis balls - blue, red, and yellow - and their precise drop into a blue barrel, which in the basic stage is stationary, and in the advanced stage is mounted on a vehicle travelling at approximately 2 m/s. The software layer is developed within the ROS 2 Humble framework, and the PX4 Autopilot is used as the flight controller. Validation of perception algorithms, the mission state machine, and safety mechanisms is conducted in the Gazebo Harmonic simulator in Software-In-The-Loop (SITL) mode, which reproduces the competition field together with sensor models, the barrel, and the target vehicle prior to real-world flight tests. A core component of the solution is a detection module based on the YOLO architecture, responsible for localising the balls, identifying the barrel, and tracking the moving vehicle. For model training, a synthetic dataset has been built from on-board camera recordings in the Gazebo environment, with bounding box annotations generated automatically from object poses within the simulator, thereby eliminating the need for manual labelling.

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AGH AVADER

Application of Curriculum Learning methods in reinforcement learning for a bipedal walker

This paper presents the application of Curriculum Learning (CL) methods in the reinforcement learning (RL) process for a bipedal walking robot. CL methods are inspired by the natural education process - the sequential generation of tasks with increasing difficulty, which allows the agent to explore more effectively and gradually acquire competence.
Within the framework of the work, various task selection strategies were implemented and compared, including the Oracle method and the ALP-GMM (Absolute Learning Progress Gaussian Mixture Model) algorithm. Leading policy gradient algorithms, PPO and SAC, were utilized and compared. Tests conducted in a simplified 2D simulation environment demonstrated the highest effectiveness of the ALP-GMM algorithm in systematically increasing the agent's competence. The selected method was then applied to train a digital twin of the robot in the advanced NVIDIA Isaac Lab environment, utilizing GPU acceleration for physics simulation and depth image rendering.
The paper describes the neural network architecture, the reward function design process, and domain randomization techniques. The control system architecture based on the ROS 2 framework is also presented.

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AGH AIOTA

Your Desktop Companion: A Tangible Companion Robot Based on Local AI Processing Addressing the Problem of Loneliness

The problem of loneliness and digital isolation poses a growing challenge for modern engineering. The response to this need is a tangible companion robot designed for daily emotional support. Unlike commercial assistants dependent on cloud computing, the proposed architecture processes imagery and classifies emotions entirely locally (Edge Computing). This guarantees complete privacy and the highest cybersecurity standards by eliminating the transmission of sensitive data.

The design combines custom 3D-printed components, ESP32 microcontroller-based electronics, and software performing real-time face detection, emotional state analysis, and text-to-speech (TTS) synthesis. A key innovation is the device's physical reaction to analyzed stimuli: the robot actively maintains eye contact and, upon detecting signs of sadness, dispenses a physical reward (e.g., candy) to improve the user's mood.

The realized prototype proves the feasibility of a low-cost hardware implementation oriented towards social interaction. It also forms the foundation for further development, which assumes integration with local Large Language Models (LLMs) using microcomputers. In the future, this will enable natural conversations while maintaining full independence from external, paid services.

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KN Zgarek

Design and manufacturing of a prototype aluminum alloy engine block with „wet" cylinder liners using casting technology.

Concept "Design and manufacturing of a prototype aluminum alloy engine block with „wet" cylinder liners using casting technology" is carried out by members of the "Zgarek" Student Scientific Association at the Faculty of Foundry Engineering, AGH University of Krakow, under the "Excellence Initiative – Research University 2026" (IDUB 2026) program. It's aim is to design and manufacture a prototype aluminum alloy engine block with wet cylinder liners using gravity casting.

The planned casting will be made of aluminum alloy AlSi0.7Mg with a target weight of 14.6 kg, using a metal permanent mold.

The manufacturing process includes several key stages. First, it is necessary to design and manufacture the permanent mold. Then, sand cores will be produced to reproduce the internal geometry of the casting. The prepared mold will be poured with molten aluminum alloy. After solidification, the casting will be analyzed in order to identify and evaluate casting defects.

Currently, the project is at the stage of technological development, including optimization of the technology and its further development. Numerical simulations of the filling and solidification processes have been carried out using MAGMASOFT and AnyCasting software, and the simulation results have been compared. At present, the team is engaged in the preparation of casting patterns. The project schedule assumes completion of the work by the second half of October 2026.

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KN Zgarek

Analysis of the effect of laser height on the strength of a 3D print madę of PLA material.

In the process of producing prototypes using additive manufacturing techniques, the user can select many printing parameters, including the layer height into which the three-dimensional model is divided. Different settings result in prints of varying quality (surface roughness, tendency to crack, strength, etc.).

As part of this study, an analysis was conducted to determine the effect of layer height on the strength of a printed model. The research involved preparing a 3D model of a standard specimen for a tensile testing machine (so-called “dog-bone” sample). The object was then imported into a slicer dedicated to the Bambu Lab A1 Mini printer, and G-code was generated for this device, taking into account printing with PLA material.

The study included printing dog-bone specimens at different layer heights: 0.08 mm, 0.12 mm, 0.16 mm, 0.20 mm, 0.24 mm, and 0.28 mm. For each layer height, three samples were printed. The specimens were then tested to failure on a tensile testing machine, and the obtained results made it possible to determine the effect of layer height on the strength of the printed parts.

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KN Zgarek

Manufacturing and analysis of properties of a selected metallic foam

The study examined the possibility of using calcium carbonate and dolomite as foaming agents in the foaming of Al–Cu5-Mn alloy. Thermogravimetric analysis showed that dolomite underwent more intense decomposition and released a greater amount of CO_2, indicating a higher gas-forming potential. Molding coatings were prepared with the addition of both powders and three melts were performed at temperatures of 920 °C, 1020 °C, and 1100 °C. The lowest porosity was obtained at 920 °C (0.64%), and the highest at 1100 °C (2.16%). Tests of the mechanical properties of samples after T4 heat treatment showed that samples cast at 1020 °C provided the best compromise between strength, ductility, and microstructure homogeneity. Samples at 1100 °C achieved high strength but were more brittle, while those at 920 °C had low strength and the lowest ductility. The results emphasize the critical importance of selecting the melt temperature to control porosity and the fracture mechanism of the material. The foaming method using a calcium carbonate-based gas-forming coating did not produce satisfactory results, and the foamed materials exhibited a lower modulus of elasticity compared to the literature data for analogous alloys in the solid state.

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KN Zgarek

The use of reverse engineering and 3D printing technology to recreate a hip joint endoprosthesis

The study analyzes the possibilities of applying reverse engineering and 3D printing technologies to reconstruct the geometry of a hip joint endoprosthesis in the absence of technical documentation. In this work, 3D scanning was used to acquire geometric data of a real object, which were then processed and reconstructed in a CAD environment.

The process included object preparation, data acquisition, mesh processing (including triangle reduction and surface reconstruction), and preparation of the model for additive manufacturing. The developed geometry was used to produce physical prototype models using 3D printing technology, specifically the FDM method.

As a result of the study, a model enabling the assessment of process accuracy was obtained. Comparative analysis showed dimensional deviations of 1–2 mm relative to the reference object, confirming the suitability of the applied methods for prototyping processes.

The obtained results indicate that the combination of 3D scanning, reverse engineering, and 3D printing constitutes an effective tool for reconstructing the geometry of biomedical components and their rapid prototyping.

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KN Hefajstos

Analysis of the possibility of using hydrogen in liquid reduction processes

This paper presents an analysis of the possibility of using hydrogen in the reduction of iron oxides in a liquid state. The scope of the study includes a description of experiments conducted on an Arc Melter device in an atmosphere of argon and hydrogen mixture. The reduction processes for two types of feed materials are presented: pure iron oxides and GOK concentrate with the addition of biocoal. The text includes the methodology of smelting with varying durations and a description of the influence of the physical form of the feed (lumps, pieces) on the course of the reaction. The paper includes microstructural documentation and the results of chemical composition analyses of the obtained metallic products and slag phase, performed using a scanning electron microscope (SEM) and an EDS detector.

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KN Zgarek

Design and application of a sliding core box for manufacturing a spline connection in an iron casting during the reverse engineering of an MF-70 transmission connecting rod

This paper addresses the reconstruction of a connecting rod for the cutter bar drive of the MF-70 walking tractor using reverse engineering techniques. The primary technological challenge was to obtain the internal geometry of a spline connection without the use of machining processes, relying exclusively on casting technology.

As part of the study, an original design of a sliding-type core box was developed, inspired by solutions used in high-pressure die casting. The proposed core box enabled the production of a sand core reproducing the complex geometry of the spline, which was subsequently applied in a sand mould during the casting of ductile iron.

The research involved the digitization of the damaged component using direct measurement methods, CAD modelling, simulation of mould filling and solidification, and the fabrication of tooling using 3D printing. As a result of the conducted research, a casting with accurate geometric reproduction and material properties confirmed by non-destructive testing and microstructural analysis was obtained.

The proposed approach represents a viable and cost-effective alternative to conventional manufacturing methods, enabling the elimination of finishing machining operations in the production of spline connections.

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KN Zgarek

Evaluation of the microstructure and thermal conductivity of gray cast iron intended for thick section castings

The paper evaluated the microstructure and thermal conductivity of cast iron intended for thick-walled castings operating under variable thermal load conditions, such as sprues. The experimental part included melting cast iron in an induction furnace and casting samples in the form of technological rods. Based on the actual chemical composition of the obtained castings, a simulation of the phase composition and selected properties of the alloys were carried out using ProCast software. Then, microstructure studies were conducted using optical microscopy and thermal conductivity measurements were performed using the Laser Flash Analysis method and the steady-state heat flow measurement method. The results of the studies confirmed the possibility of obtaining cast iron with increased thermal conductivity while maintaining a pearlitic matrix.

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Wydział Odlewnictwa

KN Zgarek

Design and development of technology for making cast iron casting

The subject of this paper is the design and technological development of a manifold casting made of EN-GJL-200 grey cast iron with a mass of 242 kg. The geometry of the gating system and the pattern equipment were engineered using SolidWorks CAD software, whereas the numerical simulations of the filling and solidification processes were performed using MAGMASOFT.

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KN Zgarek

Effect of heat treatment on the microstructure, hardness, impact strength, and abrasive wear of chromium tool cast steel

Chromium tool cast steels are used in heavy industry for structural components exposed to abrasive wear, their performance properties depend primarily on the applied heat treatment. The aim of this study was to evaluate the influence of the type of heat treatment on the microstructure, hardness, impact strength, and abrasive wear of the investigated cast steel.
The microstructure of the examined cast steel consists of a ferritic matrix and chromium carbides precipitated along the grain boundaries. After isothermal quenching, an average hardness of 775 HV was achieved, while air quenching resulted in 715 HV. Correspondingly, the impact strength changed from 2.2 to 3.9 J/cm². In the Miller test, lower wear values were obtained compared to the chromium cast iron commonly used in the industry.

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KN InScience

Effect of Leaching Agent Type on the Kinetics of Cobalt and Molybdenum Extraction from a Spent Catalyst Derived from Petroleum Desulphurisation Processes

Spent catalysts used in industrial desulphurisation processes ist a valuable secondary source of strategic metals, primarily cobalt and molybdenum. In view of the growing demand for critical raw materials and the need to reduce the volume of industrial waste, the development of efficient methods for metal recovery from end-of-life materials is becoming important. Of significance is the search for solutions that offer not only high extraction efficiency, but also provide a basis for the subsequent, as selective as possible, separation of the recovered components. One of the stages of hydrometallurgical recovery is leaching, which depends both on the chemical properties of the starting material and on the type of leaching agent employed.The present work reports the results of a preliminary study of the development of a new method for metal recovery from a spent petroleum desulphurisation catalyst. The main objective was to identify the most suitable leaching agent among systems based on inorganic acid solutions: 1 M HCl, 1 M H_2SO_4, and 1 M HNO_3. The study focused on analysing the dissolution kinetics of the catalyst material, monitored through changes in the concentrations of the elements as a function of time. This approach made it possible not only to assess the final extraction degree of the individual metals, but also to compare the process dynamics depending on the reagent used.

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KN Hefajstos

Development of a technology for smelting Damascus (Wootz) steel under laboratory conditions

The purpose of this work is theoretical research and literature analysis as part of a diploma thesis. The main assumption of the work is the melting and plastic forming of Damascus steel, and the analysis of its properties. The work presents the melting conditions of the input materials and the process of alloy crystallization. Particular emphasis is placed on the description and analysis of factors influencing crystallization and selected methods for ingot production. The characteristic features of historical Damascus steel are also described and their advantages and disadvantages are considered. The work also includes a history of Damascus steel, discussing examples of such steels, their chemical compositions, and unusual alloying elements used in this type of steel. A comparison of historical Damascus steel with its contemporary counterparts is also provided.

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KN Zgarek

Analysis of CO_2 emission in the production process of a cast iron casting using computer modeling

This paper presents an analysis of the carbon footprint of a cast iron casting originating from one of the Polish foundries. The Good Guy Index software developed by NovaCast was used to assess the impact of the production process on CO_2 emissions. As part of the analysis, the significance of the production defect rate and the effect of its reduction on the total carbon footprint per kilogram of casting were determined. Additionally, the impact of the energy source used in the foundry on the final CO_2 emissions per kilogram of product was evaluated. Subsequently, selected quality control tools were used to simulate actions aimed at reducing the level of production defects. The conducted analyses demonstrated that reducing the number of non-conforming products leads not only to a decrease in the carbon footprint but also to an improvement in the company's economic efficiency. The obtained results confirm the important role of integrating engineering and quality tools in the process of sustainable production management. The study also demonstrated the high usefulness of the Good Guy Index software in analyzing and optimizing foundry processes from an environmental perspective.

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KN Hydrogenium

Application of spectroscopy techniques to study sodium intercalation reactions in prussian blue analogues for Na-ion cells.

Intercalation reactions are a fundamental type of reactions used for reversible electrochemical cells, both Li-ion and Na-ion. Understanding of these reactions is a crucial aspect in development and fabrication of these cells.
In this work, results of infra-red spectroscopy (FT-IR), Raman spectroscopy and X-Ray absorption spectroscopy (XAS) have been presented.
FT-IR and XAS spectroscopy have been conducted in ex-situ mode, Raman spectroscopy has been conducted in operando and in-situ mode.
Obtained results allowed to determine changes in the material's structure during charging and discharging processes. In particular, changes of iron oxidation state during it's oxidation and reduction reactions have been revealed. Furthermore, the obtained results allowed of better understanding of reversibility of sodium intercalation and deintercalation processes in the material's structure.

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KN Feniks

Plant biomass waste as a precursor for sorbents

Plant waste, such as tree leaves (maple, oak, chestnut), pine needles, or wood chips, can be used to produce sorbents. The preparation process involves several stages. First, the biomass is dried and shredded. It is then subjected to pyrolysis, i.e., heating at high temperatures in the absence of oxygen, resulting in the formation of biochar—a form of charcoal. The next step is the activation of the material, which increases its porosity and specific surface area, and thus its sorption capacity.

Activation can be physical (using steam or CO_2) or chemical (using substances such as NaOH, H_3PO_4, or $ZnCl_2$). Physical activation requires higher temperatures and greater energy input, whereas chemical activation allows for better control of the pore structure, is more efficient, faster, and enables the sorbent to be tailored to specific pollutants.

Wood biomass possesses favorable sorption properties due to its chemical composition. It contains cellulose and hemicellulose, which bind polar compounds; lignin, which promotes the sorption of aromatic compounds; and waxes and cuticle, which enable the adsorption of hydrophobic compounds. Additionally, the natural structure of leaves is porous, which facilitates the sorption process.

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SKNF Bozon

Ordered macromolecular nanowires for resistive switching purposes

Nowadays, the nanoscale silicon-based electronics are approaching their fundamental physical limits. Furthermore, modern computer architectures are affected by the von Neumann bottleneck, in which the physical separation between memory and processing units, combined with their mismatch in operational speed, leads to significant energy loss during repeated data transfer.

To address these challenges, memristors, named after the concept of "memory of resistance," are being intensively investigated due to their potential to function as artificial synapses and to overcome the aforementioned limitations.

In this work, a new approach to the fabrication of memristors based on ferrocene-functionalized polymer brushes and their characterization are presented. The active layers are synthesized on indium tin oxide (ITO) glass substrates via the surface-initiated atom transfer radical polymerization (SI-ATRP) method, forming highly ordered macromolecular architectures. Structural and electrical characterizations of the synthesized systems are carried out to investigate their design and resistive switching behavior.

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SKN Tryton

Sorption of selenium on iron oxide-based composite material

Selenium removal from aquatic environments is critical due to its narrow range between necessity and toxicity. This study investigates ferruginous sludge, a wastewater treatment byproduct, as a potential sorbent for selenium. Batch experiments assessed pH levels (2.0–10.0), initial concentrations (5–300 mg/L), and kinetics (up to 48 h), while AAS analysis and redox monitoring ensured species stability. Results showed that removal is highly pH-dependent, with an optimum at 4.0–5.0. The sorbent displayed a significantly higher affinity for Se(IV) than Se(VI), achieving maximum capacities of 42.5 mg/g and 15.8 mg/g, respectively. Among the tested mathematical models, including Langmuir, Freundlich, BET, and Temkin, the Sips model provided the best fit, indicating adsorption on a heterogeneous surface via combined monolayer and cooperative interactions. The research confirms that repurposing this industrial byproduct is a sustainable and efficient strategy for Se(IV) remediation in industrial effluents.

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KN Indygo AGH

Synthesis of the HKUST-1 metal–organic framework with Fe(III) ions and its stability in the aqueous phase for adsorption applications.

Metal–organic frameworks (MOFs) constitute a rapidly developing class of porous crystalline materials composed of metal ion clusters connected by organic ligands. One of the most widely studied and promising representatives of this group is HKUST-1 (Cu-BTC), in which copper(II) dimers are linked by trimesic acid residues, forming a regular three-dimensional network. This material is characterized by a high specific surface area and the presence of so-called open metal sites, which makes it particularly attractive for applications such as gas storage and separation, as well as advanced catalysis.
A significant limitation of the practical application of HKUST-1 is its low hydrothermal stability. Water molecules readily coordinate to unsaturated copper centers, leading to the hydrolysis of coordination bonds, irreversible degradation of the crystalline structure, and a drastic decrease in porosity. One promising strategy to improve stability is the modification of the material through doping with other metals.
The aim of this work is the synthesis of HKUST-1 modified with iron(II) ions and a comprehensive investigation of the effect of varying concentrations of this modifier on the physicochemical properties of the MOF. The project focuses on evaluating the specific surface area, degree of crystallinity, hydrothermal stability, and adsorption capacity toward contaminants in the aqueous phase. The study will include samples with iron contents of 2.5, 5, and 10 wt%.

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KN Hydrogenium

Novel perovskite-based electrode materials for Solid Oxide Fuel Cells

For the last couple of years, interest in renewable energy technologies has significantly increased. One of the most promising solutions is the utilization of Solid Oxide Fuel Cells. Symmetrical Solid Oxide Fuel Cells with identical anode and cathode materials are an excellent example of electrochemical devices capable of using hydrogen and carbon-contained fuels (such as natural gas) for efficient energy conversion. Electrode materials for such symmetrical systems must fulfill challenging criteria such as high mixed-ionic electronic conductivity and structural stability both in reducing and oxidizing operation atmospheres.

In the presented work, novel double perovskite with in situ exsolved nanocatalysts have been designed and evaluated as potential electrode materials for Symmetrical Solid Oxide Cells. Proposed new symmetrical electrode materials exhibit excellent stability with typical used electrolytes, maximum power density output of around 1 Wcm^{-2} and stable performance surpassing 200h without significant degradation were recorded. The results obtained indicate that the developed new symmetrical electrode materials can be potentially applied in the symmetrical cells for effective energy conversion.

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AGH Eko-Energia

Analysis of the effect of SORIC core application on the bending properties and mass efficiency of basalt laminates

This research presents an analysis of the effect of using a SORIC core on the bending properties and mass efficiency of basalt fiber-reinforced composite laminates.

The research is being conducted in the context of the lightweight roof structure of the "PERŁA" solar vehicle, developed by the AGH University of Science and Technology's Eko-Energia Research Group. This structure will serve as the mounting surface for the photovoltaic panel installation, so a key aspect of using a basalt composite (as opposed to a carbon composite) is its insulating properties. Four laminate variants were designed: two classic laminates and two sandwich laminates with a SORIC core of varying thicknesses, manufactured using the vacuum infusion method.

The evaluation was conducted using a three-point bending test in accordance with the ISO 14125 standard, with particular emphasis on the effect of the core on structural behavior and mass efficiency.

The aim of this work is to assess the feasibility of using sandwich structures in lightweight composite structures.

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SKNF Bozon

Uranium and wellness in Iceland geothermal waters

Geothermal activity can mobilise naturally occurring radioactive elements as a result of high-temperature water-rock interactions. Iceland's geothermal hot springs attract millions of tourists, widely uses these waters for relax and recreation, which raises questions about radiation exposure. This study examines the concentrations of uranium isotopes in geothermal waters from tourist-frequented locations and geologically diverse sites across Iceland.
Uranium was selectively separated using extraction chromatography and measured via liquid scintillation counting, ensuring accurate detection at low concentrations. The results show that the concentrations of uranium radioactivity vary by location, reflecting local geochemical conditions. Most samples contained low uranium radioactivity levels, with only sporadic increases remaining well below the 3.0 Bq·l-1 reference level for 238U used in the assessment of drinking water (Council Directive 2013/51/Euratom of 22 October 2013). Overall, the findings indicate that typical recreational use of geothermal waters in Iceland does not pose a significant radiological risk. Even extended bathing would result in radiation doses that are negligible compared to everyday natural background exposure. This study supports environmental safety assessments and provides useful guidance for tourists, including many visitors from Poland.

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AGH Solar Boat

Mechanical property comparison of HM and UHM carbon fiber composites in the context of stiffness and geometry optimization of the "Delta" solar boat struts

The boats built by the AGH Solar Boat are hydrofoils, which requires additional structural elements not found in most vessels. This pion focuses on the materials used for foil strut and their mechanical analysis. In the construction of the latest boat, "Delta", the goal was to maximize performance by reducing mass and hydrodynamic drag.

The research involved a comparative analysis of carbon fiber composites with different Young's moduli: standard, high (HM), and ultra-high (UHM). The tests focused on determining the stiffness and deflection of the samples. The objective was to evaluate the potential for future optimization of foil strut geometry. Higher material stiffness is intended to allow for a reduction in the strut's chord while maintaining required strength.

To ensure repeatability and allow for direct comparison of results in future studies, the tests were conducted according to the ISO 14125 standard: "Kompozyty tworzywowe wzmocnione włóknem - Oznaczenie właściwości przy zginaniu ".

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KN Glider

ESOA-Tuned Hybrid CNN-XGBoost Model for Multi-Class Skin Lesion Classification

In our study, we propose an innovative hybrid approach for multiclass skin lesion classification, combining the EfficientNetV2L architecture as a feature extractor with XGBoost as the classifier. The main contribution of this work is the application of the Egret Swarm Optimization Algorithm for automatic hyperparameter fine-tuning of the XGBoost model, which helps avoid local minima and enhances generalization capability. The research was conducted on an integrated dataset composed of HAM10000 and MSLDv2.0, comprising 14 diagnostic categories.
The results demonstrate that the proposed hybrid model optimized by ESOA achieves the highest performance, with an accuracy of 0.85 and a weighted F1-score of 0.84, outperforming the standalone base EfficientNetV2L model. Special attention was given to skin cancer detection. A statistically significant improvement in sensitivity (recall) was observed for basal cell carcinoma, increasing from 0.80 to 0.85, along with a clear upward trend in melanoma detection performance.
Additionally, we provide a comprehensive analysis of the impact of classical image preprocessing techniques, such as DullRazor and CLAHE, indicating that modern convolutional neural networks achieve better generalization when trained on raw dermoscopic images. The proposed solution represents a significant step toward the development of accurate clinical decision support tools in dermatology.

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KN BioMetr

Predicting Parkinson's Disease Clinical Outcomes from Multimodal Mixed-Reality Recordings with Unlearning-Aware Modeling

Parkinson's disease is a heterogeneous neurodegenerative disorder whose motor and non-motor symptoms are not fully captured by episodic clinical ratings. This study evaluated whether multimodal mixed-reality (MR) recordings can predict clinical scale scores and support post-hoc data deletion through machine unlearning.
Data were collected from 93 Parkinson's disease patients using Microsoft HoloLens 2 headsets. Each participant completed 17 tasks covering speech, motor, and eye-tracking assessments, yielding 4,850 features per subject. Prediction was performed for 14 clinical scales using single-target regression, multi-output learning, and late fusion strategies, with leakage-safe fold-wise preprocessing applied throughout. Positive hold-out R^2 was obtained for 9 of 14 scales, with the strongest results for Hoehn Yahr (R^2=0.53), MDS-UPDRS IV (R^2=0.48), VHI (R^2=0.33), MoCA (R^2=0.27), and BERG (R^2=0.21). A certified ridge-based unlearning experiment demonstrated that prediction error remains close to baseline after feature-expert deletion, with stacking emerging as the most deletion-tolerant fusion strategy. These findings confirm that short standardised tasks recorded with a single MR device capture clinically meaningful variance across motor and non-motor domains, while also enabling GDPR-compliant post-deployment data governance.

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Koło Naukowe BIT

MolPILE - large-scale, diverse dataset for molecular representation learning

The size, diversity, and quality of pretraining datasets critically determine the generalization ability of foundation models. Despite their growing importance in chemoinformatics, the effectiveness of molecular representation learning has been hindered by limitations in existing small molecule datasets. To address this gap, we present MolPILE, large-scale, diverse, and rigorously curated collection of 222 million compounds, constructed from 6 large-scale databases using an automated curation pipeline. We present a comprehensive analysis of current pretraining datasets, highlighting considerable shortcomings for training ML models, and demonstrate how retraining existing models on MolPILE yields improvements in generalization performance. This work provides a standardized resource for model training, addressing the pressing need for an ImageNet-like dataset in molecular chemistry.

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Koło Naukowe BIT

Large-scale benchmark of pretrained neural networks for molecular representation learning

Pretrained neural networks have attracted significant interest in chemistry and small molecule drug design. Embeddings from these models are widely used for molecular property prediction, virtual screening, and small data learning in molecular chemistry. This study presents the most extensive comparison of such models to date, evaluating 25 models across 25 datasets. Under a fair comparison framework, we assess models spanning various modalities, architectures, and pretraining strategies. Using a dedicated hierarchical Bayesian statistical testing model, we arrive at a surprising result: nearly all neural models show negligible or no improvement over the baseline ECFP molecular fingerprint. Only the CLAMP model, which is also based on molecular fingerprints, performs statistically significantly better than the alternatives. These findings raise concerns about the evaluation rigor in existing studies. We discuss potential causes, propose solutions, and offer practical recommendations.

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Koło Naukowe BIT

LBVSLitmus - The platform for benchmarking ligand-based virtual screening methods

Discovering a new drug is a process that spans over a decade and costs billions of dollars. One of its critical stages involves searching vast chemical libraries, which often contain millions of compounds, in order to find those that may interact with a disease-related protein. Testing each one in a laboratory is physically and financially infeasible, which is why researchers employ computational methods known as virtual screening to pre-select the most promising candidates. In ligand-based virtual screening (LBVS), chemical structures are converted into numerical vectors and classified using machine learning algorithms. The problem is that each research group uses different datasets, metrics, and evaluation procedures, making results across groups incomparable. We present LBVSLitmus, an open-source Python platform that standardizes this process. It integrates five established benchmarks covering over 5 million molecules and 151 protein targets, providing a unified pipeline from data acquisition to evaluation. Our large-scale analysis revealed, among other findings, that count-based ECFP4 molecular fingerprints systematically outperform their binary counterparts. This result challenges the current default in cheminformatics. The platform is publicly available on PyPI.

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KN Artificial Intelligence in Medicine

ML-API: Bridge Between ML Research and Production

Modern clinical decision support systems increasingly rely on advanced machine learning models, whose deployment requires specialized programming environments, substantial computational resources, and dedicated IT expertise. The ML-API platform addresses these challenges by providing a unified ecosystem for deploying and managing machine learning models in clinical settings. It introduces a resource abstraction layer alongside our fastmlapi Python package, enabling automated containerization and efficient hardware utilization. The platform incorporates intelligent queuing based on VRAM demand and leverages shared memory to reduce data transfer overhead, thereby supporting high-throughput, multi-stage inference. Through adaptive inference and asynchronous processing, ML-API ensures scalability and reliability in dynamic medical environments, effectively bridging the gap between model development and real-world application. Rather than statically assigning models to GPUs, the platform employs dynamic resource allocation strategies that optimize hardware usage while maintaining control over resource consumption. This approach enables efficient parallel processing of smaller tasks, maximizing pipeline utilization and significantly improving system throughput in hospital workflows. As a specialized MLOps framework, ML-API facilitates the translation of academic research into production systems by offering fine-grained customization adapted to specific requirements.

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KN Artificial Intelligence in Medicine

From Class Activation Maps to Superpixel Perturbations: A Review of XAI Methods for ResNet18 on the Stanford Dogs Dataset

Image classification with deep convolutional neural networks works well in practice, but understanding why a model makes a particular decision remains a challenge. This issue is addressed by explainable artificial intelligence (XAI) methods, which are the focus of this paper.
As a common reference point, we used a ResNet18 model pretrained on ImageNet and fine-tuned for 120 dog breed recognition (Stanford Dogs) that is a difficult task due to high visual similarity between classes. We evaluated five explanation techniques on this model: Grad-CAM, Guided Grad-CAM, Integrated Gradients, Input × Gradient, and occlusion, alongside two model-agnostic methods, namely LIME and SHAP. The methods differ in both their approach (gradient analysis, input masking, feature perturbation) and computational cost. A shared experimental setup allowed us to directly compare them and assess how consistently they highlight the image regions relevant to the model's decision. Our results show that different techniques can produce noticeably different explanations for the same input especially when classes look alike. This calls for caution when interpreting XAI outputs and careful selection of the right method for a given task.

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SKNF Bozon

Finding the "Perfect Swish": Using a PINN to Optimise the Physics of a Basketball Shot

Nowadays, neural networks have become an important tool in scientific research, being applied in material synthesis, pharmacology, meteorological forecasting and more. A specific class of machine learning algorithms, called Physics-Informed Neural Network, integrate the laws of physics in form of partial differential equations into their loss function, to ensure the results calculated by the model are in line with known laws of nature.
In this study, a PINN was implemented to model the trajectory of a basketball. The model was designed to calculate the initial velocity vector required for the ball to cleanly go through the hoop, based on given position on the court. Beyond accuracy, the model was also incentivised to minimaze the total value of the velocity in order to limit the energetic expenditure, as well as increase the arc to increase the difficulty of making a defensive block.
This work serves as a foundational baseline for the development of more robust PINN models optimizing a basketball shot in the future. Future version aim to incorporate player parameters, like height and wingspan, amongst others. Precise simulations of kinematic systems like those are hoped to find applications in personalizing athletes training protocols.

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SKNF Bozon

Electron/muon classifier

Ultraperipheral heavy-ion collisions at the Large Hadron Collider provide a unique environment for studying the production of vector mesons, such as J/ψ, and for testing quantum chromodynamics models in the regime of low Bjorken-x. However, the analysis of their decay products requires efficient identification methods in the presence of background and detector-related limitations of the ATLAS experiment.

In this contribution, we present a classifier for the decay products of the J/ψ particle in ultraperipheral collisions recorded by the ATLAS experiment. The proposed approach is based on modern machine learning techniques, exploiting kinematic and topological features of the events.

The resulting classifier achieves significantly higher performance compared to previously used algorithms, leading to improved data selection efficiency. These results demonstrate the strong potential of machine learning methods in the analysis of ultraperipheral collisions and open the way to more precise measurements of vector meson properties within the ATLAS experiment.

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KN Glider

Detection of Polish Sign Language Alphabet Letters in Augmented Reality

As part of a project, a methodology was developed for recognizing signs of the Polish Sign Language alphabet using an augmented reality system. The signs were divided into two categories: static and dynamic, which made it possible to adapt the detection process to the specific characteristics of hand movement. For the purposes of the research, a custom dataset was created and using deep learning a model was developed to identify the gestures.

A key aspect of the solution design was achieving high real-time performance, since image lag in augmented reality systems may lead to user discomfort or even dizziness. The proposed solution was consulted with experts from the Polish Association of the Deaf in order to better adapt the system to the needs of potential users and improve its practical usability.

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SKN Analizy Danych Anatomicznych

Evaluation of Generative AI Models in Producing Anatomically Accurate Illustrations: A Comparative Study of Text-to-Image Generators

Generative artificial intelligence (GAI) is increasingly used in medical education; however, the anatomical accuracy of generated illustrations remains uncertain. The aim of this study was to evaluate selected text-to-image models in terms of anatomical correctness.

Six generators (DALL·E, Gemini, Freepik, Midjourney, DeepAI, and Canva) were analyzed using a standardized prompt for various anatomical structures. A total of 144 images were evaluated for the presence and physiological correctness of structures based on Terminologia Anatomica. Assessments were performed by four independent reviewers, and the results were subjected to statistical analysis.

DALL·E achieved the best performance (56.7% of correctly identified structures; 66.0% physiologically correct), although the proportion of fully correct structures remained low across all models (maximum 37.4%). The lowest accuracy was observed for complex structures such as the lumbar plexus and celiac trunk.

Current GAI models show significant limitations in generating anatomically accurate illustrations, highlighting the need for expert verification before their use in medical education or scientific contexts.

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A Hybrid Agent-Based Model for Rainfall-Runoff Dynamics and Adaptive Flow Control in Urban Sewer Systems

This paper presents a hybrid agent-based model (ABM) for simulating rainfall-runoff dynamics and flow propagation in urban sewer systems. The framework, fully implemented in Python, integrates a nonlinear runoff transformation with graph-based routing and rule-based control of a wastewater treatment plant.

The network is represented as a directed graph where nodes act as autonomous agents, generating local inflow based on rainfall intensity and time-dependent baseflow. This Python-based approach enables flexible modeling of spatial interactions and local heterogeneity within the network.

The model was calibrated using real-world data from the Żywiec region. The implementation allowed for advanced exploratory data analysis and the generation of automated visualization dashboards, including diurnal flow profiles and residual distribution plots used to evaluate model bias.

Results indicate good agreement under baseline conditions, while discrepancies during high-flow events suggest the influence of unmodeled external factors. Scenario-based seasonal sensitivity analysis, conducted for multiple rainfall intensities, shows that the system remains robust under typical conditions. However, extreme scenarios visualized through dynamic retention and overflow plots reveal system overload and the necessity for emergency bypass activation.

This computationally efficient tool supports infrastructure decision-making under varying hydrological stress.

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SKN Analizy Danych Anatomicznych

Comparative Analysis of the Effectiveness of ChatGPT-5.2 and AnatomyGPT Language Models in Solving Multiple-Choice Questions in Human Anatomy

Introduction: Artificial intelligence is one of the fastest-growing fields of technology and is increasingly used in medicine. The rapid development of language models, such as AnatomyGPT, calls for evaluation of their usefulness in medical sciences, particularly anatomy. The aim of this study was to assess the effectiveness of AI in solving theoretical anatomy exams in a medical curriculum.

Methods: Two models were evaluated: ChatGPT-5.2 and AnatomyGPT 5.2. A dataset of 550 multiple-choice questions (145 in Polish, 405 in English) from past exams was used. The questions were prepared and verified by an experienced academic teacher. Each question was presented twice to both models and classified by topic.

Results: ChatGPT-5.2 achieved 84.36% accuracy in the first attempt and 86.36% in the second, while AnatomyGPT scored 82.73% and 85.27%. Both models performed better in English. The highest accuracy was observed in innervation and vascularization, and the lowest in multiple-select questions. Differences were not statistically significant.

Conclusions: The models enable satisfactory exam performance, posing challenges for academic staff. Well-designed questions may still limit AI effectiveness, but further development may increase pass rates. AnatomyGPT shows strong potential for future medical applications.

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KN Glider

Symbiotic Multi-Strategy Swarm Optimization: A Hybrid Metaheuristic with Predator-Prey and Parasitic Dynamics

In recent years, nature-inspired metaheuristics have proven highly effective in solving complex optimization problems. This paper introduces the Symbiotic Multi-Strategy Swarm (SMSS) algorithm, a novel hybrid metaheuristic that models a complex, multi-agent ecosystem to achieve a robust balance between exploration and exploitation. The SMSS ecosystem comprises four distinct agent fractions: the Herd (responsible for broad search space exploration and reproduction), Solitary agents (acting as memetic optimizers utilizing Differential Evolution and Particle Swarm mechanisms for precise local exploitation), Parasites (inducing targeted mutation and forcing hosts to escape local minima), and Apex Predators (eliminating overcrowded regions and triggering Levy-flight-based panic responses). To further prevent premature convergence, the algorithm incorporates spatial crowding penalties and a cataclysmic extinction mechanism during severe stagnation. The efficacy of the proposed model is evaluated on both continuous multimodal functions (e.g., Rastrigin) and discrete combinatorial challenges, such as the Traveling Salesperson Problem (TSP) using the Random Key representation. Results demonstrate that the multi-species symbiotic dynamics and extreme environmental pressures empower the SMSS algorithm to effectively escape deep local optima and achieve highly competitive convergence rates.

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AGH Code Industry

An Educational Research Program for Audio Compression Techniques Using AI Evaluation

Understanding data compression processes is one of the fundamental challenges in education within the field of digital signal processing. These algorithms form the backbone of modern communication, yet their teaching is often limited to theoretical formulas. The goal of the presented project is to aid in the understanding of these processes by creating an interactive environment that transforms data optimization into an experimental process.

The ACRE (AI-evaluated Compression Research Engine) system introduces an innovative approach to designing processing pipelines using modular components. The user constructs custom audio file compression systems by selecting and connecting "blocks" corresponding to real-world techniques, such as denoising or advanced coding that optimizes the file structure. Subsequently, the player's efforts are evaluated by artificial intelligence, which, acting as a judge, performs a psychoacoustic analysis and assesses whether the message contained in the audio file remains intelligible.

This paper presents the technical architecture of the program and analyzes its dual role: as a didactic tool facilitating the understanding of compression mechanics, and as a research platform. Thanks to the high degree of freedom in configuring methods, the system allows for the testing of non-standard sequences of algorithms, which may lead to the discovery of new approaches to compression.

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KN BioMetr

Assessment of coronary artery disease using cardiac computed tomography imaging

This paper presents an automated engineering solution for the detection and assessment of coronary artery stenoses based on pre-segmented cardiac computed tomography images. Binary masks in NRRD format were used in the data preparation and analysis process, with strict consideration of spatial resolution (spacing) to ensure the isotropy of physical measurements. An approach based on graph theory and digital image processing was employed, encompassing smoothing, skeletonization, and the determination of the minimum-cost path (centerline) using an accurate Euclidean Distance Transform (EDT). The proprietary decision algorithm identified pathological stenoses by analyzing the local gradient of diameter changes and avoiding bifurcation zones, which allowed for the final classification of patients according to the clinical CAD-RADS scale. The obtained F1-Score of 0.838 confirms the high effectiveness of the method in identifying hemodynamically significant stenoses. However, the presentation discusses the challenges associated with analyzing vessels with highly atypical topologies and the impact of calcification artifacts, pointing to directions for further research, including potential integration with machine learning methods.

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Generative Image Compression Based on Deep Neural Networks: Architecture and Experimental Analysis

This paper presents a generative image compression method utilizing deep neural networks. We propose the LINC (Learned Intelligent Neural Compressor) model family, whose architecture is based on the HiFiC approach. The experimental analysis was conducted on the AFHQ dataset, focusing on high-resolution images with complex textures. The quality of image reconstruction was evaluated using PSNR, SSIM, and bitrate metrics, and compared with classical JPEG and WebP codecs. The results demonstrate that LINC models maintain high perceptual quality even at extremely low bitrates, significantly outperforming traditional standards in visual characteristics. Notably, LINC preserves fine details and natural textures without blocky artifacts, which are typical for JPEG/WebP at similar compression rates. Although objective metrics (PSNR, SSIM) for LINC may be lower due to generative restoration of textures, subjective visual quality is considerably higher. The integration of perceptual and adversarial losses in training allows overcoming the "blurring effect" and ensures realistic texture reconstruction. The practical significance of the results lies in the potential application of such models in systems where visual recognizability at minimal data volume is critical, such as medical imaging, satellite photos, and mobile applications. Future work may focus on decoder optimization, color fidelity improvement, and adaptation to other image and video types.

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AGH AVADER

End-to-End Keyword Spotting on FPGA Using Graph Neural Networks with a Neuromorphic Auditory Sensor

With the rapid growth of mobile robotics and embedded intelligence, there is an increasing demand for efficient on-device data processing on edge platforms. A promising research direction is the use of neuromorphic sensors inspired by human sensory systems, which generate sparse, event-based data encoding changes in the environment. This paper presents the first end-to-end FPGA implementation of a keyword spotting system that integrates a Neuromorphic Auditory Sensor (NAS) and a graph neural network (GNN) on a single FPGA device, enabling real-time processing of raw audio data. The proposed architecture eliminates conventional signal preprocessing and operates directly on event-based audio streams. Leveraging a compute-near-memory network architecture, the system achieves efficient inference with low latency and low power consumption. Experimental results demonstrate an accuracy of 87.43% after quantization on the Google Speech Commands v2 dataset processed through the neuromorphic sensor, with end-to-end latency below 35 μs and average power consumption of 1.12 W.

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KN Glider

KAN vs. MLP in computer vision: Is the new architecture breaking the dominance of traditional networks?

This study presents a comprehensive comparison of classical MLP networks and KAN architectures in computer vision tasks. The analysis covers three model scenarios: pure architectures (MLP vs. KAN), convolutional hybrids (MLP+CNN vs. KAN+CNN), and an approach utilizing transfer learning. Each configuration was thoroughly tested on three diverse datasets: Imagenette, Food-101 (10-class subset), and STL-10. The models were evaluated not only in terms of prediction quality but also computational efficiency. The analysis considered the number of parameters, the number of MAC operations, training time, and standard classification metrics: accuracy, precision, recall, and F1-score. The aim of the study is to answer the question of whether KAN is a viable alternative to MLP in computer vision applications.

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Koło Naukowe BIT

Refactoring and Optimization of the Mordred Descrptior for Scalable Molecular Feature Extraction

The efficiency, reliability, and scalability of descriptor calculation libraries are critical for machine learning applications in chemoinformatics. Despite its widespread use, the mordred-community library suffers from legacy inefficiencies, implementation inconsistencies, and suboptimal molecular preprocessing, limiting its applicability to large-scale datasets.

In this work, we present a systematic refactoring and integration of the Mordred descrptior into the scikit-fingerprints package. The codebase was audited to eliminate redundant Python-based numerical operations, correct the treatment of explicit hydrogens in topological descriptors, and improve the 3D geometry processing pipeline. Core computations, including distance matrix and spatial descriptor calculations, were delegated to the optimized native backend of RDKit.

Benchmarking on large molecular datasets demonstrates significant improvements in execution time and memory usage compared to the original implementation, while ensuring consistent and accurate descriptor values.

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Koło Naukowe BIT

Application of Liquid Neural Networks (LNNs) in Pulse Signal Analysis

Research on the use of Liquid Neural Networks (LNNs) for the recognition and classification of pulse signals. The project focuses on evaluating the effectiveness of LNNs in interpreting biomedical signals and compares their performance against traditional deep learning models.

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KN Glider

SafeSpace: Design and Implementation of a Secure Well-being Support Ecosystem with a Risk Detection System, Multi-level Content Filtering, and Privacy Guarantees

This paper describes the architecture and initial prototype implementation of the SafeSpace system—a full-stack web application designed to support mental well-being through a secure conversational interface. We have developed an AI-driven risk detection system utilizing modern Natural Language Processing (NLP) and machine learning models, integrated with a Python (FastAPI) backend and a TypeScript frontend. The platform's mechanisms enable real-time content analysis for crisis symptoms, the identification of potential threats, and the activation of appropriate intervention procedures. Based on a dynamically accumulated risk score, the system implements a multi-level escalation protocol that governs the response generation process and determines whether generative models are permitted to engage in the interaction. The system architecture places a high priority on privacy (including data anonymization, RAM-based session management, an emergency "exit" button, and the destruction of chat history) and security. The proposed solution demonstrates that integrating advanced server-side security logic with modern frameworks allows for the creation of an ethical emotional support tool, effectively minimizing the risks associated with the autonomous operation of artificial intelligence in the mental health domain.

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Koło Naukowe BIT

KOŁO NAUKOWE

Multimodal Bayesian Networks in Autonomous Triage

Development of a decision support system for emergency medical services using Bayesian networks to integrate uncertain data from computer vision. The models were constructed exclusively using expert knowledge, and their application has improved both prediction quality and diagnostic accuracy.

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Koło Naukowe BIT

Benchmarking MNAR Scenarios for Data Imputation Methods

This project focuses on the development of a unified benchmark suite for Missing Not At Random (MNAR) data scenarios. The goal is to create a test environment that enables objective evaluation of imputation algorithm quality and facilitates the verification of the impact of domain knowledge on data completion accuracy.

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Koło Naukowe BIT

Analysis of Missing Data Handling Mechanisms in XGBoost

The objective of this study is to evaluate the effectiveness of XGBoost's built-in missing data handling mechanisms. The analysis aims to determine whether automated strategies for assigning values to missing observations lead to improved prediction quality compared to traditional preprocessing methods.

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KN mHealth SpaceMed

sMouthguard - Instrumented mouthguard for impact detection and brain trauma severity classification

Traumatic brain injuries (TBI) remain a critical challenge in contact sports due to the lack of reliable, real-time monitoring systems. This work presents the ongoing development of an instrumented mouthguard (sMouthguard) designed for impact detection and head trauma severity classification.

The proposed system integrates an inertial measurement unit (IMU) with a low-power embedded platform supporting Bluetooth Low Energy (BLE) communication. The intraoral placement provides more stable mechanical coupling with the skull than externally mounted sensors.

The project focuses on a complete data processing pipeline, including high-frequency signal acquisition (~1kHz), preprocessing, and feature extraction. In particular, wavelet-based representations are investigated to capture transient impact characteristics. These features are intended for classification using machine learning approaches such as Support Vector Machines (SVM) and learned wavelet encoders.

Current work includes the redesign of the hardware platform with an upgraded high-performance dual-range IMU (LSM6DSV320X) and the development of a real-time data visualization and analysis environment using modern C++ tools.

The project aims to establish a scalable and extensible platform for future experimental validation and data-driven modeling of head impact severity. Planned work includes dataset acquisition, model evaluation, and system integration for real-world testing scenarios.

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Koło Naukowe AGH New-Tech

Analysis and interpretation of biometric data to support the achievement of training goals

The presented project involves developing a biometric data analysis system that supports training planning and assessing the body's recovery level. The application integrates with the Garmin ecosystem via an API, enabling automatic download and archiving of user data in a relational SQL database. Multidimensional information is analyzed, including sleep quality, heart rate variability (HRV), resting heart rate, stress level, physical activity, and training load. Based on the collected data, key stress indicators are determined, such as the acute-to-chronic workload ratio (ACWR), monotony, and strain, as well as parameters describing the body's recovery capacity. A key element of the system is the proprietary, synthetic "Fitness Level" indicator, which aggregates key physiological signals into a single, easy-to-interpret value. Analysis results are presented in an interactive dashboard, enabling analysis of both long-term trends and detailed daily data. Additionally, the system generates training recommendations based on the body's current condition and training load history. The aim of this study is to assess whether a multidimensional approach can more effectively support the achievement of training goals and reduce the risk of overload compared to the analysis of single parameters.

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Koło Naukowe BIT

Efficient solvers for Maximum Diversity Picking problem

Modern data analysis frequently deals with information redundancy, necessitating the selection of the most representative samples. This work focuses on the Maximum Diversity Picking (MDP) problem, specifically the MaxMin variant. This approach aims to maximize the minimum distance between selected elements, ensuring optimal coverage of the search space, reducing experimental costs, and avoiding redundant data. As an NP-hard problem, its complexity significantly limits the applicability of exact methods for large-scale datasets in practical scenarios.

The primary objective of this project was to implement an efficient tool for processing massive datasets, with a focus on chemoinformatics. The resulting library combines the high performance of C++ with the flexibility of the Python environment. It incorporates both exact methods based on mathematical programming and scalable heuristics designed for high computational complexity, where traditional approaches prove ineffective.

Comparative analysis, including benchmarks against the RDKit package, demonstrated high solution quality alongside excellent scalability. The developed software effectively overcomes memory and time constraints-notably by avoiding full distance matrix precomputation-providing stable results for large problem instances.

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Koło Naukowe BIT

An Integrated AI System for Earth and Space Monitoring: Fire Detection and Routing Optimization Using Graph Neural Networks

This article presents an innovative Earth and space monitoring system. This solution integrates machine learning techniques with modern web technologies and consists of two technologically interlinked modules.

The first of these - the Fire Detection System - is responsible for the early detection of fire hazards through the automatic analysis of satellite imagery. Using computer vision algorithms and geospatial libraries, the system precisely identifies fire hotspots. Furthermore, the system also offers the ability to predict and simulate the future direction of a detected fire's spread. Results are processed in the FastAPI environment and visualized in real-time on interactive maps using React technology.

The second module - GNN Satellite Routing - is a simulation system for modeling and route planning in dynamic satellite constellations. At its core are Graph Neural Networks, which simulate and optimize network throughput while minimizing latency in constantly changing space topologies.

In summary, this project serves as a successful proof of concept for the use of artificial intelligence - from object-based image analysis to deep graph learning - in critical systems that combine environmental monitoring with modern satellite telecommunications.

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Koło Naukowe BIT

CR39 Track Detection and Segmentation

CR39 nuclear track detectors are widely used in neutron dosimetry, where accurate identification and counting of etched tracks is essential for reliable dose estimation. Manual analysis is time-consuming and prone to human bias, motivating the development of automated methods. However, this task is challenging due to the presence of dirt, defects, and mechanical damage that resemble tracks, as well as overlapping tracks at high radiation doses.

Recent approaches use deep learning models, such as Faster R-CNN and Mask R-CNN, to detect and count tracks. Although current methods enable automation, they often struggle in high-density areas where tracks overlap and rarely distinguish between different particle types.

In this project, we explore multiple approaches to automated track analysis. As a baseline, we implement classical computer vision techniques, including adaptive thresholding and morphological processing. These methods exploit the geometric properties of tracks, but they are sensitive to noise and may miss irregular track shapes. Despite these limitations, they are used to generate initial annotations for training more advanced models.

We also investigate YOLO-based models that incorporate physical information about track size and geometry and compare it with a Mask R-CNN-based approach.

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AGH Solar Boat

Perception System for an Autonomous Surface Vessel: Vision-Based Object Detection and Point Cloud Clustering Algorithms

In recent years, autonomous control systems have gained increasing popularity. They provide a more cost-effective and efficient way for autonomus surface vessels perform specific tasks. Recently, autonomous technology has also found applications in aquatic environments, where it can be used for environmental research, transportation, and military operations.

A key aspect of the detection system is identifying objects on the water that may affect the vessel's trajectory. This system relies on a camera and a LiDAR sensor. Such a combination of sensors allows for the collection of sufficient data to ensure safe control of the boat. Object detection is performed using the YOLO neural network, whose training process, hyperparameter selection, and architecture have been optimized for efficient operation in an autonomous boat system. The system also analyzes point clouds from the LiDAR sensor using clustering algorithms. Two approaches were compared: Euclidean clustering and DBSCAN. Both data sources are combined through a sensor fusion process, which minimizes detection errors and provides reliable information about the vessel's surroundings. Accurate spatial data about object positions enables the design and implementation of optimal algorithms for safe path planning and collision avoidance.

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KN mHealth SpaceMed

How much data is enough? Abstention-Aware Menstrual Cycle Inference from Wearable Sensors

Wearable devices for menstrual cycle monitoring must determine when sufficient data have been accumulated for reliable phase prediction. Existing approaches rely on fixed minimum-data rules that ignore individual variation in signal quality and cycle regularity.
We propose an evidence sufficiency framework based on conformal prediction generating a three-valued decision: predict, defer, or request more data. We analysed the mcPHASES dataset (n = 42); the primary endpoint was a binary hormone-anchored cycle phase relative to the urinary LH surge. The sufficiency point was defined as the earliest moment the prediction set collapsed to a singleton for at least two consecutive observation windows. The approach was compared against six reference strategies using nested leave-one-subject-out cross-validation.
The sufficiency threshold varies substantially across participants. The covariate-conditional model reduces the median number of required nights while maintaining controlled error rates. Replacing fixed data-window rules with an uncertainty-aware framework incorporating explicit abstention yields safer inference, with practical implications for user onboarding and regulatory defensibility of reproductive health classification systems.

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AGH Solar Boat

Enhancing Autonomous Surface Vehicle Pose Estimation with Deep Learning for Vision-Based Odometry

This paper investigates the enhancement of vision-based odometry for Autonomous Surface Vehicles (ASVs) by integrating deep learning methodologies. The primary objective was to evaluate and compare the performance of a classical computer vision algorithm - ORB (Oriented FAST and Rotated BRIEF) against a deep learning-based framework, SuperPoint, for trajectory estimation. The study utilized three distinct datasets: the standard KITTI benchmark for automotive scenarios, a synthetic maritime dataset generated via Gazebo simulation, and real-world experimental data collected by the "Barka" Autonomous Surface Vehicle.

The experiments consisted of a two-step comparison: first, between the baseline methods, and second, by fine-tuning the SuperPoint network on domain-specific maritime images, in order to evaluate the influence of fine-tuning the model on the pose estimation of specific datasets. Results on the KITTI benchmark showed that the deep learning approach clearly outperformed the classical one. In maritime scenes, the pretrained SuperPoint model revealed better local tracking stability compared to ORB. However, fine-tuning the model for marine environments revealed a trade-off. While the model effectively learned to filter out unstable water keypoints in favor of static shoreline features, the reduced distinctiveness of the descriptors ultimately led to higher trajectory errors than the pretrained baseline.

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AGH Racing

Camera-LiDAR-based track detection for autonomous racing

This work presents a lightweight perception pipeline based on integration of LiDAR and camera sensors for cone detection and classification. LiDAR is used as a reliable source of 3D cone positions, while the camera provides color information, enabling a complementary fusion of geometric and visual data to detect track boundaries.

A key component of the system is accurate sensor calibration. Camera intrinsic parameters and LiDAR-camera extrinsic transformation are calculated for our experimental setup, enabling projection of 3D points onto the image plane for direct association of image regions and LiDAR-detected cones on the track.

For color classification, we adopt a simple, non-learning-based approach using threshold-based color masks. To improve robustness to illumination changes, the pipeline incorporates transformation to the HSV color space and a color correction method based on a Macbeth ColorChecker, reducing color variability across different lighting conditions.

Experimental results demonstrate that the proposed system achieves reliable cone classification under moderate conditions while maintaining very low computational cost, significantly outperforming a YOLO neural network baseline in terms of runtime. However, limitations remain under challenging lighting scenarios.

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KN Synaptica

Virtual Reality in the Treatment of Male Sexual Disorders

This project explores the use of virtual reality (VR) environments in the treatment of sexual disorders in men. Sexual disorders can significantly affect mental health and overall quality of life. While existing therapeutic approaches are often limited by low adaptability and difficulties in providing safe, controlled exposure, VR offers immersive and customizable environments that can help overcome these limitations. The project focuses on recreating therapeutic scenarios using modern technologies, particularly the Unity engine, to improve immersion, flexibility, and clinical applicability. It builds upon foundational studies conducted by Gabriel Optale, between 1997 and 2003, which demonstrated the potential of VR-based interventions in psychotherapeutic contexts, though their implementation was constrained by small sample sizes and outdated hardware. This study aims to replicate and extend these early approaches using contemporary tools. The research design includes a pilot phase to assess user immersion and potential cybersickness, followed by a controlled study comparing psychotherapy supported by VR with standard therapeutic methods. The primary objective is to improve the quality and effectiveness of treatment through the integration of advanced VR technology with clinical psychology, fostering more engaging, controlled, and personalized therapeutic environments.

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KN Energetyków "Caloria"

Assessment of fuel properties of solid products produced in the process of hydrothermal carbonization of sewage sludge.

The amount of sewage sludge is steadily increasing due to population growth and the expansion of wastewater treatment systems, making its management for energy recovery an important research issue. The presence of heavy metals limits its direct use in agriculture; therefore, thermal processing is considered a promising solution. Hydrothermal carbonization (HTC) enables the conversion of wet biomass under elevated temperature and pressure without prior drying. Its solid products, known as hydrochars, exhibit improved physicochemical properties compared to the raw material, including higher energy density, increased calorific value, and greater hydrophobicity, which facilitates dewatering and reduces waste volume. The properties of hydrochars depend largely on the type of biomass, including sewage sludge. The aim of this study is to investigate the fuel properties of HTC-derived hydrochars produced at 200°C, 210°C, and 220°C with a reaction time of 2 hours. The research includes both quantitative and qualitative analyses, covering parameters such as calorific value, moisture content, sulfur, oxygen, volatile matter, and ash. The study also aims to compare the results obtained at different temperatures and evaluate the potential of HTC as a technology for energy recovery from sewage sludge.

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KN Green Energy

Analysis of the possibilities of using renewable energy sources in single-family houses

This paper presents an analysis of the possibilities of utilizing renewable energy sources in single-family buildings under Polish conditions. In particular, it examines the current energy market situation, the potential of renewable energy resources in Poland, and various programs involving subsidies, grants, and tax relief. Furthermore, the paper provides a synthetic overview of solutions enabling the use of renewable energy in residential housing. Two identical buildings with different methods of providing thermal and electrical energy were analysed. The study emphasizes the necessity of conducting a comprehensive analysis of economic, energetic, and social aspects when planning investments in renewable energy sources installations. Additionally, particular attention was paid to the need for a comprehensive modernization of buildings to increase energy efficiency before planning any investments in renewable energy sources.

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KN Nabla

Optimization and Additive Manufacturing of a Honeycomb Structure for a Wind Tunnel

This paper presents the optimization and manufacturing of a honeycomb flow straightener dedicated to a closed-circuit wind tunnel. The primary focus is placed on the optimization of key geometric parameters, such as cell diameter, channel length, and wall thickness, in order to achieve high flow uniformity and stability while minimizing pressure losses. The optimization process was carried out using CAD modeling and CFD simulations, allowing for the evaluation of multiple design variants and their impact on flow characteristics. The final geometry was tailored to the specific operating conditions of the wind tunnel and manufactured using additive technologies. In parallel, the wind tunnel was constructed, providing the target environment for the developed structure.

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KN Green Energy

Analysis of Selecting the Optimal Heating System for a Specific Single-Family Building

This paper presents an analysis regarding the selection of an appropriate heating system for a specific single-family house. The study outlines the procedure for selecting the aforementioned system, taking into account fundamental building data, its location, climate zone, and current Polish and EU regulations in this field. In the conducted analysis, particular emphasis is placed on the preliminary adaptation of the building's energy efficiency to accommodate the installation of a specific heating system. Additionally, the paper highlights various approaches to thermal modernization, considering legal, socio-economic, and environmental factors.

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KN Green Energy

The Use of Artificial Intelligence in the Development of MOF Structures for Next-Generation Energy Storage Systems

The development of high-performance energy storage systems is currently hindered by the physical limitations of traditional adsorbent materials. Metal-organic frameworks (MOFs) offer a promising solution due to their tunable porosity; however, the vast number of potential combinations of metals and linkers makes it impossible to discover new solutions manually. This paper discusses the applications of a "virtual laboratory" that uses high-throughput virtual screening (HTVS) and graph neural networks (GNNs) to navigate molecular network spaces. By treating crystal structures as mathematical graphs, artificial intelligence models allow for rapid prediction of physicochemical parameters at minimal computational cost. Understanding how this "reverse design" approach identifies the best materials for improving energy density can effectively shorten the research and development cycle.

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KN Nova Energia

Analysis of the performance of the piston expander and the electric power generator assembly and the method for operating point regulation

The paper describes the operation of an energy storage installation based on compressed air and a piston expander coupled with an electric power generator under various supply pressure conditions and load current values. It analyzes the proposed control method in terms of its effectiveness and the impact of load variation on system performance. The study also examines the operation of the installation itself, the achieved power output, efficiency, and the dependence of these quantities on other parameters. The results indicate that the system efficiency ranges from 4% to 12%, depending on the operating point, with useful electrical power on the order of several tens of watts. Individual stages of the energy conversion process are analyzed. Among them, the largest relative losses are observed in the mechanical components of the installation. These losses increase dynamically with rotational speed. The calculated performance indices demonstrate increasing power output and efficiency with rising load. However, an increase in load also results in a slower energy supply to the system, which limits the positive effect of this correlation by constraining the maximum achievable power.

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KN GEOWIERT

Geochemistry and distribution of trace elements and rare earth elements in lakes affected by acid mine drainage in the Muskau Arch

Pit lakes within the Muskau Arch constitute one of the largest complexes in Central and Eastern Europe affected by acid mine drainage (AMD), which developed as a consequence of historical mining activities involving the extraction of lignite, ceramic clays, sands, and gravels. The present study focuses on the geochemistry of trace elements (TEs) and rare earth elements (REEs) in the waters of five selected lakes, three of which are meromictic. These water bodies exhibit substantial variability in pH and differing degrees of neutralization. Water samples were collected along vertical profiles and analyzed using ICP-QQQ-MS. Significant variability in TE and REE concentrations was observed, primarily controlled by pH, redox conditions, and water stratification, as confirmed by principal component analysis. Furthermore, the application of the trace metal toxicity load (TMTL) approach indicates that Al, Mn, Zn, Co, Ba, and Ni should be prioritized in planned remediation efforts due to their highest toxicological significance in the studied waters. REE concentrations ranged from 0.15 to 149.3 μg/L. All lakes were characterized by enrichment in LREE and a weaker enrichment in MREE relative to HREE. Positive Gd anomalies were identified in all lakes, while positive Eu anomalies occurred in all except Lake Africa, which is the most strongly affected by AMD.

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KN Energetyków "Caloria"

3D Printing in Wind Energy – How Surface Quality Affects Turbine Blades?

The presentation will focus on the possibilities of prototyping wind turbine blades at a laboratory scale using 3D printing technology. Particular emphasis will be placed on analyzing the impact of the manufacturing method on the surface quality of the blades. Differences resulting from process parameters, such as print orientation and surface finishing methods, will be discussed. Experimental results will also be presented to determine the extent to which surface condition influences aerodynamic properties and measurement accuracy. The aim of the presentation is to evaluate the applicability of 3D printing in laboratory research and to identify the limitations of this technology in the context of prototyping new designs and manufacturing existing wind turbine blade profiles.

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KN Energetyków "Caloria"

TEG generators – present and future

The paper presents a review of scientific literature on TEG (thermoelectric generator) modules, with particular emphasis on their operating principle based on the Seebeck effect. The study discusses the main application areas of these modules, such as waste heat recovery in industry, automotive engineering, and power generation. It also analyzes the factors affecting the performance of TEG modules, including the properties of thermoelectric materials and operating conditions of the systems.
The author synthesizes the results of available experimental and simulation studies, pointing out current technological limitations. The conclusions highlight the development potential of TEG modules and the need for further research aimed at improving their efficiency and economic viability.

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KN FENEC

The effect of climatic conditions on drone battery performance

Batteries used to power electric drones must provide sufficient energy to sustain flight under various climatic conditions. This presentation will present the results of tests on a lithium-polymer battery consisting of a pack of six cells connected in series with a rated capacity of 10Ah, conducted under controlled conditions of constant temperature and humidity simulated in a climate chamber. The presented measurement results will indicate the effect of the battery's operating temperature on its voltage characteristics and the relationship between the battery's capacity and its operating temperature. These tests aim to determine, based on known battery parameters and climatic conditions, the performance of a battery designed for a drone, which in turn translates into the duration and efficiency of the drone's flight. Additionally, the results of drone tests with the battery under study during flight will be presented to verify how the laboratory test results translate into the actual performance of the battery operating under real-world microclimate conditions outside the laboratory.

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KN FENEC

Recovery and Use of Waste Heat from Fuel Cell Stacks for Temperature Control of Hydrogen Tanks in Submarines

A concept of waste heat recovery from a hydrogen-fueled PEM fuel cell stack, supplied with hydrogen from a metal hydride storage tank, is proposed for application in submarine power systems. During hydrogen desorption from the storage tank, a temperature drop occurs, which adversely affects the amount of hydrogen that can be released. The waste heat recovered from the cooling system is utilized to heat and stabilize the operating temperature of the metal hydride tank, thereby increasing the amount of hydrogen released and extending the operating time of the power system.
A thermal balance analysis of the system is conducted, taking into account the operating parameters of the fuel cell and the properties of hydrogen storage materials. Particular attention is given to the impact of recovered heat on the stabilization of tank temperature under variable load conditions. The results indicate that integrating the fuel cell stack cooling system with the tank heating system effectively reduces temperature drops during hydrogen desorption and improves the operational stability of the submarine power system.
The proposed approach is applicable to systems requiring high reliability and precise control of operating conditions, such as underwater vehicles.

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KN mHealth SpaceMed

NaIon Batteries in Stratospheric Environments - Modeling Low Temperatures and Usage Profiles

The demand for energy storage in cold and extreme environments is growing. High-altitude sensing applications, in particular, require reliable, environmentally friendly solutions operating across −40 °C to +40 °C.
Lithium-Ion Batteries (LIBs) are currently the dominant technology for this purpose. An emerging alternative, commercial Sodium-Ion Batteries (SIBs), offers comparable safety but with significantly lower toxicity and emissions. In addition, they allow for independence from rare earth metals, which strengthens the sovereignty of energy storage solutions and is a strategic advantage. However, their utility at low temperatures remains limited by sluggish Na^+ diffusion in electrodes and increased electrolyte viscosity accompanied by a drop in ionic conductivity.
Capturing these challenges requires models that account for the interplay of transport, kinetic, interfacial, and thermodynamic effects. This paper presents the challenges of modelling SIBs at low temperatures and the use of Bayesian methods to parameterise physics-based models, with a particular focus on the Single Particle Model. Bayesian parameter inference offers a systematic way to integrate diverse models with experimental data, quantify uncertainty, and identify which low-temperature mechanisms dominate under different conditions.

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KN Cipher

Application of Machine Learning for Dynamic Management of Firewall Rules

Creating and maintaining firewall rules is a complex and time-consuming task for a network administrator. It requires continuous analysis of logs and incidents in network traffic, as well as designing new rules in a way that does not disrupt system operation or cause an excessive number of false alarms.

Since 2025, there has been growing interest in applying Reinforcement Learning algorithms to automate firewall rule management. The proposed approaches focus on improving threat detection effectiveness and reducing false alarms; however, available publications often omit implementation details.

The aim of this thesis is to develop a system supporting the automatic creation of firewall rules based on the analysis of network traffic and system logs. The system processes network connection data - IP addresses, ports, protocols, and event frequency - in order to identify unwanted traffic. Based on the collected data, the algorithm makes decisions on classifying traffic as potentially malicious or safe, and then automatically generates and applies appropriate rules for the iptables firewall. This process runs continuously, enabling dynamic adaptation of the security policy to the changing environment.

The result of the work will be a demonstrative system serving as a foundation for further research into more advanced automation methods, including those utilizing Reinforcement Learning algorithms.

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KN Cipher

Application of blockchain technology in vehicle data storage systems

Data provided by CARFAX (2026) and carVertical (2023-2024) indicates that the used car market is susceptible to manipulation regarding mileage, damage history, and overall vehicle history. The growing importance of vehicle history verification makes access to reliable data increasingly critical, yet existing systems rely primarily on centralized databases, which creates a risk of data tampering.

The aim of the project is to verify the feasibility of using blockchain technology as an alternative to traditional solutions. A prototype system based on an open-source blockchain platform will be designed and implemented, enabling the decentralized recording of vehicle data - including mileage, ownership changes, damage, repairs, technical inspections, and insurance details. Smart contracts will be used to record events as blockchain transactions, with data access provided through an application interface.

Unlike existing solutions, which typically focus on mileage or repair history, the proposed system will enable comprehensive data collection comparable in scope to CARFAX or carVertical reports. Data integrity will be ensured through cryptographic mechanisms, although it should be emphasized that blockchain guarantees the immutability of recorded data without eliminating the issue of initial data credibility.

The proposed solution is expected to increase the level of trust in vehicle history data and may serve as an alternative to centralized systems.

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KN Zero Day

Scan-tastic or Scam-tastic? Overtrusting QR Codes

The rapid growth in the popularity of QR codes in public and digital spaces has increased their usability while simultaneously creating new threats to information security and personal data protection. This presentation discusses the results of a study assessing users' awareness of risks related to QR code usage. The study was conducted as a controlled phishing experiment simulating a training offer and a contest. The analysis focuses on QR code scans, form submissions, and the scope and correctness of the data provided along with the likely psychological causes of the observed behaviors.

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KN Telephoners

Image Compression using Image-GS in SAR – Assessment

In the recent years, neural image representation took the world by storm, offering novel approaches to encoding visual data. When integrated with learning-based approaches, they allow for previously unreachable fidelity/memory footprint balance.

In this paper, a context-aware image compression implementation based on "Image-GS: Content-Adaptive Image Representation via 2D Gaussians" paper is proposed. Data compressed with Image-GS retains a high degree of fine details in complex images while producing minimal artifacts. It utilises a technique similar to that in Gaussian Splatting - it reconstructs images by adaptively allocating and progressively optimising a group of anisotropic, 2D Gaussians, with the density of Gaussians directly corresponding to the level of detail in image region.

Feasibility of applying this approach to Search and Rescue operations conducted by Unmanned Aerial Vehicles is assessed, in scenarios where it is a necessity to reliably transfer high-resolution camera images over sparse, wireless media. Image-GS model is deployed on a server, its reliability when paired with human detection YOLO model is tested with different parameters. Should the results be promising, the algorithm will be used in AGH Rescue Drone project. The paper demonstrates an approach novel by itself, applied to a field where it has not been tried before.

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KN Cipher

The impact of compression and the choice of machine learning model on the size and performance of network traffic classifiers in Tiny Machine Learning systems

The aim of this research project is to analyse the impact of machine learning model compression techniques on the effectiveness of cyberattack detection in resource-constrained edge nodes (e.g. the ESP32 microcontroller). The research will be conducted in a Python environment using the ToN_IoT dataset, omitting resource-intensive Deep Packet Inspection in favour of lightweight analysis of headers and traffic statistics.

Three approaches will be evaluated: a Multilayer Perceptron, a One-Dimensional Convolutional Neural Network for analysing sequential patterns (e.g. Distributed Denial of Service), and the Categorical Boosting algorithm. Analysis of its variants will highlight the problem of rapid memory consumption in embedded systems. Key work will include model reduction through post-training quantisation and pruning.

The effectiveness assessment will be two-pronged: qualitative (Accuracy, F1-Score) and hardware-related (model size, number of parameters, RAM usage). The expected outcome is a set of performance metrics confirming the feasibility of deploying advanced security systems on Internet of Things (IoT) devices using minimal resources.

The project is distinguished by the evaluation of models against the hard limits of the ESP32. Despite profiling on a workstation, aggressive quantisation and pruning are intended to show the feasibility of effective TinyML systems. This research is intended to address hardware constraints and high memory costs in mass IoT production.

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KN Telephoners

Rescue Drone: optimization of detection and preparation for data prioritization (QoS)

The project is an extension of the Rescue Drone initiative carried out by the Telephoners Student Science Club, focusing on increasing the effectiveness of human detection and optimizing drone networks. The main goal of the work is to improve the detection model through a systematic comparison of hyperparameter tuning methods, such as grid search, random search, and Bayesian optimization. This allows for identifying the most effective configurations in terms of accuracy and computational efficiency.

A significant element of the project is the development of an autoencoder for automatic labeling of video frames containing people. This solution will streamline the data selection process and allow for the introduction of QoS (Quality of Service) metrics, inspired by traffic prioritization mechanisms in Wi-Fi standards, e.g., IEEE 802.11e. It is planned to differentiate transmission priorities – assigning a higher priority to data with detected individuals (analogous to voice or video classes) will allow for better bandwidth utilization and faster transfer of key information.

The project results directly translate into improved operational range and reliability of drones in search and rescue scenarios. The integration of model optimization with intelligent visual data processing creates an autonomous and scalable rescue support system. To date, no studies have been found that combine both of these elements into a single coherent system.

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KN Telephoners

Intelligent focus and posture assistant based on edge ai technology - HEALTHY BUDDY

The goal of the project is to create an application supporting effective studying by monitoring concentration and ergonomics in real-time. The solution integrates productivity tools (Pomodoro timer, to-do list) with advanced vision analysis, creating an interactive environment for students.
Monitoring is provided by a vision system using a webcam, OpenCV, and MediaPipe. Calculations are performed locally (Edge AI), ensuring data privacy. The system analyzes gaze direction and posture, reacting to distractors (e.g., phone use) or slouching. The project integrates previously fragmented solutions into a coherent whole.
The assistant system consists of:
Detection and Classification Module (HAR): utilizes 3D key point estimation to detect posture deviations and physical objects (e.g., smartphones).
Performance Optimization Engine: uses adaptive framing and noise filtering (Kalman Filter/EMA) for smooth operation without excessive CPU load.
User Interface (UI): integrates a notepad with feedback loop logic that adjusts notification frequency to avoid Alert Fatigue.
The project includes spatial analysis algorithms for 2D-to-posture mapping and tests the effectiveness of various alerts on the speed of returning to deep focus. This solution fits the Affective Computing trend, reacting to the user's psychophysical state to improve well-being and learning performance.

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KN Telephoners

RL-Drive: Comparative Analysis of Reinforcement Learning Models in Vehicle Navigation

The goal of the project is to develop and compare two autonomous vehicle control systems within an original racing game featuring an isometric perspective. The conducted study analyzes the effectiveness of Deep Reinforcement Learning agents based on two types of input data: video frames and physical parameters. Two models were trained:

Vision Model (CNN): makes decisions based on a raw pixel matrix, simulating driver perception.

Parametric Model (State-based): operates on a vector of physical features, such as (x, y) coordinates, velocity vector, heading angle, and distance to track edges and checkpoints.

The systems learn the optimal racing line by maximizing a reward function. The scope of the research tasks includes: analyzing sample efficiency, measuring control precision (lap time, smoothness), and testing the system's robustness against obstacles.

The project verifies whether visual perception can compete with precise mathematical data. Literature analysis suggests that visual input promotes generalization, while parametric data offers higher precision and learning speed. This study confronts visual intuition with the raw accuracy of coordinate-based data.

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KN Telephoners

Analysis of Firepower Threat Defense system effectiveness against advanced evasion techniques

The project aims to evaluate the effectiveness of the Firepower Threat Defense system, which integrates Next-Generation Firewall with Intrusion Detection and Prevention Systems. For demonstration purposes, a LAN topology connected to an edge router leading to a WAN will be configured and deployed within the Cisco Modeling Labs environment. Additionally, Firewall Management Center for FTD administration and Identity Services Engine as a network access control server will be implemented. The infrastructure will be subjected to network attacks across layers 3 to 7. Using the Scapy library, custom scripts generating malicious traffic will verify the robustness of deployed security policies and anti-intrusion mechanisms. The research focuses heavily on testing the Snort 3 engine against complex attack vectors and traffic obfuscation techniques. Evasion methods will include TCP overlapping, Time-To-Live manipulation, packet fragmentation, encoding evasion, and asynchronous slow-rate attacks. While numerous scientific papers over the years have explored the operation of next-generation firewalls and scanners, none have focused on FTD and its unified feature set. The project is directed at security engineers and infrastructure security vendors. It intends to expose vulnerabilities in existing security systems like FTD and highlight areas requiring refinement.

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Koło Naukowe Przetwarzania Sygnałów "Spectrum"

Evaluation of Small Language Models as Linux Terminal Emulator in the Context of SSH Honeypot

In the era of rapid artificial intelligence development, language model-based technologies are increasingly applied in cybersecurity - as both offensive and defensive tools. This paper focuses on analyzing the potential of Small Language Models (SLMs) within Honeypot systems used for Cyber Threat Intelligence.

A selected group of lightweight models is evaluated before and after the fine-tuning process regarding their ability to accurately emulate the Linux command line. The study is based on System Prompts explicitly defining response criteria, structure, and constraints across four key metrics:
- persona adoption stability,
- censorship and refusal rates,
- structural formatting reliability,
- quality of generated fictional content (hallucination realism).

Chosen models include:
- meta-llama/Llama-3.1-8B-Instruct
- Qwen/Qwen2.5-7B-Instruct
- mistralai/Mistral-7B-Instruct-v0.3

To ensure statefulness during testing, a simulated file system was implemented in Python, allowing for context injection and dynamic environment persistence during the session.

The results were assessed using the LLM as a judge methodology on a 0-5 scale. The final score for each model represents an average of 100 iterations conducted across 5 automated test scenarios.

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KN Cipher

Framework for Evaluating Impact of Cryptography on Video and Audio Transmission Quality

The assessment of audio and video transmission quality is fundamental to performance evaluation of emerging telecommunications solutions. However, the escalating computational demands imposed by modern cryptographic algorithms can present a significant challenge to maintaining high-quality, low-latency transmissions.
Presented is a simple, open-source framework for quality analysis of video and voice transmissions. It is designed to assist in measuring the impact of implementing increasingly demanding solutions - such as cryptographic protocols - on various transmission parameters.
Current approaches, such as the latest ITU-T recommendation (POLQA) or X256-PVMAF, focus on analyzing parameters of received service. Commonly used metrics quantify the impact of network interference or the specific codecs employed. This project proposes an analytical scheme utilizing a reference signal - a full-reference approach - with an emphasis on examining the impact of encryption deployment on transmission quality. The evaluation is conducted based on transmission between two containers.
An exemplary quality analysis of widely used encryption techniques, performed using the proposed solution, is also presented.

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KN Cipher

Assessing QR phishing in an academic environment through job and internship advertisements

The project aims to examine the susceptibility of the academic community to selected social engineering techniques used in phishing campaigns and to assess how message format affects recipients' interaction with the prepared materials. The study will be conducted on university premises using posters designed as job and internship advertisements for students, placed in various campus buildings.
The experiment will compare two variants of materials: posters containing a QR code and posters containing a short text link. The analysis will cover the number of interactions with both forms of communication, as well as the impact of content presentation and the type of redirect medium on recipients' behaviour. The study will not involve collecting passwords, sensitive data, or any other information enabling the direct identification of participants.
The project is innovative because it combines the analysis of QR phishing with its assessment in a real academic environment, taking into account the context of job and internship advertisements. Its novelty also lies in comparing the effectiveness of two forms of communication - a QR code and a short text link. The project outcomes may be used in awareness campaigns, training materials, and best practices for recognizing social engineering attempts among students and university staff.

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KN Cipher

Development and Evaluation of an Attack Vector Against Digital Watermarks Using Deep Learning compared to Classical Methods

This project aims to develop and implement a new attack vector against digital watermarks using deep learning techniques. The core element of the work, constituting its main contribution to the field of multimedia security, is a novel model utilising a CNN (Convolutional Neural Network) architecture with reduced computational complexity, built upon a U-Net structure. The innovation of this approach lies in the development of a dedicated network training strategy, optimised for the elimination of steganographic security measures. The neural network is trained on sets of image pairs (the cover image and the watermarked image) in order to estimate and reconstruct the original pixel values in the modified areas. A key research aspect of the project is to conduct a systematic comparative analysis, contrasting the performance of the proposed model with classical signal distortion methods, which will allow for an objective quantification of the advantages of artificial intelligence algorithms in this application. The model uses a complex loss function, optimised to minimise image reconstruction error using the PSNR (Peak Signal-to-Noise Ratio) and SSIM (Structural Similarity Index Measure) metrics, whilst maximising the degree of distortion of the watermark's structure itself. The effectiveness of the attack is verified by measuring the BER (Bit Error Rate) for the signal extracted by the target detector.

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KN Telephoners

MFCC-based speech emotion recognition

Speech Emotion Recognition (Speech Emotion Recognition - SER) based on MFCC (Mel-Frequency Cepstral Coefficients) excels in controlled environments, but environmental noise degrades the spectral envelope. This study explores the impact of background noise on accuracy using the RAVDESS corpus. A Random Forest pipeline was trained on clean audio and tested against versions with white Gaussian noise at various SNRs. The project yields a per-class robustness profile. The hypothesis suggests that low-energy emotions (sadness, neutral) degrade faster than high-energy ones (anger, fear) as their spectral patterns overlap more easily with the noise floor.

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KN Telephoners

Adaptive workplace lighting system utilizing machine learning techniques to reduce eye fatigue

The project's goal is to create an intelligent lighting system for the dynamic optimization of office work conditions. The system uses a camera to monitor the user and microcomputer to control the color of an LED strip. A real-time vision algorithm calculates the Eye Aspect Ratio (EAR) based on 6 eyelid landmarks to detect blinking. A Support Vector Machine (SVM) classifier analyzes EAR patterns in time windows to detect fatigue. In response, the system automatically corrects light intensity and color.

The scientific aspect involves studying the impact of automatic lighting changes on physiological parameters. It is based on the literature-proven body response to light (90-180 lux), manifested by melatonin inhibition and a reduction in slow eye movements (SEMS). The system verifies this relationship by measuring vision-based fatigue equivalents: the PERCLOS parameter and blinking frequency, thus counteracting Computer Vision Syndrome.

Compared to existing literature, the project stands out by creating a closed-loop feedback system. Previous studies mainly analyzed passive exposure to constant light, and EAR systems served primarily as driver alarms. This solution autonomously adjusts the lighting to the user's biometric state without their intervention. Tests will be conducted at a laboratory workstation.

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KN Telephoners

Investigating the "sim-to-real gap" in AI vision systems

The project aims to analyze the impact of synthetic data generation parameters for vision systems and compare the robustness of different artificial intelligence architectures against the "Sim-to-Real gap". The test environment will consist of ABS plastic LEGO minifigures, which, due to their reflective material and complex geometry, constitute a demanding research subject that significantly disrupts the performance of detection algorithms.
The experiment uses the variable isolation method. First, synthetic training images will be generated from 3D models. The training process for detection models, representing classical YOLO (You Only Look Once) convolutional neural networks and RT-DETR (Real-Time Detection Transformer) architectures, will be performed in several variants. Individual disruptive factors, such as background, lighting, or digital sensor noise, will be added to the simulation. The effectiveness of the models will be tested on real photographs using the mean average precision metric.
The core of the project is to conduct an ablation study and analyze the decision-making process of the algorithms. Instead of merely testing the overall effectiveness of the networks, the experiment breaks down their learning process into fundamental components. Incorrect predictions will be verified with Explainable AI tools by generating Grad-CAM (Gradient-weighted Class Activation Mapping) activation maps, to verify whether the networks lose the physical edges of the objects.

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KN Telephoners

Driver safety monitoring system

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DRIVER SAFETY MONITORING SYSTEM
The aim of this project is to develop and implement a real-time driver monitoring system that goes beyond standard, monolithic solutions. The key innovation lies in its multimodal approach, which integrates visual analysis with behavioral and acoustic diagnostics.
The solution is based on a modern distributed architecture. Time-critical reactions are processed locally, while the most complex calculations and deep analytics are performed in the cloud, ensuring optimal performance and scalability.
Key Diagnostic Modules:
• Authorization Verification and Age Estimation – Automatic detection of underage drivers using the Deep Expectation model, fine-tuned on the UTKFace dataset
• Fatigue Detection – The system monitors fatigue levels through facial landmark analysis. This module utilizes the MediaPipe Face Mesh model.
• Object Classification and Prohibited Actions – A module designed to detect distractions (e.g., phone usage) powered by the YOLOv8 Nano model.
• Sobriety Analysis – Advanced assessment of ocular micro-movements, fixation stability, and nystagmus. It employs the GazeML model for precise pupil localization and an SVM classifier for the final evaluation of the driver's state.
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KN Cipher

Implementation, Analysis, and Comparison of Post-Quantum Password-Authenticated Key Exchange Algorithms

Password-authenticated key exchange protocols with low-entropy passwords are used when a public-key infrastructure is not available, e.g. in the WPA3-Personal protocol. The development of this class of protocols in the post-quantum context is still in its early stages, with only theoretical proposals available in the scientific literature. Performance testing is currently limited due to the lack of implementations, which prevents the assessment of the feasibility of certain attacks in real network environments. Furthermore, the authors of some proposed protocols do not demonstrate clear advantages over previous post-quantum solutions in this category and remain uncertain regarding potential gains or losses when it comes to algorithm execution time.

The primary objective of this project is the implementation of the NICE-PAKE and TEMPO algorithms, along with their RKEM-augmented variants (NICE-PAKE:RE and TEMPO:RE), which utilize the standardized post-quantum algorithm ML-KEM in their schemes. Subsequently, a comparative performance analysis will be conducted, including the examination of the feasibility of the literature-described timing attack on the NICE-PAKE protocol, verification of TEMPO resistance to this attack under appropriate assumptions, and assessment of the benefits of integrating RKEM into these algorithms. Performance will be evaluated by measuring the execution time of the library's isolated code, without integration with other software or dedicated hardware.

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KN Creative

Capital flows and blockchain forensics in decentralized prediction markets as a source of early warning in the era of disinformation

The paper examines decentralized prediction markets as platforms where participants stake real capital on the outcomes of geopolitical and political events, treating them as a potential intelligence tool. Drawing on blockchain data from documented cases of insider trading from the 2025–2026 period, the authors demonstrate that profits are extremely concentrated, pointing to the dominance of informationally advantaged actors rather than the collective wisdom of the crowd. Insider trading on geopolitical contracts proves empirically detectable through the analysis of volume anomalies and on-chain traces.
The paper warns, however, of the other side of this mechanism: the same tools can be exploited by state actors to monetize classified information or deliberately spread disinformation. The authors propose an anomaly detection analytical framework and advocate for its integration into national early warning systems. More broadly, they argue that Europe's dependence on analytical infrastructure outside its jurisdiction constitutes a structural vulnerability, and that regulated national prediction markets with mandatory identity verification could provide a valuable complementary signal for national security decision-making.

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KN Telephoners

Benchmark for autonomous agents in detecting and repairing failures within distributed microservice systems

Modern microservice systems are highly complex, leading to unpredictable failures. This paper proposes a comprehensive testing environment (benchmark) to evaluate autonomous agents capable of diagnosing and remediating such incidents.

The key research contribution is an evaluation platform for agent mechanisms, with a particular focus on the Dual-Layer Memory architecture. The benchmark verifies how effectively agents combine external documentation (e.g., runbooks) with the memory of previous repair attempts, learning from experience without the need to retrain the model.

Agents are tested in a closed reasoning loop: they analyze logs, metrics, and request traces to formulate hypotheses and autonomously execute corrective actions (e.g., scaling, restarting). Experimental scenarios are based on intentionally injected, complex faults that go beyond standard operational knowledge.

The environment is built on a local Minikube cluster. Effectiveness is measured by four metrics: system health restoration, mean time to repair (MTTR), number of attempts to success, and the side-effect rate on unrelated services.

The proposed approach addresses a gap in the literature: the lack of unified environments for testing the cross-session memory of agents in microservice architectures. The MicroRemed system serves as the baseline for this benchmark.

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KN Telephoners

"More social, less media" - The Student Campus App

The project aims to develop a mobile social application for Android, targeted at the AGH Student Campus community. The platform's main objective is to facilitate the initiation, management, and participation in social and cultural events on campus, fostering student integration. The application enables the creation of public or private events. A key element of the system is an interactive map visualizing available activities in real time. Through filtering and sorting mechanisms, the solution streamlines the coordination of meetings in the crowded campus space. Users can interact via a comment system, expressions of interest, and invitations, as well as personalize their profiles based on academic affiliation. From an engineering perspective, the system is implemented in a client-server architecture using the Flask (Python) and React Native (JavaScript) frameworks. The design process adheres to OWASP security standards and ensures full GDPR compliance. The software acts as a digital catalyst - its goal is not to maximize screen time, but to stimulate users to leave the virtual space. The project is a proactive response to the problem of digital isolation, encouraging direct interactions and the building of authentic relationships in the real world.

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Koło Naukowe Konstruktorów MechaniCAD

Implementation of an Integrated Module for Precise Vehicle Positioning Using Differential GNSS Systems, Inertial Navigation and Odometry

This paper presents the design and implementation of a low-cost, integrated navigation system for Hydrive 1, an ultralight hydrogen-powered vehicle competing in the Shell Eco-marathon. The developed module utilizes data fusion in a loosely coupled architecture, integrating measurements from a satellite receiver (GNSS-RTK), an inertial measurement unit (IMU), and odometry. The core of the computational system is a Linear Kalman Filter, which estimates inertial sensor errors based on reference differential positioning data. To minimize navigation drift, algorithms utilizing non-holonomic constraints and vehicle zero-speed updates were implemented. An experimental analysis conducted on a surrogate platform in a dynamic test demonstrated that the system achieves a root mean square error (RMSE) of 1.36 m for trajectory estimation when RTK corrections are available. Measurements of simulated satellite signal loss demonstrated the algorithm's ability to maintain dead reckoning navigation with an average error of 4.11 m over a 10-second window. The solution surpasses autonomous GNSS receivers in stability, compensating for satellite signal losses.

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KN Cipher

Simulation and routing in quantum key distribution network

In recent years, significant progress has been made in the implementation of quantum key distribution networks. Projects such as the Quantum Key Distribution Network (QKDN) Germany-Poland-Czechia, co-developed by NASK, demonstrate that this technology is gaining increasing importance. Consequently, there is a growing demand for tools supporting research contributing to the development of functionalities for such networks. Our solution is a tool that enables advanced simulations of quantum links and the overall operation of the network. The proposed simulator is tailored for research purposes - it features an advanced module for collecting and formatting data from network traffic. The collected data allows for further analysis and research on modern solutions in the field of QKDN operation, which may find application in real-world implementations of such infrastructure. Our research using the simulator focuses on the deployment of advanced routing mechanisms that take into account various metrics that can be specified in the management of QKDN traffic, as well as on evaluating their performance, thereby expanding the current state of knowledge.

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KN Telephoners

The Impact of Thermal Contrast on the Effectiveness of Human Detection in UAV Systems Using the YOLOv8 Model

This paper addresses the reliability of ML-based object detection systems under varying thermal characteristics of the environment. The primary research objective is to determine the critical contrast threshold between an object and its background at which the YOLOv8 model loses the ability to correctly classify a person in images acquired from an Unmanned Aerial Vehicle (UAV).
The research methodology is based on the HIT-UAV dataset, from which thermal signatures of "person" class objects were extracted. For each sample, the Weber contrast was calculated according to the formula K = |Iobj - Ibg| / Ibg, where Iobj represents the object pixel intensity and Ibg represents the background intensity. The test set was divided into groups based on the level of thermal difficulty (low, medium, and high contrast), followed by a separate validation of the YOLOv8 model for each group.
The results allow for the determination of a strict correlation between the physical image parameter delta T and performance metrics such as mAP (mean Average Precision) and Recall. The conducted analyses help identify the boundary conditions (the relationship between body temperature and ambient temperature) under which machine learning systems used in rescue operations become unreliable. The conclusions of this work may serve as a vital guide for selecting thermal imaging sensors for specific drone missions, minimizing the risk of error in critical search and rescue operations.

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KN Telephoners

Roller skater movement analysis using machine learning algorithms and sensor fusion

The paper presents a project of an original measurement system based on the ESP32 microcontroller and an IMU (Inertial Measurement Unit), designed for real-time analysis of inline skating dynamics. The main objective of the work is to investigate the effectiveness of motion pattern classification algorithms characteristic of freestyle slalom, with particular emphasis on the problem of inertial sensor drift in a high-vibration environment.
As part of the project, a low-cost sensory module mounted on the skate boot was developed. The research part focuses on the implementation of digital filters (Madgwick and Kalman) for the purpose of sensor fusion of accelerometer and gyroscope data. A key scientific aspect is the development of a methodology for compensating cumulative error (drift) and eliminating mechanical noise resulting from wheel-to-ground interaction, which is essential for precise estimation of the module's spatial orientation.
A significant element of the work is the process of building an original dataset. Data labeling is performed via remote event triggers sent by the operator during the execution of figures, allowing for precise signal segmentation in the time domain. To recognize the figures, deep neural networks with a hybrid architecture were used: Convolutional Neural Networks (CNN) for extracting morphological features of the signal and Long Short-Term Memory (LSTM) recurrent networks for modeling the temporal dynamics of the skater's movements.

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KN Cipher

Quantum Starry Night - Using Entangled Quantum States to Generate Julia Set Fractals

This paper presents an original method for generating fractals using quantum computation. A 2-qubit quantum circuit consisting of a Bell state and a randomized unitary U gate is simulated using the Qiskit Aer statevector simulator. The complex amplitudes of the resulting statevector are transformed into a single complex number via ratio-based operations — this number serves as the parameter c in the Julia set iteration formula ($z \to z^2 + c$). Each program run yields a unique fractal due to randomly sampled quantum gate angles. The visualization references Van Gogh's "Starry Night" through a custom blue-yellow colormap and compositing with the original painting. The project demonstrates an intersection of quantum mechanics and generative computer art.

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KN Telephoners

Project Shepard-Low-cost XR headset

The project proposes the development of the low-cost XR headset using accessible hardware components in order to investigate the differences between low-cost XR headset and a commercial VR device such as Meta quest 2. In addition to the headset prototype, haptic controllers will be constructed. The proposed system will be able to render an interactive interface and launch a simple game prepared in a real-time graphics engine. This study will focus on evaluating key performance metrics such as end-to-end latency, frame rate stability and stereo configurations. Furthermore, a user study will be conducted to asses how these technical parameters will influence their experience. The project aims to contribute to a better understanding of design constraints in low-cost XR systems and their implications for future accessible VR technologies.

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AGH Skylink

Long range free-space infrared laser ethernet system

Radio bands are approaching the limits of their data transmission capacity. In telecommunications, there is growing interest in solutions based on free-space optical communication. AGH Skylink has developed an optical data transmission system operating in the 900 nm band, capable of transmitting at speeds of 10 Mb/s. The system, referred to as a laser transceiver, operates under the Ethernet standard and replaces a conventional cable connection with a laser link. The optical assembly consists of two compact telescopes and filters operating in the 900 nm band. A 10BASE-T signal drives a laser diode with a continuous output power of 200 mW. The signal received by an identical device reaches a sensitive InGaAs photodiode, then passes through a receiving path equipped with optical filters and an amplifier with automatic gain control (AGC), before being restored as a 10BASE-T signal. The system functions as a media converter, requiring no additional microprocessor-based control. It is applicable in infrastructure where the use of radio links is impossible or does not provide a sufficient level of security. Intercepting the transmission would only be possible through direct optical observation of the line connecting the devices. The solution has significant commercialization potential. Among those expressing a need for this type of system is the ISRO HOPE Habitat in the Himalayas, located 13 km from the mission control center.

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AGH Eko-Energia

Design and Optimization of Front Headlights Construction for the PERŁA Solar Car

The paper presents the process of designing and constructing front headlights for the PERŁA solar car developed by the AGH Eko-Energia Student Research Group for participation in solar vehicle competitions. The main objective of the project was to develop a solution that meets regulatory requirements while maintaining low weight, ease of manufacturing, and reduced production costs. Particular emphasis was placed on designing the headlight structure to enable easy assembly, servicing, and adaptation of the construction to future competitions with changing technical requirements.

The study discusses the selection of structural materials and manufacturing technologies, including the use of 3D printing in resin-based additive manufacturing as an alternative to costly casting methods. Optical phenomena occurring within the headlight, such as light refraction and scattering, were analyzed, along with issues related to heat generation and dissipation from light sources. Design solutions limiting the fogging of the headlight lens were also presented, ensuring tightness and reliable operation under varying environmental conditions.

The result of the project is a lightweight and functional headlight design tailored to the specific requirements of a solar vehicle and enabling rapid adaptation to future changes in competition regulations.

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AGH Drone Engineering

Thermodynamic analysis of operational measurements of a miniature turbojet engine

The study presents a thermodynamic analysis of operational measurements of a miniature turbojet engine, focused on performance parameters under various load conditions. The collected data provide insight into the state parameters prevailing in individual sections of the engine, which translate into its performance and service life. The aim of the study was to determine the engine's characteristics and to identify optimal operating conditions for its application in an unmanned aerial vehicle. The measurement results indicate that miniature turbojet engines, despite their small size, exhibit complex thermodynamic relationships similar to those of full-scale units. The obtained results may serve as a basis for further design improvements and for enhancing the operational efficiency of this type of propulsion system, particularly in model aviation and unmanned aerial systems.

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AGH Eko-Energia

Door Opening and Closing System in the Lightweight Solar Vehicle "PERŁA"

The paper concerns a system for opening and closing doors in a lightweight solar vehicle with a composite body "PERŁA". At the beginning, the “PERŁA” project will be briefly presented. In the introductory part, solutions used in conventional vehicles will be presented, constituting a reference point for the developed project. Subsequently, the design assumptions and constraints resulting, among others, from the specificity of the vehicle structure, competition regulations, and the applied manufacturing methods will be discussed. In the following part, the process of designing the key elements of the system will be presented. These include the external handle, internal handle, locking mechanism, and a cable system responsible for transmitting motion between individual components. The principle of operation of the system and the integration of its components will be presented. The justification for the adopted design solutions will also be presented. Structural and technological problems encountered during the design and manufacturing stages will also be discussed, together with the solutions applied. The paper will conclude with a presentation of the manufactured components and the results of preliminary functional tests of the system.

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AGH ECOnstruction

Investigation into the feasibility of electrifying a classic motorcycle: a case study of the WSK 125

Global ecological trends and the gradual departure from fossil fuels are driving the rapid electrification of transport. However, despite their growing popularity, the prices of factory-made electric vehicles still exceed the financial capabilities of many people. This paper investigates the possibility of electrifying a 125 cm^3-class motorcycle using the WSK 125 as an example.

It examines whether an older motorcycle design is suitable for converting the drive system from internal combustion to electric, under the assumption that the motorcycle, like the original version, will meet the requirements for operation under an A1 or B driving licence. The focus is placed on minimizing interference with the vehicle's appearance so that it can retain its classic design. The performed calculations and selection of appropriate components enabled an assessment of the validity of the proposed conversion.

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AGH Solar Boat

Delta Solar Racing Boat Quadrant Design and Analysis

This paper presents the design of a steering quadrant for the Delta solar boat, developed within the AGH Solar Boat Team. The main objective was to create a solution ensuring high reliability and optimal load transfer under operating conditions. The proposed system features a proprietary cable tensioning mechanism, enabling precise adjustment and stable operation of the steering system. A strength analysis was conducted, taking into account the torque generated by the drive motor, which allowed for the selection of an appropriate number and diameter of structural pins. Additionally, numerical simulations were performed to evaluate the influence of the cables and the pushrod on the quadrant, including stress and deformation distribution. Based on these results, the optimal cable arrangement was determined to minimize overload risk and improve overall system efficiency. The obtained results confirm the validity of the adopted design assumptions and indicate the potential applicability of the proposed solution in lightweight autonomous and solar-powered vessels.

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AGH ECOnstruction

Analysis of the dynamic properties of a WSK motorcycle after electric drive conversion.

In light of the progressive electrification of the automotive sector and increasingly stringent carbon footprint regulations, the future operation of internal combustion engine (ICE) vehicles has become a critical issue. This paper focuses on investigating the feasibility and impact of converting an internal combustion engine to an electric drive, using a motorcycle as a case study.

Particular attention is given to the dynamic analysis of the vehicle, encompassing parameters such as acceleration, top speed, and motion stability. As part of the methodology, computer simulations of the new powertrain were conducted and compared with empirical data obtained from road tests of the original WSK motorcycle. A comparison of the traction characteristics of both drives enabled a reliable assessment of the feasibility and efficiency of the implemented modernization.

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AGH Eko-Energia

AGH
EKO-ENERGIA

Positioner for the precise joining of solar cells.

First, the problem of manually joining solar cells to maintain constant spacing between them will be presented. Next, methods for achieving such high precision during soldering will be discussed, along with examples of solutions used in the industry. The main part of the presentation will introduce the design of a positioner intended to facilitate the connection of the cells. Its construction will ensure uniform, precisely measured distances between the cells. Additionally, problems encountered during the later stages of designing and manufacturing the positioner will be outlined, alongside simple and practical ways to solve them. Finally, the completed positioner will be showcased, and its practical operation will be demonstrated using an example of connected cells.

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AGH Solar Boat

How to build a "flying" boat - Applying computational fluid dynamics during the design of the hydrofoil boat Delta

The significance of Computational Fluid Dynamics (CFD) during the design process of a hydrofoil boat will be explained. Boat parts undergo simulations separately and in an assembly, which allows for the fine-tuning of individual parts, as well as examining the interactions of turbulent flows between the parts. One of the most important results of these simulations is the net lift force, which tells us whether the boat's hull will raise out of the water at the expected velocity. Setups and results of simulations will be showcased.

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AGH Marines

Optimization of an ROV Tether Management System.

This paper presents the iterative design and optimization process of a tether management system for a Remotely Operated underwater Vehicle (ROV). The primary challenge was to design a reliable retraction mechanism that compensates for cable length variations in an aquatic environment while maintaining signal continuity via a slipring. Initially, the project explored multi-stage reduction gearboxes, including planetary systems, manufactured using 3D printing combined with CNC-machined stainless steel and aluminum shafts.However, detailed kinematic and structural analysis—including the reduction of the overestimated tension force from 150 N to an optimal 20 N—revealed that complex gear systems introduce unnecessary failure risks and friction. Consequently, the design evolved towards a Direct Drive approach utilizing heavy-duty, flat spiral power springs capable of performing dozens of working rotations. The paper discusses the technological challenges of designing shaft-hub connections while accounting for FDM 3D printing tolerances. Furthermore, it analyzes a pragmatic approach to Rapid Prototyping through the adaptation of Commercial Off-The-Shelf (COTS) components. The result is an optimized, hybrid mechanism capable of withstanding harsh operational conditions.

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Koło Naukowe MechaBajt

KN MechaBajt

Intelligent System for Acoustic Field Parameter Synthesis

The creation of an acoustic field distribution is a fundamental aspect of sound engineering, where the function of a facility—such as a philharmonic hall, conference room, or auditorium—strictly determines design requirements. In order to improve the process of shaping acoustic field distributions, the aim of this thesis was to design and implement a hybrid information system for the automatic control of sound source settings according to defined criteria. The developed tool selects sound source parameters in such a way as to achieve the desired values of acoustic field indicators.
The core of the system is a proprietary application written in the C++ language. In its initial phase, it uses a Genetic algorithm, which through crossover and mutation operations selects sound source parameters such as power and time delays. The application operates in cooperation with Raynoise, which calculates acoustic field distributions. The collected data are stored in a database.
The designed system uses both a forward and inverse model to determine acoustic field indicators and sound source parameters according to the adopted quality criterion. As part of the work, a bounded space model was prepared, an algorithm was developed, and a computer program operating in the Microsoft Windows environment was implemented. The final stage of the work consisted of verification tests confirming the correctness of the system's operation.

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KN MechaBajt

Design and Construction of a Vertical Take-Off and Landing Aircraft Model

The aim of this thesis was to design, build, and test a functional VTOL aircraft platform combining the features of a multirotor and a fixed-wing aircraft. The scope of the work included the development of a physical structural model, selection and integration of electronic components such as servomechanisms, propulsion motors, electronic speed controllers, a radio communication control system, and a flight controller with its control system. Additionally, a hybrid flight mode was configured, enabling hovering, transition phase, and forward flight.
The platform model was manufactured using 3D printing technology, using a specialized PLA-LW filament, characterized by reduced density resulting from the foaming process during printing, which provided a favorable strength-to-weight ratio. The material, combined with carbon fiber reinforcement elements, enabled the creation of a lightweight structure while maintaining the required stiffness of load-bearing components.
As part of the work, ground tests and flight trials were conducted to verify platform stability, correct operation of the control system, and smooth transitions between flight modes. The obtained results allowed for an assessment of the effectiveness of the designed structure and the identification of potential directions for further system development.

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KN MechaBajt

Intelligent System for Generating and Recognizing Signs of the Polish Sign Language

The aim of this thesis was to design, implement, and carry out verification tests of an intelligent system for generating and recognizing signs of Polish Sign Language (PJM), using a sensory glove and image analysis. The system was developed as an autonomous solution, employing a sensory glove and image analysis for wireless data acquisition and conversion into text form.
The work was carried out in stages including problem analysis, design, implementation, and experimental verification. As part of the implementation phase, a prototype glove equipped with finger bend sensors and an Inertial Measurement Unit (IMU) was developed, enabling the recording of hand orientation in space. In parallel, an image acquisition setup using a vision camera was prepared, and software responsible for synchronizing and processing the data streams was developed.
The system was built using a Raspberry Pi 5 as the central processing unit and an ESP32 microcontroller with a Bluetooth Low Energy interface for transmitting sensory data. The data processing and sign recognition algorithms were implemented in the Raspberry Pi OS environment, and the analysis process was based on machine learning methods, including neural networks. The applied approach enabled the automatic differentiation of static and dynamic signs based on the motion trajectory of the hand over time. The conducted tests confirmed the effectiveness of the developed system.

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KN MechaBajt

Analysis of the Properties of a Snowboard Model Used in Alpine Snowboarding

The application of advanced numerical methods in engineering, including the Finite Element Method (FEM), enables precise equipment optimization and verification of its behavior under operational loads, without the need to manufacture numerous costly physical prototypes.
The aim of this thesis was to develop a numerical model and analyze the mechanical properties of a snowboard used in competitive alpine snowboarding. The work included a literature review on riding techniques and biomechanics, which made it possible to identify the actual position of the athlete during descent. Based on this, boundary conditions and the most unfavorable load cases acting on the snowboard were defined.
The next stage involved reproducing the geometric characteristics of the snowboard based on available CAD models. Numerical simulations and model discretization were carried out in the MSC Marc Mentat environment. A key element of the work was the definition of an appropriate material model that considered the composite structure of the snowboard (a sandwich-type construction with orthotropic properties), selected on the basis of literature data. Static analyses were then performed for selected loading scenarios using the developed model. In the longer term, this model was prepared as a comparative basis for the analysis of systems with additional components, such as reinforcement plates.

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KN MechaBajt

Intelligent Pathfinding System in a Graph

Modern IT systems frequently use algorithms based on graph analysis. Graph structures are applied in many fields of science, ranging from robotics and navigation to data analysis. A key issue in these areas is the pathfinding problem, which involves finding the optimal route between selected points in a graph while taking specific conditions into account. The research object in this study is the road network map of the Kraków metropolitan area. The aim of this thesis is to design, implement, and carry out verification tests of an intelligent graph pathfinding system. The scope of the work includes an analytical and critical study of search system solutions, the characterization of selected issues in graph theory, the description of selected artificial intelligence methods and techniques, and the development of the graph structure and the system algorithm. The developed system was initially implemented in the MATLAB environment and subsequently in the C++ language, where both classical and artificial intelligence algorithms were implemented. The work applied, among others, Dijkstra's algorithm, the ant colony algorithm, the swarm algorithm, and the heuristic A* search algorithm. The developed and implemented system is characterized by a dynamic capability of determining routes according to various criteria, such as minimum distance, minimum travel time, and air pollution levels.

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KN MechaBajt

Koło Naukowe
MechaBajt

Numerical Analysis of the Mechanical Strength of an Electrical Power Product Subjected to Electric Arc Exposure

The aim of this thesis was to develop and validate a numerical model enabling the simulation of the impact of an electric arc—treated as an explosive phenomenon—on the structural components of an electrical power product, with particular emphasis on their mechanical response.
During the research stage, simplified models based on classical equations of state were compared with the Jones–Wilkins–Lee equation of state explosive model. It was demonstrated that the simplified models allow only a qualitative description of gas interactions under conditions of low energy levels and slower pressure variations. In the case of rapid energy release, high pressure gradients, and short-duration phenomena, these models proved insufficient, which justified the use of the JWL model.
The main part of the work involved developing a numerical model in the Abaqus environment using the Coupled Eulerian–Lagrangian method (CEL) approach, enabling coupled modeling of post-explosion gases and the structural elements of the analyzed electrical power device. The electric arc phenomenon was approximated by applying the explosion model of TNT described by the JWL equation of state, treated as the energy equivalent of the electric arc.
Based on the obtained results, the suitability of the proposed approach for engineering analysis of the mechanical strength of electrical power devices was evaluated. The thesis was carried out in cooperation with ABB.

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Koło Naukowe MechaBajt

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KN MechaBajt

Intelligent vehicle identification system

Digital image processing and analysis constitute the foundation of modern monitoring and traffic control systems. The application of artificial intelligence methods enables effective extraction of information from visual data, which is essential in areas such as access control systems, automated toll collection, and intelligent transportation systems. The process of vehicle identification requires the use of advanced algorithms capable of precise object detection and classification under varying lighting and weather conditions.
The aim of this thesis is to design, implement, and conduct verification tests of an intelligent vehicle identification system. Based on field studies and the collected research material, the system architecture and the assumptions for the control algorithm were developed, taking into account the specifics of recognizing moving objects and determining their speed. In the practical part, the proposed solution was implemented in software. The developed system algorithm was implemented in the C++ programming language, based on the use of multilayer and convolutional neural networks, which currently represent the leading technology in the field of image recognition. The final stage of the work consisted of verification tests, which made it possible to evaluate the correctness of the implemented system and confirm its effectiveness in the process of identifying passenger cars, trucks, vans, buses, and motorcycles.

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AGH Eko-Energia

Design, fabrication, and testing of a flexible steering rod seal for the PERŁA solar car

This project presents the design and fabrication process of a flexible seal for the steering rod in the PERŁA solar car. The presentation begins by introducing the specific design challenges and comparing them to standard automotive industry solutions. Subsequently, the development of prototypes using two different methods is discussed: direct 3D printing with TPU and silicone casting within 3D-printed molds. Furthermore, the technical challenges encountered throughout the development process will be addressed. A dedicated crank-slider testing rig, used to simulate the seal's dynamic operation, is also showcased. Finally, both technologies are compared based on performance metrics. The presentation concludes with test results that led to the selection of the optimal seal version for final vehicle integration.

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KN MechaBajt

Portable Mechanical Vibration Meter Integrated with the IoT Cloud

The aim of this thesis is to develop a portable device enabling the measurement and basic analysis of vibrations in rotating machinery, integrated with a cloud-based system within the Internet of Things (IoT) architecture. The proposed solution includes a complete measurement chain consisting of a vibration sensor, a signal acquisition and preliminary processing module, a communication layer, and a user application.
The device uses the AVS1001HF high-frequency vibration acceleration sensor, which enables signal acquisition over a wide frequency range, including high-frequency components used in the early diagnosis of bearing and rotating element faults. The measurement data are preprocessed at the device level, where basic signal analysis is performed along with the determination of selected diagnostic estimators such as acceleration RMS, VRMS for measurements compliant with ISO standards, and peak-to-peak (P-P) values. The recorded data are then transmitted to the cloud system via a communication interface, where they can be archived, further analyzed, and visualized. The developed system constitutes an application-oriented diagnostic solution that combines portable vibration measurement with IoT infrastructure, enabling further expansion with trend analysis and predictive maintenance functions.

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KN MechaBajt

Research on the Potential Use of Jute Fiber in Composite Materials

The aim of the project was to investigate the possibility of reusing this type of fibers in composite technologies and to preliminarily develop a repeatable processing method.
As part of the work, an analysis was conducted on the influence of material preparation on the quality of the resulting composite, with particular emphasis on the drying process and issues related to fiber moisture content. The behavior of jute bags dried at different temperatures was examined, observing their shrinkage, deformation, and the formation of wrinkles. In parallel, a flat mold was designed and prepared based on an aluminum plate, protected with layers of PVA release agent, enabling the resin infusion process.
In subsequent stages, composite infusion trials were carried out, analyzing the impact of material irregularities and moisture content on the quality of the final structure. The presence of voids and local defects was observed, which significantly limit process repeatability and prevent reliable mechanical testing. In response to the identified issues, additional material preparation methods were tested, such as dry pressing and vacuum conditioning of the fiber prior to infusion.
The project is currently at the stage of process optimization. Further work will include achieving production repeatability, conducting mechanical tests, and developing spatial (3D) structures.

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KN Mechaników

Condition monitoring system simulation as a game in Unreal Engine 5

Condition monitoring system simulation as a game in Unreal Engine 5 focuses on analyzing user decision-making processes in the context of designing fault detection systems for rotating machinery within an artificial simulation environment. Acquiring data in real-world conditions is challenging due to the unique nature of each installation, environmental factors, geographical dispersion of wind turbines, and data confidentiality concerns. Additionally, field studies are costly and time-consuming.

To address these challenges, a computer game was proposed as a research tool. Developed in Unreal Engine 5, the simulation allows users to assume the role of maintenance engineers in the wind energy sector and make decisions regarding condition monitoring systems (CMS), which are then analyzed.

The thesis includes descriptions of wind turbine structure and operation, as well as elements of energy economics that form the foundation of gameplay. It presents the architecture of the simulation environment, core gameplay mechanics, and an analysis of player strategies and their outcomes. Potential future developments, including enhanced immersion and system optimization, are also discussed. The proposed solution serves as an effective research tool and a valuable educational resource.

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Koło Naukowe AGH New-Tech

SSR-Sematic Space Reconstruction

The presented project involves developing a 3D reconstruction and semantic analysis system to support the creation of digital representations of the environment for autonomous mobile systems. The system integrates data from various sources, including the ZED 2i stereo vision camera and a 360° camera, enabling the capture of both geometric and contextual information. Images, depth data, and camera positions are processed and used to reconstruct the space using methods such as 3D Gaussian Splatting, TSDF fusion, and marching cubes.

A significant element of the project is the extension of 3D reconstruction with a semantic layer. Segmentation and semantic description are performed before the model is created, allowing for the labeling and classification of objects and their association with the appropriate parts of the 3D space. This allows not only the representation of geometry but also the assignment of interpretive meaning, crucial for decision-making systems.

This work analyzes various algorithm variants, including approaches based on segmented Gaussian Splatting and data fusion within a TSDF framework. The result is a 3D model that can be visualized, analyzed, and used in simulations. The goal of the work is to assess whether integrating geometric reconstruction with semantic information improves the model's usability over classical methods.

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KN Mechaników

Design and development of a MotoStudent-class electric racing motorcycle

The project presents a racing electric motorcycle designed and built for the MotoStudent International Competition VIII, held at the MotorLand Aragón. It was developed as an interdisciplinary student initiative aimed at creating a safe, regulation-compliant prototype capable of competitive track performance.

Key components, including the fairings and subframe, were manufactured from carbon fiber, ensuring high strength at low weight. The motorcycle is equipped with a telemetry system that collects data such as speed and temperatures, available both to the rider in real time and for post-run analysis by the team.

The vehicle successfully passed both static and dynamic scrutineering and was approved for track use. In October 2025, it competed as part of the Polish representation, reaching a top speed of 186 km/h. The motorcycle demonstrates good balance, stability, and full compliance with competition requirements, reflecting effective teamwork and the practical application of engineering knowledge.

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SKN KINEMATICS

Conceptual design of a composite bucket seat for a buggy-type vehicle

The aim of this paper is to design a composite seat for a buggy participating in the Baja SAE competition, optimized in terms of geometry, costs, and compliance with regulatory requirements. Proven solutions from professional motorsport, which served as inspiration for the project, will be presented. The geometry was developed from scratch, taking into account regulatory requirements to ensure driver safety and ergonomics. Due to the nature of the loads occurring during operation, a comparative material analysis was conducted in this study. It justifies the selection of a polyester-glass laminate as a safer, more flexible, and more affordable alternative to carbon fiber or Kevlar. The work is supplemented by a cost estimate and the selection of the required quantities and types of materials. The culmination of the project is a custom CAD model, serving as the foundation for the physical construction of the prototype. The manufacturing process was planned so that most of the work required for the fabrication of the seat is feasible in "garage" conditions without specialized equipment, demonstrating the accessibility and cost-effectiveness of the chosen composite technology.

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AGH Racing

Design, CFD analysis and thermal performance parametric optimization of a Formula Student electric motor cooling jacket.

Development of electric drive systems and their control algorithms in Formula Student (FS) electric racing cars necessitates the development of increasingly efficient solutions for cooling traction system components. A particular challenge are the cooling components of the motors mounted in the wheel hubs, which due to their share in unsprung mass, require rigorous mass optimization.

The subject of this presentation is the design and optimization of a cooling jacket for an electric motor in a FS class racing car. As part of this work, parameterized surface models were created and optimized using computational fluid dynamics (CFD). To ensure the independence of research results from domain discretization, computational mesh convergence study was conducted using the Grid Convergence Index (GCI).

The analyses enabled the identification of key parameters affecting the heat exchanger's thermal efficiency and the development of a final component adapted to the technological requirements of 3D metal printing (SLM). The results indicate a 16°C reduction in the maximum motor temperature while achieving a 30% weight reduction compared to the previous solution.

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KN Synaptica

Machine learning and Neural Networks in biomimetic mechatronic prosthesis

In recent years, due to the increase in ongoing conflicts, it has become apparent that limb loss has become an important challenge to conquer in the fields of engineering and medicine. In response to these needs, it is essential to develop innovative biomimetic prostheses (prostheses that aim to fully emulate the biological original—in this case, the hand), replicating not only mechanical functions but also the control methods characteristic of human limbs.

The aim of this project is to utilize neural network systems for the real-time control of biomimetic prostheses. In the proposed approach, neural networks will be trained based on data fusion: visual models of actual hand positions will be cross-referenced with readings from bioelectric sensors (EMG). This solution is designed to establish a correlation between muscle activity and specific gestures.

The project involves optimizing the motion mapping process through the use of feature extraction and latency reduction algorithms. Combined with the implementation of independent motors for each degree of freedom, this allows for the smooth and precise control of a mechatronic hand model based solely on bioelectric data. A prosthesis constructed in this manner should increase the chances of restoring functional ability to amputees due to its high precision and reduced production costs.

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Section Metal Engineering

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KN Hexagon

Analysis of the mechanical and structural behavior of AZ31 magnesium alloy under ambient and cryogenic conditions

Magnesium, owing to its low density (approx. 1.7 g/cm^3), high specific strength, good vibration damping capacity, and relatively high stiffness, is widely used in, among others, the automotive and aerospace industries. Among magnesium alloys, the AZ31 alloy (Mg–3Al–1Zn) is of particular importance and has been the subject of numerous scientific studies. The properties of this alloy are strongly dependent on processing conditions and service temperature, which justifies the need for detailed investigation. The present study focuses on evaluating the effect of extrusion temperature on the microstructure and mechanical properties of the AZ31 alloy, both at room temperature and under cryogenic conditions. Structural characterization was performed using scanning electron microscopy (SEM), EBSD analysis, and X-ray diffraction (XRD), enabling the determination of grain size, crystallographic texture, and phase identification. These investigations were complemented by mechanical testing, including tensile and compression tests, as well as strain rate sensitivity analysis, allowing for the identification of the dominant deformation mechanisms. The obtained results enabled a comprehensive assessment of the differences between materials extruded at various temperatures, as well as the determination of relationships between microstructure and mechanical properties of the AZ31 alloy under different temperature conditions.

Research supervisor of the paper:
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KN Hexagon

Analysis of the effect of solution and ageing heat treatment on the microstructure and mechanical properties of WE43 magnesium alloy

To meet the specific requirements of modern industry, especially in the automotive and aerospace sectors, which aim to reduce the weight of products, it is necessary to use modern metal alloys with suitable properties. Magnesium alloys, characterized by low density combined with relatively high strength, are particularly attractive. One of the modern magnesium alloys is WE43, which contains rare earth elements (REE) as alloying additions. Magnesium alloys with REE show an increase in strength during ageing, which is related to the decomposition of a supersaturated solid solution. The addition of element from the lanthanide group, such as neodymium and praseodymium, improve the strength of the alloy and shorten the ageing time needed to reach maximum strength. This work attempts to increase the strength (hardness) of the WE43 alloy by using heat treatment in the form of precipitation hardening. This process involves solution treatment and ageing at two different temperatures for different periods of time. The study included hardness measurements, supported by microstructure observations using SEM, EBSD and STEM microscopy, as well as phase analysis. This allowed for a structural and phase characterization of the material. Based on the obtained results, the effectiveness and efficiency of the precipitation hardening process of the WE43 alloy were evaluated.

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KN Hexagon

The influence of retrogressive aging parameters on the mechanical properties and microstructure of the Al7010 alloy

Aluminium is one of the most versatile engineering materials. Alloys from the 7xxx series, are particularly known for their high strength and are widely applied in aerospace and automotive industries. Service conditions in these sectors often require both high strenght and good corrosion resistance. Conventional heat treatment of the Al7010 alloy to the T6 temper provides excellent mechanical properties, but with limited corrosion resistance. In contrast, the T7 temper ensures high corrosion resistance at the expense of strength. This creates a significant challenge in selecting appropriate processing parameters, as it is difficult to simultaneously achieve both desired properties. A potential solution to this dilemma is advanced heat treatment involving pre-aging, retrogression, and re-aging (RRA - Retrogression and Re-Aging). The present study aims to determine the effect of temperaturę and time of the retrogressive aging, on the mechanical properties and microstructure of the 7010 alloy. The influence of heat treatment conditions was evaluated using hardness measurements and microstructural analysis employing SEM, STEM, EBSD, and HRSTEM techniques. Additionally, calorimetric studies were carried out to analyze changes occurring in the supersaturated material. For comparison purposes, the 7010 alloy was also subjected to conventional solution treatment and aging, leading to the peak hardness condition (T6) as well as a state after prolonged annealing.

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KN Creative

Theoretical and experimental analysis of the influence of aluminum heat sink inserts on the performance characteristics of a PLA drone frame.

The subject of this study is an analysis of the effectiveness of using aluminum heat sink inserts in the construction of a 7-inch drone frame, manufactured from poly(lactic acid) (PLA) using 3D printing technology. The primary research problem focuses on the low thermal resistance of PLA, which in standard applications leads to structural degradation of the frame due to heat generated by brushless motors.

As part of this work, an original CAD model of the frame was designed, featuring 1 mm thick aluminum sheet inserts integrated at the motor mounting points. A series of numerical analyses were conducted using the Finite Element Method (FEM) in the SolidWorks environment to investigate temperature distribution and thermo-mechanical stress within the motor-arm joint.

The research was complemented by experimental verification, including flight tests of the prototype. The results of both theoretical and experimental studies confirmed that the use of aluminum inserts not only significantly improves structural stiffness but, most importantly, effectively dissipates heat, preventing the polymer from exceeding its glass transition temperature. It was demonstrated that this solution enables the use of low-cost and eco-friendly filaments (PLA) in the construction of high-performance and durable drone frames without the risk of thermal weakening.

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KN Hexagon

Influence of heat treatment conditions on selected properties of theAlCuBiPb Alloy

The study investigated the effect of heat treatment conditions on the AlCuBiPb alloy (aluminum series 2011), focusing on the process known as precipitation hardening. The samples underwent solution heat treatment for 1 hour at 520°C, quenching in water, and aging for durations ranging from 0.5 to 192 hours at two temperatures: 160°C and 185°C. Following the heat treatment process, various tests were conducted, including Vickers hardness testing, electrical conductivity measurement, and SEM analysis. The highest hardness was achieved by the sample aged for 25 hours at 160°C, reaching 140.50 HV2. In contrast, the highest electrical conductivity was observed in the sample aged at 185°C for 192 hours, with a conductivity of 26.20 MS/m.

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KN Hexagon

Characterization of the Mechanical and Structural Behavior of Technically Pure Titanium at Room and Cryogenic Temperatures

Titanium, due to its advantageous properties such as high specific strength, excellent corrosion resistance, and good ductility, is widely used in many branches of industry. Therefore, it is important to understand its behavior under varying temperature conditions, including cryogenic environments. This study focuses on the characterization of the mechanical and structural properties of commercially pure titanium at room temperature (298 K) and at 78 K. Uniaxial tensile tests were performed to determine the key mechanical parameters, including yield strength, ultimate tensile strength, and elongation at failure, at both temperatures. The experiments were contucted at strain rates of 10-4s-1 and 10-5s-1, which also enabled the evaluation of the material's strain rate sensitivity. Microstructural analysis was carried out using scanning electron microscopy (SEM), allowing for detailed observation of structural changes occurring in the material depending on the deformation temperature. Fractographic studies were also performed to identify fracture mechanisms. Complementary analyses included X-ray diffraction and EBSD measurements, which provided information on the crystal structure and the distribution of crystallographic orientations of grains before and after plastic deformation.

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KN Metaloznawców AluminaTi

The effect of joining methods on the mechanical properties and microstructure of a fine-grained Al 6082 alloy produced by rapid solidification

Grain refinement methods are an effective way to improve the mechanical properties of aluminum, leading to increased strength and hardness. Despite extensive research on the production of fine-grained materials, the issue of joining them—particularly using various joining technologies—remains insufficiently understood.

The aim of this study was to compare the conventional TIG welding method with the modern friction stir welding (FSW) technology. The mechanical strength of the joints and their visual quality were analyzed, taking into account the influence of FSW process parameters and TIG welding conditions.

The tests were conducted on 6082 aluminum alloy obtained by rapid solidification, characterized by a fine-grained structure. Uniaxial tensile tests and hardness measurements were performed to evaluate the mechanical properties of the joints. Additionally, microstructural analysis was conducted using the EBSD (Electron Backscatter Diffraction) method. Based on
a visual assessment of the FSW process, samples were selected for detailed testing.

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KN InScience

Synthesis and investigation of the photocatalytic properties of In_2O_3 enriched with gold nanoparticles of various morphologies.

The project involves developing synthesis procedures for indium oxide (In_2O_3) composites enriched with gold nanoparticles of varied morphology (e.g., spherical, rod-shaped). The aim is to obtain materials with optimized photocatalytic properties, whose structure will be precisely controlled at the nanometer scale. It is expected that differences in the morphology of the gold nanoparticles will have a significant impact on the photocatalyst's performance.

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KN 3AXES

Influence of Copper Electroplating Parameters on Polymer Components Manufactured by Additive Technologies

The paper presents work focused on the selection of optimal conditions for the electrolytic deposition of copper from a copper-ion-containing electrolyte onto polymer components manufactured using additive technologies. The study involved the analysis of several samples with identical geometry, tested on an experimental setup consisting of a soluble copper anode, an electrolyte containing diluted sulfuric acid (VI) and copper(II) sulfate pentahydrate, a cathode in the form of an FDM-printed specimen coated with a conductive layer, a rectifier, and a system of copper wiring. The optimization of the process aims to determine current, time, and surface-related parameters that ensure the highest quality of the copper layer deposited on the cathode. The conducted research includes the adjustment of electrical conditions (appropriate current density), surface preparation prior to deposition, selection of electrolyte composition, and determination of the duration of the entire electroplating process.

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KN 3AXES

The Effect of Copper on the Properties of a Polyurethane Matrix Composite Manufactured by Selective Laser Sintering Technology

The paper presents the results of comprehensive material investigations of a polyurethane matrix composite reinforced with copper particles, manufactured using Selective Laser Sintering (SLS), including the development of process parameters. The conducted analyses enabled the determination of changes in compressive strength, hardness, wear resistance, impact strength, and density as a function of copper content in the material. Additionally, the biocidal properties of the composite were evaluated, and its microstructure was analyzed using scanning electron microscopy (SEM).

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KN 3AXES

Investigation of Metal Components Manufactured by 3D Printing Using FDM Technology, Including the Development of Post-Processing Parameters for Produced Parts

The paper presents the results of investigations on composite components manufactured by 3D printing using FDM/FFF technology with metal–polymer filaments containing powders of 17-4PH and 316L stainless steels. The aim of the study was to determine the influence of printing process parameters on the physical and mechanical properties of the produced parts.
In the experimental section, printing parameters were optimized, followed by a series of tests including density measurement using the Archimedes method, hardness testing by the Vickers method, surface roughness analysis, impact strength testing, as well as uniaxial tensile and compressive tests. The obtained results enabled an assessment of the effect of technological parameters on the mechanical properties, material structure, and surface quality of the components. A comparative analysis of composites based on 17-4PH and 316L steels revealed significant differences in their properties, resulting from their distinct material characteristics. The findings indicate that FDM/FFF technology using metal-filled filaments can be effectively applied to manufacture components with specific functional properties, provided that process parameters are appropriately selected. The final stage of the research involves further studies on the post-processing of the analyzed composites, aimed at obtaining a material with a possibly homogeneous, metallic structure comparable to that of fully metallic components.

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SKN AluminaTi

Evaluation of Titanium Grade 2 and Grade 5 for Use in Electronic Device Enclosures

Titanium and its alloys, due to their favorable strength-to-weight ratio and high corrosion resistance, are used in many branches of industry. In recent years, interest in their application in consumer electronics has increased, especially in the construction of device enclosures. The aim of this work is to compare the properties of Grade 2 titanium and the Grade 5 alloy (Ti-6Al-4V) in terms of their potential suitability for this application.

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SKN AluminaTi

Study of selected properties of the Ti–13Nb–13Zr alloy.

The aim of this study is to evaluate the influence of sintering temperature on the properties of the Ti–13Nb–13Zr alloy fabricated by the SPS method (spark plasma sintering). The samples were densified at three different temperatures. The study includes density and hardness measurements as the primary parameters describing the quality of the obtained material.

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KN InScience

Optimization of Rhodium Nanoparticle Synthesis in a Flow Microreactor for Catalytic Environmental Applications

The research focuses on identifying optimal conditions for producing nanometric rhodium (Rh) as a catalyst for environmental applications. Rhodium is one of the most important noble metals used in heterogeneous catalysis due to its exceptional activity in reduction and oxidation reactions. Achieving very small nanoparticle sizes is particularly crucial, as the increased surface area and the high number of low coordinated atoms significantly enhance catalytic performance. To this end, experiments were carried out to determine the parameters of the process conducted in a flow microreactor, taking into account the hydrolysis of Rh(III) ions in a water–organic solvent system. The obtained data enabled the determination of the complexation time and the optimal flow rate. As a result, Rh nanoparticles with an average diameter of approximately 3 nm were obtained, exhibiting catalytic activity in the model reaction of reducing toxic 4 nitrophenol to 4 aminophenol.

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Section Metal Forming and Modern Manufacturing Processes

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KN Promat

Simulation and Analysis of Radial Extrusion of Radiator Fin in a Steel–Copper System

The research focused on the radial extrusion process in a steel–copper bimetal system, combining finite element method (FEM) simulations in QForm UK with laboratory verification. The main objective was to assess the feasibility of forming a copper radiator fin on a steel core with a specified radius, without external or internal defects. Simulations were performed for various initial heights of the copper billet, which determined the final fin diameter, complemented by laboratory extrusion trials and microstructural analysis of the deformed samples. Results showed a clear correlation between billet height and fin diameter, enabling precise control of the heat exchange surface through appropriate selection of billet volume. Analysis of strain and stress distributions confirmed the ability to achieve the target fin geometry, while microstructural observations validated the proper bonding of copper to the steel core. The study demonstrated that radial extrusion is an effective method for producing bimetallic components while meeting technological and quality requirements.

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KN Promat

Numerical Analysis and Tool Material Selection in Isothermal Forging of a Titanium Alloy

The research focused on designing tools and dies for isothermal forging of a β-titanium alloy and conducting a detailed numerical analysis of the process using QForm software. Simulations included different tool materials, such as H11 and H13 tool steels, Inconel 718, and TZM alloy, enabling evaluation of their influence on forging behavior, temperature distribution, strain intensity, and stresses in both the workpiece and tools. Particular attention was given to die filling, uniformity of deformation, and the effect of tool temperature on process stability. The analyses allowed identification of the most wear-resistant materials suitable for isothermal forging conditions. Based on the results, recommendations were formulated regarding process parameter optimization, tool material selection, and ensuring high repeatability and workpiece quality. The findings provide a foundation for further improvement of titanium forging technology, including modeling multi-stage processes and predicting tool life under industrial conditions.

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KN Hefajstos

The quality of the joint zone in steel plates produced by hot forging processes

The aim of this study was to evaluate the quality of the joint zone in steel plates produced by hot forging using diffusion welding. As part of the project, bimetallic joints were made using two different steels with significantly different properties and chemical compositions. Material selection was dictated by the desire to obtain a layered material with potentially high toughness while maintaining good core ductility, as well as by analyzing the challenges associated with joining materials with different properties. The technological process involved surface preparation of the joined samples, their arrangement in a layered configuration, and heating to a temperature within the hot forging range. During heating, measures were taken to limit oxidation of the contact surface, a significant factor influencing the diffusion process and the quality of the resulting joint. Next, the forging process was carried out, during which high temperature and pressure intensified the diffusion processes, brought the atomic surfaces closer together, and eliminated discontinuities at the phase interface. The quality of the resulting joints was assessed based on microstructural analysis and mechanical property testing. The analysis included identifying the nature of the boundary between materials, the presence of any discontinuities, and assessing the nature of the diffusion zone.

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Koło naukowe metalurgii surówki i stali

Design and Additive Manufacturing of Complex Geometry Components Using Laser Powder Bed Fusion

Laser powder bed fusion (LPBF) enables production of complex geometry components, including thin-walled functional structures. For CuCr1Zr alloy, LPBF presents significant challenges due to high laser radiation reflectivity and high thermal conductivity of the material.
The aim was to design and manufacture thin-walled, complex geometry components from CuCr1Zr alloy via LPBF and evaluate their quality. The scope included geometric design and analysis of geometric, surface, and material properties of printed parts.
Geometric accuracy was assessed with particular focus on thin walls. Surface quality was evaluated through roughness parameter measurements. Microstructure was analyzed using optical and scanning electron microscopy, revealing characteristics typical of rapid melting and solidification, as well as LPBF-specific defects — pores and unsintered powder particles. Porosity analysis and hardness measurements were also conducted.
It was concluded that LPBF enables manufacturing of thin-walled CuCr1Zr components with complex geometries while maintaining dimensional stability and material properties. The results confirm the viability of LPBF for producing components from this alloy.

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KN Promat

Development of an Interactive Training Workstation for Programming and Operation of a Forging Robot

During the project, an interactive training workstation for learning industrial robot programming and operation was developed and implemented. The process included designing a physical mock-up, taking into account both its mechanical structure and control functionality, followed by the fabrication of infrastructure components using FDM 3D printing technology. After manufacturing, the workstation was assembled, including the integration of mock-up elements and the construction of a transport system in the form of a locomotive with wagons driven by an electric motor. In parallel, a control program for the industrial robot was developed, enabling loading and unloading operations as well as synchronization of the robot with the mock-up control system. The system was validated on a real robotic workstation to verify its proper operation. The obtained results confirmed the stability of the system and the correct integration of mechanical and control subsystems. Additionally, a training scenario was developed to support the use of the workstation in the educational process. The completed work resulted in a functional and interactive platform that can be used both for teaching purposes and for further research on the robotization of forging processes.

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KN Hefajstos

Technological challenges in the forging of large-scale components for the energy, oil and gas industries

This paper presents the challenges of plastic forming of large-scale components used in the energy, oil, and gas industries. The primary focus is on products manufactured from nickel-based superalloys of the Inconel group. Large-scale hot-forged elements constitute the foundation of industrial installations operating under the most demanding conditions. They must withstand temperatures ranging from 700–800°C, aggressive corrosive media, and high, often variable mechanical loads. Under such conditions, even minor technological deviations can lead to failure; therefore, these materials are expected to exhibit exceptional stability of mechanical properties, as well as resistance to corrosion, creep, thermal fatigue, and brittle fracture. The oil and gas sector utilizes nickel forgings for components exposed to extreme pressures, temperatures, and environments containing H2 and CO2. Nickel alloys are crucial for both downhole components (drill bits, cutters, tool joints, casing hangers, pump and drill pipe elements) and surface or offshore infrastructure (valves, pumps, connectors, heat exchangers, pipelines, and subsea connectors). They ensure the reliability of installations where failure-free operation determines the safety and efficiency of extraction. The research was funded under the TURBOgrant 2025 project titled: "INCO–ENERGY–FORM – Integrated analysis of robotic shaping of difficult-to-deform nickel alloy products for the energy, oil and gas sectors".

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KN Hefajstos

Design analysis of thermally assembled shrink-fit tooling dedicated for robotic manipulation

The objective of the conducted research was to develop geometric variants of tooling for the die forging process. The proposed technological concept incorporates the use of shrink-fit assembly tools, adapted for operation within an automated system utilizing a robotic arm. Numerical analyses performed in the QForm environment enabled the evaluation of material behavior during die cavity filling and the identification of potential discontinuities and defects resulting from unfavorable material flow. As part of the study, models of preforms and final forgings were developed and subsequently fabricated using 3D printing technology. These models were utilized to analyze the feasibility of employing a Kawasaki RS030N robotic arm for component transport between successive forging operations. The robot programming was conducted using the block teaching method, taking into account the hydraulic press workspace and the requirement for an ejector system for post-operational forging positioning. The research was funded by the National Centre for Research and Development (NCBR) under the LIDER13/0097/2022 project titled: "Innovative production technology of composite forging dies dedicated to large-scale forgings shaped in high-energy processes".

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KN Transpeed AGH

Process and material analysis in additive manufacturing of Zr-based metallic glasses

Additive manufacturing of zirconium-based metallic glasses is a promising technology that enables the production of materials with exceptional mechanical properties and high corrosion resistance. A key factor influencing the quality of the final product is the state of the feedstock material, particularly the properties of the powder obtained through the atomization process.

The objective of this work is to analyze the process and the material used in the additive manufacturing of Zr-based metallic glasses. Within the scope of the research, feedstock was prepared by casting rods intended for reference testing and the atomization process, respectively. Metallographic specimens were prepared from the resulting powder, and microstructural observations were conducted using light microscopy (LM) and scanning electron microscopy (SEM) for the castings, the powder, and the additively manufactured samples.

Structural studies using X-ray diffraction (XRD) to confirm the amorphous nature of the material, as well as oxygen content analysis in the castings and powder, are planned for the next stage of the work. The results obtained to date provide a basis for a preliminary analysis of the impact of these processes on the properties of the feedstock and the additively manufactured samples in the process of Zr-based metallic glass additive manufacturing.

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KN Creative

Investigation of the influence of the vision system parameters on the accuracy of automatic dimensioning of metallic components.

The aim of this thesis was to analyze the influence of camera properties and vision system configuration on the accuracy of dimensional measurement of forgings in low-cost image analysis systems. As part of the study, a measurement workstation based on the Raspberry Pi platform was designed and built, equipped with various types of cameras, interchangeable lenses, and configurable lighting sources. Image processing algorithms were developed using the OpenCV library to enable automatic determination of linear dimensions and curvature radii of the examined forgings. Camera calibration and optical distortion correction were taken into account in terms of their impact on measurement results. In the experimental part, a series of comparative tests was conducted to analyze the influence of camera type, lens focal length, lighting conditions, exposure parameters, and object position within the camera's field of view on the accuracy and repeatability of the results. The obtained results made it possible to identify the factors with the greatest impact on measurement precision the determination of optimal hardwareand software configurations. The research was carried out as part of a project co-financed by the National Centre for Research and Development under the LIDER XV Programme No. LIDER15/0183/2024.

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KN 3AXES

Design and Investigation of Loop Handles for Public Transport Vehicles with Antibacterical Properties Manufactured Using SLS Technology

The project focuses on the design and testing of loop handles for public transport vehicles with biocidal properties, manufactured using Selective Laser Sintering (SLS) technology. The aim of the study is to evaluate the feasibility of using a composite material under real operating conditions, taking into account both its mechanical performance and biocidal effectiveness. The research problem arises from the intensive use of handles in public transport and the associated risk of microbial growth on their surfaces. In the first stage, mechanical and fatigue tests will be conducted to assess the durability of the material and its suitability for application in public transport. In the next stage, the handles will be installed in vehicles, where changes in biocidal properties will be analyzed over time under real usage conditions. The expected outcome is to confirm both sufficient mechanical strength and the persistence of biocidal properties during эксплуатации, enabling practical implementation of the developed solution in public transport systems.

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KN 3AXES

Investigation of the Applicability of 3D Printing for the Prototyping and Production of Propellers Dedicated to Unmanned Aerial Vehicles

The aim of the study was to investigate the applicability of 3D printing technologies for the prototyping and manufacturing of propellers intended for unmanned aerial vehicles (UAVs). As part of the project, existing propellers were digitized using the ATOS Compact Scan system, and their digital models were subsequently developed, processed, and optimized. The components were manufactured using various additive manufacturing technologies, including FDM, SLA, and SLS, with the use of materials such as ABS, ASA, PP, PC, PA12, as well as carbon fiber–reinforced composites. The fabricated prototypes were subjected to a series of experimental tests, including geometric accuracy analysis, surface wettability measurements (contact angle), and evaluations of lift force, vibration, and noise emission. The results indicate a significant influence of both the manufacturing technology and the applied material on the aerodynamic and operational properties of the propellers. Particular attention was paid to the potential for performance improvement through the application of hydrophobic coatings and geometry optimization. The obtained findings confirm that 3D printing represents a promising method for rapid prototyping and potentially the production of UAV propellers, enabling flexible selection of materials and geometries. Further work will involve field testing, strength assessments, and the development of new material and structural solutions.

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KN Promat

Implementation of adaptive control program for an industrial robot in the open die forging process, supported by FEM simulation

As part of the project, a control program for the open die forging process of C45 steel was developed and verified using a Kawasaki industrial manipulator integrated with a hydraulic press. In the KIDE environment, a robot control algorithm was implemented in the AS language, enabling billet manipulation, while process parameters, including forces and temperature distribution, were evaluated through numerical simulations in QForm UK. A key aspect of the project was the implementation of a wrist compliance function (Soft Absorber) to protect the robot's mechanics from dynamic overloads, along with adaptive billet positioning to ensure stability and repeatability of operations. he analysis of FEM simulation results, including stress, strain, and temperature distributions, was used to develop the robot motion sequence, enabling the forging process to be carried out in an automated manner while maintaining the required technological parameters. The developed system fulfills the intended functions and provides a solid foundation for further research and development, including full hardware automation, integrating the robot with the press control system and heating furnace. The results demonstrate that the robotization of low-volume open die forging processes is both technically feasible and economically justified, opening perspectives for modernization of forging operations in line with Industry 4.0 principles.

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KN Hefajstos

Application of CAM software for designing tool trajectories in Single Point Incremental Sheet Forming (SPIF)

The research focuses on analyzing the feasibility of adapting commercial CAM systems to the specific technological requirements of the Single Point Incremental Forming (SPIF) process. The primary research problem stems from the fact that most commercially available manufacturing software is oriented toward subtractive machining, which necessitates the development of a proprietary programming methodology for plastic forming processes. Based on the analysis of the process characteristics, guidelines necessary for the study were formulated, and various process simulation variants were conducted within the SolidWorks CAM 2023 environment. The first attempt revealed significant limitations of automatic feature recognition algorithms, leading to incorrect geometry interpretation and the generation of inefficient tool paths. The second variant, utilizing a standard layering strategy, revealed geometric defects in the form of a "technological seam" resulting from incremental tool plunging. The third and optimal variant was based on a proprietary helical trajectory configuration and a precise stock definition, which ensured the continuity of the forming process. This research was funded by the IDUB project titled "ROBOSPIF 2.0 – single point forming of hard-to-deform materials using an industrial robotic arm" (Action D12, application no. 16577).

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AGH Eko-Energia

Comparative analysis of gelcoat mold production methods for composite components of the "PERŁA" solar vehicle

This paper analyzes and compares methods for manufacturing open gelcoat molds reinforced with fiberglass mats used to fabricate body components for the "PERŁA" solar vehicle. The "PERŁA" project will begin with a brief introduction. The introductory section will outline the current mold-making process. The advantages and disadvantages of the process and its results will be described. A new technology aimed at improving the quality of the molds will then be presented. This method will be tested. Various proportions of the materials used will be used in the tests: Epidian53 epoxy resin, glass fiber scrap, and Phylosphere T75 microballoon. The presented technologies will be compared for ease of lamination, mold quality, and financial viability. Based on the results, the most optimal method will be selected.

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KN Hefajstos

Designing and creating a jewelry element through plastic forming of metals

The aim of the research was to design and manufacture a ring using plastic forming and surface engineering processes. The research material used was a semi-finished bimetallic material joined by explosive welding, consisting of austenitic corrosion-resistant steel – 316L (structural function) – and technically pure Grade 1 titanium (decorative element). The material selection stemmed from the desire to manage waste generated by cutting these expensive materials – one of the project's objectives was to attempt to recycle them by using even the smallest fragments. The manufacturing process involved hot rolling at 850°C to reduce thickness, followed by bending to obtain an open rail with a lenticular profile. To improve aesthetics, the titanium layer was electrochemically anodized in a sodium bicarbonate solution. Applying a voltage of 68 V allowed for the desired interference color of the titanium, creating a distinct contrast with the natural, silvery color of the passive stainless steel. During subsequent stages of plastic processing, no delamination of the material was observed, despite significant deformation, indicating that the bond was maintained. The obtained results confirm that the use of advanced, technically advanced bimetallic systems represents a fully functional and attractive alternative to classic precious metals in modern jewelry.

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KN Creative

Determination of the critical stress intensity factor of titanium nitride based on Molecular Dynamics simulations

With the increasing use of hard ceramic coatings in modern materials engineering, there is an increasing requirement to better understand their mechanical properties, particularly fracture resistance. Titanium nitride (TiN), widely applied as a protective coating, exhibits a brittle failure mechanism whose description at the atomic scale remains a significant research challenge. The aim of this work was to analyze the fracture resistance of TiN and calculate the influence of size effects on numerical simulation results.

In the methodological part, a numerical model based on molecular dynamics (MD) was developed with using the LAMMPS simulation package. Interatomic interactions were described using the 2NN-MEAM potential, enabling proper representation of the B1 crystallographic structure. The analysis was performed for single-edge notched beam specimens subjected to uniaxial tension. Models with different volumes were considered, ranging from several hundred thousand to several million atoms.

Two approaches for estimating fracture toughness were analyzed: the force-based method and the energy-based approach using the J-integral. Additionally, the influence of the computational domain size was examined, and the scalability of the simulations together with computational resource requirements was analyzed using high-performance computing infrastructure.

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KN Powierzchnia

Pulsed laser interference heating of FeAgNbB alloy ribbon as a tool for precise control of microstructure and properties

The subject of this study was pulsed laser interference heating (PLIH) of an amorphous FeAgNbB alloy ribbon. The primary objective of the research was to evaluate the effect of laser annealing on the magnetic properties of the material. In particular, the relationship between the number of laser pulses and the microstructural changes in the near-surface layer of the ribbon, as well as the resulting variations in magnetic parameters

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AGH Drone Engineering

35CrMnSi steel in Dual-Use applications enabled by diverse heat treatment variants

The developed research project presents a basic analysis from the perspective of mechanical and materials engineering, focusing on the potential offered by 35CrMnSi steel for various branches of heavy industry. A deeper understanding of the material's parameters and their analysis can positively contribute to expanding its implementation across a wider range of technical applications.
35CrMnSi steel is primarily used for the production of highly loaded machine components. By understanding its physicochemical parameters and mechanical properties, as well as having knowledge of appropriate heat treatment parameters, it is possible to develop a technological process for manufacturing dual-use components based on this material.

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KN Hefajstos

From Explosion to Safety: The Application of Explosive Cladding in Nuclear Power Plants

Comparison of the Microstructure and Selected Properties of Explosively Clad P295GH Steel–Grade 1 Titanium Plates for Nuclear Power Plant Components. Materials manufactured by Explomet for the AKKUYU and El-Dabaa projects were analyzed. The P295GH/Ti Grade 1 system combines the favorable mechanical properties of structural steel with the high corrosion resistance of titanium, which is particularly important in equipment operating in contact with cooling water and under demanding service conditions. From the safety point of view, such materials can be used in components responsible for system leak-tightness and effective separation of working media, such as heat exchanger tube sheets.

The fundamentals of explosive cladding and the mechanism of bond formation between the material layers are discussed. The study includes analysis of the bond interface geometry, determination of wave height and wavelength, assessment of local melted zones, hardness testing, and microstructural observations. Particular attention was paid to comparing the bond zone in materials from two industrial projects. The character of the bond interface, microstructural features, and the effect of the process on local strengthening were evaluated. The results will allow assessment of bond quality and identification of features important for the durability and reliability of components used in nuclear power engineering.

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KN Powierzchnia

Steel Fitness: How Materials Engineering Protects Gyms from Costly Corrosion

In light of the increasing operational intensity of sports facilities, the durability of infrastructure has become a decisive factor for the profitability and safety of the fitness industry.

The primary objective of this study was to verify the corrosion resistance of metallic materials in an artificial sweat environment, which is the most prevalent cause of degradation in strength-training machinery. As part of a comparative analysis, several market-standard solutions were tested: ranging from economical S235JR structural steel (in raw, galvanized, and powder-coated variants) to C45 chrome-plated steel and high-grade stainless steel.

Utilizing advanced electrochemical methods and immersion tests, the durability of individual components was determined. The results provide critical data on the susceptibility of these materials to corrosive destruction, offering comprehensive guidelines for manufacturers and investors aiming to minimize losses and extend the life cycle of professional training equipment.

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KN Powierzchnia

How to effectively join aluminum alloys? The influence of joining technology on the microstructure and properties of 5xxx and 7xxx series aluminum alloy joints.

For years, the industry has been searching for effective and reliable methods of joining advanced aluminum alloys. Producing dissimilar joints, such as the joining of 5xxx and 7xxx series alloys, remains a particular technological challenge. The aim of the research presented in this paper was to compare two joining technologies: traditional Tungsten Inert Gas (TIG) arc welding and Friction Stir Welding (FSW). As part of the research, an analysis of the macrostructure, microstructure, and chemical composition was conducted, along with hardness and corrosion resistance tests. The results clearly revealed the limitations of the arc method. Despite the selection of optimal parameters, it was not possible to avoid imperfections in the TIG welds. Conversely, FSW technology, with an appropriately selected tool shape, allowed for the production of imperfection-free joints. The research proved that FSW guarantees a significantly more favorable microstructure and limits the decrease in hardness in the heat-affected zone compared to classical welding. Furthermore, completely different mechanisms of corrosion behavior were observed for both joining methods. The obtained results indicate the high potential of the FSW method in structural applications, where durability and high quality of joints are the priority.

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KN Era Inżyniera

Quantitative and qualitative assessment of the microstructure of ductile iron used in the railway industry

Cast iron is one of the most commonly used materials in machine building. This material has been associated with the railway industry from the very beginning, as the first railway rails were made of cast iron. The ductile iron tested is used in brake pads, locomotive engine components, traction tensioning pulleys, and anchors that secure rails to pre-stressed concrete sleepers.
This study examines the microstructural characteristics of ductile iron EN-GJS-500-7 for three different SB 3/TT type railway anchors. Metallographic examinations were performed using a Carl Zeiss Axiovert 200 MAT light microscope at 5x, 10x and 20x magnifications on both etched and non-etched microsections. The characteristics of graphite precipitates were determined on the unetched microsections in accordance with the PN-EN ISO 945-1:2009 standard, as well as the graphite volume fraction using the point method. The microstructural components of the tested cast iron were identified on the etched microsections. These studies were supplemented with Vikers hardness measurements.

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KN Powierzchnia

EBSD as a Tool for Microstructure and Recrystallization Mechanism Analysis in FSW Joints of 2017A and 7075 Aluminum Alloys

This study presents the results of Friction Stir Welding (FSW) of 2017A and 7075 aluminum alloys, focusing on the impact of their placement relative to the advancing side on the joint's microstructure. Two joint configurations were prepared, with either the 2017A or the 7075 alloy positioned on the advancing side.

The investigation was conducted using SEM, EBSD, and EDS techniques. The analysis evaluated the fraction of low-angle (0–2°) and high-angle (2–15°) boundaries, the degree of material mixing, grain size, and the mechanisms of recrystallization and recovery within the stir zone. EDS analysis enabled the determination of elemental distribution and the patterns of mutual mixing between the two alloys within the weld.

The results indicate a significant influence of the advancing side on material flow asymmetry and the formation of the joint's microstructure. Differences were observed in the boundary fractions, degree of recrystallization, and grain size depending on the material configuration. Alloy 2017A showed a higher tendency to form a fine-grained structure. Alloy 7075 exhibited recovery as the dominant mechanism. EDS analysis confirmed the heterogeneous distribution of materials in the stir zone and its dependence on the joint configuration.

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KN Metaloznawców

Microstructure and property control of 30CrMnSi steel through quenching and tempering heat treatment processes

The aim of the present study was to analyze the effect of various heat treatment parameters on the microstructure and mechanical properties of 30CrMnSi structural steel intended for quenching and tempering. The investigation focused on different heat treatment variants, including quenching under various conditions and tempering carried out over a temperature range of 100°C to 700°C, with reference to recommended processing parameters.

The research scope included the evaluation of the effects of quenching conditions as well as a series of tempering processes. Mechanical testing was conducted to determine the influence of heat treatment on strength properties, accompanied by hardness measurements and metallographic observations. Based on the obtained results, the Hollomon–Jaffe parameter was applied to establish alternative tempering conditions leading to the desired hardness levels.

Microstructural analysis performed using optical microscopy was complemented by scanning electron microscopy (SEM) observations, as well as fractographic examination of fracture surfaces. The results demonstrated a significant influence of heat treatment conditions on both the microstructure and mechanical properties of the steel. Furthermore, the applicability of the Hollomon–Jaffe relationship in the design and optimization of tempering processes was confirmed.

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KN Hefajstos

Synthesis and characterization of $LaCeO_3$ materials obtained by the sol-gel method using EDTA–citrate complexing

This thesis focuses on the synthesis and preliminary characterization of the perovskite material $LaCeO_3$ obtained via the sol-gel method using EDTA–citrate complexing. The process was carried out in two variants: with the addition of EDTA as a complexing agent and without it; the pH of the solutions was maintained between 6,0 - 7,0 using ammonia. The resulting sols were evaporated to form a gel, followed by drying (120°C) and calcination (650°C). X-ray diffraction (XRD) analysis revealed the formation of a phase with the composition $La_{0.4}Ce_{0.6}O_{1.8}$, deviating from the assumed $LaCeO_3$ stoichiometry.

The obtained powders were pressed and sintered at 1100°C in an air atmosphere to prepare the material for pulsed laser deposition (PLD) on ITO and quartz substrates. It was observed that samples containing EDTA exhibited higher sintering shrinkage, which may be related to the presence of residues from the combustion of organic precursors.

Scanning electron microscopy (SEM) was used for detailed morphology analysis of both powders and thin films. Differential scanning calorimetry (DSC) was applied to determine the calcination temperature. A key direction for further research will be determining the energy band gap, catalytic properties, and electrical conductivity (using the Mott–Schottky method) to evaluate the material's application potential, including its use in galvanic cells.

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KN Metaloznawców

The influence of the feed rate of the draw rod on the formation of the cast iron structure in the Bridgeman directional crystallisation method

The aim of this thesis was to conduct qualitative and quantitative investigations of the structure of directionally solidified cast iron and to determine the influence of a key process parameter on the resulting microstructure of the alloy, namely the withdrawal rate of the pulling rod. The experimental work involved four melts of cast iron produced in a specialized device for directional solidification using the Bridgman method, at different withdrawal rates of 9, 20, 30, and 40 mm/h, respectively. Qualitative studies included microstructural analysis of the samples using optical microscopy, enabling the identification of structural constituents and the assessment of their distribution. Quantitative investigations comprised chemical composition measurements carried out with a spectrometer, microhardness measurements of individual microstructural constituents performed using a microhardness tester, as well as the determination of the average secondary dendrite arm spacing (SDAS). Variation of the investigated process parameter made it possible to evaluate its effect on the course of solidification and on changes in the morphology and microstructural characteristics of the cast iron.

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KN Era Inżyniera

The role of chromium-containing coatings in controlling the interfacial reactivity of the graphite–Cantor alloy system during FAST/SPS pulse sintering

Cantor alloy (FeCoCrMnNi) is a high-entropy alloy known for its excellent ductility, high mechanical strength, and resistance to damage. Its production methods include classical powder metallurgy, casting, and spark plasma sintering (SPS). A common hazard during sintering is carbon diffusion from the surface retention tool, which is often overlooked in the literature. In the first edition of FAST/SPS, the synthesis of Cantor alloy was performed with access to chromium in the surface layers to allow chromium depletion of the high-entropy alloy. It was hypothesized that chromium would bind to the diffusing carbon, forming chromium carbide precipitates.

Samples were prepared from cold-pressed powder at 400 MPa in 15 mm compacts. A mixture containing 95 wt% HEA and 5 wt% HEA was also prepared. Cr, surrounded by a compact in 20 mm FAST/SPS dies. Sintering was conducted at 1050°C under a load of 50 N for 7.5, 30, and 60 minutes. The results showed that the addition of chromium limited chromium depletion in the HEA grains in the surface layers. Additional hardness was achieved, reaching over 400 HV for the remaining sintering times, up to 150 HV for the HEA alloy.

This work was funded by the Excellence Initiative – Research University program (IDUB 501.696.7996).

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KN Hefajstos

Vibration-damping alloys – from the superelastic effect to practical applications

The presentation focuses on metallic materials capable of damping mechanical vibrations, with particular emphasis on shape memory alloys. Their damping capacity arises from energy dissipation during deformation, primarily due to martensitic transformation and internal friction within the material structure. The applications of these materials will be discussed, particularly where vibration damping plays a key role as a result of the superelastic effect and the associated hysteresis loop, which serves as a measure of energy dissipation. Particular attention will be given to a newly developed iron-based alloy, whose damping properties are currently under investigation. Preliminary experimental results and future development directions will also be presented.

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AGH Solar Boat

Effect of rolling direction on the bending strength of AW-7075 alloy for "Delta" propulsion system

Student research group AGH Solar Boat designs and builds zero-emmision, racing hydrofoil boats. The latest vessel "Delta" is powered by innovative, dual-propeller powertrain system, which also allows to change angle of attack of a hydrofoil. Such solutions need to use specialized aluminum alloys to maximize strength while keeping the weight as low as possible.
This paper applies to study of the effect of the rolling direction for bending strength in accordance with the ISO 7438 of AW-7075 aluminium alloy, which is used in the powertrain housing. The study covers sample production, metallographic analysis, conducting tests on a strength testing machine and final results evaluation in the context of the boats powertrain. The results of the study will enable a quantitative assessment of the impact of the material used on the bending strength of the final component.

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KN Metaloznawców

Microstructure development of low-temperature deformed austenitic steel

The aim of the project was to analyze the effect of plastic deformation on the development of microstructure and mechanical properties of a high-manganese steel. The chemical composition of the steel was - Mn-24.1%, Si-3.2%, Al-2.8%, and C-0.02%. The prepared samples were tested in their initial state and after deformation of 10%, 30%, and 50%, and after fracture. The deformation temperature was -150°C. Metallographic, diffraction, and mechanical examinations confirmed that the initial structure of the material was dominated by austenite (94%), with ferrite constituting only 6% by volume fraction. As a result of the applied deformation, a significant microstructure development was observed. New phases appeared in the material: hexagonal martensite ε and cubic martensite α'. This led to changes in mechanical properties. An increase in microhardness was observed, which was caused by the increase in structural defects and the presence of martensite.

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KN Powierzchnia

Hydrolates as potential corrosion inhibitors for steel in an acidic environment

Protection of steel against corrosion in aggressive environments is a technological and economic challenge. In an era of environmental regulations, an important research direction is the search for ecological alternatives to toxic synthetic inhibitors. The aim of the work was to evaluate the anticorrosive effectiveness of plant hydrolates: from damask rose petals, rose hips, and orange peel, as potential "green" corrosion inhibitors for S235 steel.

The research was carried out in 1 M HCl using an electrochemical method – Linear Sweep Voltammetry (LSV). The influence of inhibitors at concentrations of 200, 400, and 800 ppm on the kinetics of corrosion processes was analyzed.

The analysis of polarization curves showed that all tested hydrolates limit metal destruction, and their effectiveness is correlated with the type of extract and concentration. The recorded shift of the corrosion potential towards positive values suggests that the tested substances act mainly as anodic inhibitors, inhibiting iron oxidation. The highest ability to modify the potential was shown by the rose hip hydrolate. In turn, the addition of orange peel hydrolate resulted in a decrease in the corrosion current density, which directly reduces the corrosion rate. The results confirm the application potential of plant hydrolates as biodegradable and effective means of steel protection in acidic systems.

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AGH Space Systems

Manufacturing of lightweight composite tubes with low-density cores for sounding rocket applications

The dynamic development of space technologies necessitates the continuous optimization of sounding rocket load-bearing structures, particularly in terms of mass reduction while maintaining mechanical properties. This paper presents a manufacturing method for lightweight composite sandwich tubes, which serve as an effective alternative to classic metallic constructions and heavier monoliths.

The primary objective of the research was to develop repeatable manufacturing technology for student-grade rocket airframes characterized by low mass. The proposed methodology is based on the use of internal mandrels and a multilayer carbon fiber load-bearing structure integrated with a honeycomb core. A key innovative element is the application of a hybrid core with varying density. This solution allows for selective reinforcement of areas particularly vulnerable to structural degradation during machining and the installation of avionics systems.

The paper also details a thermal curing cycle. Basing the process on a controlled, linear temperature ramp allowed for a reduction in internal stresses and control over the curing kinetics of the epoxy resin. The developed technology enables the production of high-strength structures with reduced mass compared to monolithic carbon laminates, while maintaining the structural integrity required under sounding rocket flight conditions.

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KN Powierzchnia

Modification of surface morphology and properties of the Ti6Al4V alloy induced by pulsed interference laser heating

This study focused on investigating the effect of pulsed laser interference heating on the microstructure and properties of the biomedical Ti6Al4V alloy. Material analyses were performed using different distances between the material surface and the laser beam. The remaining process parameters were kept constant; therefore, the study aimed to determine the optimal laser – Ti alloy surface distance at which a periodic dot structure forms without melting the material. Microstructural examinations were conducted using an optical microscope and a scanning electron microscope. Additionally, studies of changes in chemical composition were conducted using EDS, and analyses of changes in the contact angle were performed using a goniometer. Partial melting of the material was observed when a smaller distance between the material and the laser beam source (40–50 mm) was used. The resulting dots/pulses were highly deformed, varied in morphology, and were not arranged periodically. The most favorable structure in terms of morphology was obtained at a distance of 60 mm between the material surface and the laser beam. The resulting areas were circular in shape, largely similar in size, and exhibited a periodic structure. Studies of the contact angle of the material before and after laser beam exposure were conducted for water and diiodomethane. The treatment had only a minor effect on the contact angle values – the material remained hydrophilic in all cases.

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AGH Lunar-Technologies

SpaceX Technologies as a Foundation for Planetary Exploration

This study analyzes key technological solutions developed by SpaceX that redefine the current model of exploration, opening the way for permanent human activity beyond Earth. The main factor enabling this change is the technology of reusable rocket systems, which drastically lowers the economic barriers to space missions. The paper presents the development of rockets capable of safely returning to Earth and relaunching, illustrated by the operational results of the Falcon 9 system. It also describes modern production methods, such as advanced metal 3D printing, which allows for the simplification of engine designs by creating them from a single element. This eliminates the risk of failure at joints and significantly accelerates the rocket construction process. An important part of the analysis is the selection of construction materials for long-distance missions. The strategic decision to use special grades of stainless steel in the Starship system is discussed. It is demonstrated that this material provides high resistance in extremely low temperatures while simultaneously enabling efficient ship production, which is difficult to achieve with traditionally used carbon materials. The conclusions indicate that the combination of mass production, modern manufacturing, and rocket recovery has allowed for a multi-fold reduction in space transport costs. This is crucial for the potential future construction of Moon bases or a manned mission to Mars.

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AGH Lunar-Technologies

Use of HRSC Images from the Mars Express Mission to Support the Selection of Safe Landing Sites on Mars

This project concerns the use of HRSC imagery from the Mars Express mission for the preliminary assessment of potential landing sites on Mars. Based on the images and elevation data, it is possible to analyze terrain features such as slope, surface roughness, and the presence of obstacles, all of which are important from the perspective of landing safety. The presented approach may support the identification of areas with lower risk.

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AGH Lunar-Technologies

Analysis of vibration data from test campaign of the "Lunaris" Moon experiment at the ESA ESEC

Devices designed for lunar missions are exposed to strong mechanical vibrations and high levels of acoustic pressure. To avoid unexpected damage to the structure, components are subjected to demanding vibration tests during the mission preparation phase. The research payload developed by AGH Lunar Technologies for the "Lunaris" mission underwent such tests during a test campaign in July 2025 at the ESA CubeSat Support Facility in Transinne, Belgium. In a series of tests with sinusoidal and random excitation, an extensive dataset was collected, including acceleration signals and their frequency spectra. During the presentation, the applied methods of analysis of the collected data and the obtained conclusions will be presented. An outline of the procedures related to the test campaign and the criteria for evaluating the results will also be presented.

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AGH Space Systems

Design of a spot welding machine with weld energy control and pulse shaping, suitable for spot welding of sheet metal and the assembly of Li-ion battery packs

As part of the work on the designs of a planetary rover and a mission support drone, spot welded joints were frequently used in the fabrication of battery cell packs. Until now, a commercial solution had been used that did not ensure the required repeatability of the joints.

This presentation will introduce a spot welding machine design aimed at achieving the necessary repeatability of joints and expanding functionality to enable the spot welding of sheet metal components as well. Ensuring adequate mechanical strength of these joints will be critical. The new design will be based on supercapacitors as the energy source and precisely controlled MOSFET transistors, ensuring appropriate pulse parameters to achieve repeatable and durable welded joints. Specific issues arising from the very high currents required for spot welding will be addressed.

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KN Astrobio AGH

Smart, self-regenerating bioelectrochemical system for space habitat life support

Long-duration space missions require low-emission, biodegradable energy solutions integrated into circular life-support systems. Traditional batteries are resource-intensive and generate waste. This research focuses on developing bioelectrochemical cells using a symbiotic culture of bacteria and yeast (SCOBY) to provide renewable power within controlled ecosystems.
A kombucha-derived biofilm was used to create a self-organizing cellulose matrix functionalized with carbon nanotubes and graphene. This formed a conductive 3D structure that enhances extracellular electron transfer. System stability was monitored via a Raspberry Pi biotelemetry suite, with future validation planned during AATC analog missions and in the HOPE habitat (Himalayas).
These self-healing, compostable biofilms offer a resilient, low-mass solution for power generation and environmental monitoring in closed-loop life-support systems. Furthermore, the cellulose produced by the consortium can serve multiple applications in space environments, such as garment production and beyond.

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AGH Space Systems

Investigating cosmic radiation via passive dosimetry: A study utilizing carbon-doped aluminum oxide (α-Al_2O_3:C)

Due to its exceptional sensitivity and radiation stability, carbon-doped aluminum oxide (Al_2O_3:C) remains a premier material for luminescence dosimetry. The AGH Space Systems student research group is currently developing a proprietary synthesis method for Al_2O_3:C-based passive detectors. A primary objective of this work is to evaluate detector response within complex ionizing radiation fields, with a specific focus on cosmic radiation.Initial laboratory benchmarks using 137 Cs (gamma) and 90 Sr ($\beta-$) sources have already validated the material's sensitivity and linear response, providing a robust foundation for further detector optimization. The next phase of the study will involve assessing detector performance in situ during a stratospheric balloon mission. In parallel, numerical simulations are being conducted in the Geant4 environment to theoretically determine dose deposition within the detector and compare experimental results with the physical model.. By integrating data from these powder-based detectors with measurements from semiconductor and Geiger-Müller counters, the project aims to deliver a comprehensive analysis of the stratospheric cosmic radiation environment.

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AGH Space Systems

Design of a 6-DoF Leader-Follower Teleoperation System for a Planetary Rover Manipulator

The presentation will introduce a teleoperation system design for the Kalman planetary rover's robotic manipulator, developed at AGH Space Systems. The project was conceived in response to the limitations of the existing approach to manipulator control, which relied on a "pad" controller and a SpaceMouse device. Operating using these devices requires extensive training to safely and effectively perform precise manipulator operations. The master arm, by directly mirroring the operator's hand movements, will enable much more intuitive control, significantly lowering the entry barrier for new team members. During the presentation, the design principles and system architecture will be presented, with the key element being a physical leader arm with six degrees of freedom, equipped with servomotors and magnetic encoders. Particular emphasis was placed on integrating the arm with the ROS 2 system - joint state readings are transmitted via a dedicated PCB to the ground station, where the MoveIt! package handles motion planning and generates commands for the rover's manipulator. Two control approaches under consideration, kinematic chain replication and inverse kinematics, will also be discussed, along with the criteria for selecting the target strategy following integration with the mobile platform.

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AGH Skylink

Mission Control Panel system for audio communication during space missions

The presentation discusses the Mission Control Panel (MCP) system, which provides audio communication during space missions. The system was designed to enable efficient broadcasting over 4 audio channels to 16 independent operator stations in full-duplex mode. During the project development, the key objective was to minimize latency. To achieve this, inter-process communication (IPC) based on synchronization mechanisms and memory fencing was used. This ensures data consistency under high load. The system is complemented by a user interface in the form of a web application and is based on similar solutions used at ESA Space Operations Centre. The system will be deployed in the Mission Control Centre at the Faculty of Space Technologies and used for communication with astronauts during analog missions, giving students an experience of real space operations.

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Studenckie Koło Naukowe Ekologia Wyrobów UEK

Utilization of Microorganisms in Space Mining Processes: The Potential of Regolith Bioleaching on Mars in the Context of ISRU Technologie

Exploration and future utilization of extraterrestrial resources represent one of the key directions in the development of modern astronautics, particularly in the context of the In-Situ Resource Utilization (ISRU) concept. In this regard, the ability to locally obtain construction materials from planetary regolith plays a crucial role, especially on the surface of Mars, which is rich in iron oxides.

The aim of this study is to determine the potential of using microorganisms in space mining processes, with particular emphasis on their role in the bioleaching and mobilization of iron compounds present in Martian regolith. The work is based on a review of literature in the fields of biotechnology and biomining, as well as a comparison between the properties of selected microorganisms and the environmental conditions on Mars.

As part of the study, a conceptual process model is proposed in which microorganisms serve as a biological pre-treatment stage of mineral resources, facilitating their subsequent extraction in technological systems. Key limitations arising from environmental conditions and challenges related to the implementation of biological processes in space systems are also identified.

This work is conceptual in nature and provides a foundation for further research on the integration of biotechnology and materials engineering in the context of future space mining systems.

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AGH Space Systems

Data acquisition modules for a static rocket test platform

In our paper, we present the design of two specialized data acquisition modules. Our boards constitute an essential part of a larger, distributed measurement system for a static rocket testing platform. The modules perform measurements of key propulsion parameters necessary for generating plots that enable analysis of engine efficiency and operating characteristics.
The first module is responsible for interfacing with sensors operating in the 4–20 mA current loop standard, allowing for precise measurement of pressure in the combustion chamber and propellant tanks. The second module is dedicated to strain gauge systems. Its purpose is to directly determine the engine thrust curve and to accurately measure the weight of heavy infrastructure components, such as gas cylinders and the rocket itself.
Both modules employ specialized 24-bit analog-to-digital converters with a sampling rate of 128 kSPS. The designed measurement nodes provide high-resolution data, which is essential for the validation and optimization of student-built rocket systems.

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AGH Space Systems

When everything works againts You: Planning and Organizing Stratospheric Missions at AGH Space Systems Student Research Club”

Stratospheric missions are a core component of AGH Space Systems’ activities, providing a low-cost and accessible platform for conducting experiments in near-space conditions. They support research in areas such as cosmic particle physics, astrobiology and the validation of space-grade instrumentation. Despite their accessibility, such campaigns remain operationally complex, with launch timelines and locations dependent on multiple external factors.
A key challenge in organizing these missions is their strong dependence on weather conditions, which introduces significant uncertainty into launch planning. Non-reusable components, such as lifting gas and balloons themselves, must be managed carefully to minimize losses, in the context of launch delays or full cancellations. This uncertainty extends to human resource management, as student teams often operate under limited availability and many responsibilities, with involvement being purely voluntary.
This work presents a case study on managing operational uncertainty in student-led stratospheric projects. It examines analogies with real space missions and outlines practical mitigation strategies, including planning, resource management under uncertainty, and rapid decision-making. It also includes lessons learned and best practices applicable to student and early-stage aerospace initiatives.

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AGH Space Systems

From theory to prototype: Igniting youth passion through a space-themed workshop

The second Polish spaceflight mission and conducted research led to a marked increase in interest in the Polish space sector. Embracing this trend and a desire to share our knowledge was the motivation to conduct classes based on space experiments. The workshops, titled "Space Technologies", were aimed at youth aged 12-14. Each of the five two-hour sessions included a theoretical introduction and an engagement section consisting of presentations of real engineering solutions and interesting facts, followed by brainstorming involving participant collaboration on practical problems. The main goal of the classes was to build two autonomous systems for plant growth to compare hydroponic cultivation with soil-based cultivation. Another crucial objective was to share the knowledge gained through work in the student research group and to demonstrate that experiments related to space engineering can be conducted even without specialized knowledge, professional equipment, or a large budget. The integration of various fields allowed participants to find areas aligned with their interests while also enabling them to gain knowledge from diverse branches of science. The results of the evaluation questionnaires indicate that thanks to the combination of interdisciplinary tasks, presentations of real experiments, and the opportunity to create their own projects, there was a marked increase in participants' interest in space-related topics after the program concluded.

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AGH Skylink

StratoLink: LoRA-based image and data link for stratospheric missions

Due to the growing number of stratospheric missions organized by the AGH Space Technology Faculty, a data transmission system has been developed that enables real-time downloading of information from the onboard computer systems of capsules during flight. This solution has significantly contributed to reducing the risk of data loss in cases where the balloon lands in difficult-to-access terrain or in a body of water.
The developed system provides real-time monitoring of the link status and its configuration, including changes to transmission channels. The system has been equipped with a data encryption method described in detail in the article (arXiv:2509.08248 [cs.CR]). The implemented solution is based on E32-900T30S modules and operates in the 868 MHz band, in accordance with the regulations of the Office of Electronic Communications. The system enables data transmission at speeds ranging from 0.3 kb/s to 19.2 kb/s, dynamic reconfiguration of link parameters during a mission, and integration with the sensor systems onboard the balloon. Preliminary tests and analysis of operating conditions indicate a possible range exceeding 100 km. Results from the test campaign and stratospheric mission taking place in April will be presented in the paper. The entire system is compatible with the existing LoRaWAN infrastructure of the AGH Space Technology Faculty and with the inter-university network currently under development.

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AGH Skylink

Biological payload with microalgae encapsulated in agarose as payload of a rocket for the Czech Rocketry Challange 2026.

The paper presents the concept of a biological experiment developed by the FST AGH Rocket Team (ThrustLab, AGH Skylink, AGH AstroBio) for the Czech Rocket Challenge 2026. The scientific payload is designed to investigate the effects of launch overloads, vibrations, and short-duration reduced gravity on microalgae encapsulated in a hydrogel matrix. Chlorella vulgaris and Chlamydomonas were selected as model organisms due to their high environmental resilience and well-characterized physiology. Agarose beads with a diameter of 5–8 mm were placed into three experimental groups differing in medium composition. The 120 g payload was integrated into a rocket reaching an apogee of 445 m. Data are recorded at frequencies of up to 500 Hz, supplemented by 1080p video footage. Post-flight analysis includes OD600 measurements, fluorescent staining, and microscopic evaluation of capsule integrity. The experiment serves as a foundation for future research under microgravity conditions.

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AGH Space Systems

Project and Integration of ISRU Subsystems in the Kalman Platform: Drill and Sample Analysis Module

Future lunar and Martian missions will increasingly rely on robotic systems capable of autonomous surface operations and in-situ resource utilization (ISRU), enabling cost reduction and long-duration presence beyond Earth. Sample acquisition and analysis are also essential for reconstructing the geological history of explored sites and searching for signs of extraterrestrial life.

This paper is part of the student project Kalman rover, which integrates a modular mechanical architecture, a control system, and expandable payloads supporting diverse mission scenarios. The innovative character of the platform results from combining ISRU-oriented tools with autonomy validated in field conditions.

The work presents the drill module and a miniaturized sample-analysis unit designed and built by the authors. The drill was developed with a focus on operations in hard icy rock. The extracted sample is transported to the analysis module, where liquid water is recovered from the material and measured using strain-gauge sensors. The module employs a custom temperature-control loop and ESP-NOW communication, ensuring reliable interaction with the rover operator. The systems were optimized for low power consumption and reduced mass, both critical for extraterrestrial environments. Iterative design, virtual prototyping, and numerical simulations enabled the development of subsystems that meet the requirements of the Australian Rover Challenge.

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Elektrotermia

Digital control of dual-mass drive system

This thesis presents the analysis and synthesis of a digital speed control system for a two-mass drive with an elastic coupling. The considered plant, composed of a DC motor, a flexible shaft, and a load machine, exhibits torsional vibrations and resonance phenomena that degrade control quality. A mathematical model of both the electrical and mechanical subsystems was developed, and a cascade control structure with an inner current loop and an outer speed loop was designed. In the speed loop, a 2DOF PI controller was applied, and its parameters Kp, Ki, and the setpoint-weighting factor b were determined by numerical optimization using a shape-based performance criterion. The controllers were then discretized, the sampling period Ts was selected, and the algorithm was prepared for real-time implementation on the ESP32S3 platform. Simulation studies and experimental verification, supported by MATLAB/Simulink data, confirmed the effectiveness of the proposed approach. The obtained results demonstrated reduced overshoot, improved suppression of torsional oscillations, and good tracking performance with satisfactory disturbance rejection.

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SKNF Bozon

Design of front-end readout electronics for photodiode radiation detectors

X-ray and gamma detectors are widely used in biomedical imaging, particle physics, materials science, and environmental radioactivity monitoring. While commercial systems are expensive and often inaccessible to hobbyists and independent researchers, low-cost alternatives based on PIN photodiodes (semiconductor devices commonly used in optical and photonic systems) offer an accessible solution.

During the presentation, it will be shown how a PIN photodiode can be used as a radiation sensor, key limiting factors for discrete component design will be discussed. A compact prototype of a photodiode-based detector will be presented, along with simulations and measurements that confirm the correct operation of the analog part of the circuit in the range of 30 keV to 1 MeV. Results from measurements of radioactive sources: Cesium-137, Americium-241, Thorium-232, and uranium ore will also be shown.

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AGH ECOnstruction

Enhancing the Energy Efficiency of an E-Bike through an Original Energy RecoverySystem Integrated with a Mid-Drive Motor.

The paper presents an original solution that increases the energy efficiency of an electric bicycle through the use of an energy recovery system integrated with the central drive. In existing e-bike designs, energy recuperation mechanisms were mainly implemented in hub-mounted motors, which limited both the operational range of the system and the possibilities for optimizing its performance. The proposed system represents an alternative design concept, enabling efficient use of the vehicle's kinetic energy in central drive architectures. The paper discusses the process of designing and implementing the system. Additionally, an analysis of the use of various types of rectifier bridges to minimize losses at PN junctions was undertaken.

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Koło Naukowe Konstruktorów MechaniCAD

Design and Implementation of an High-Performance Hydrogen Fuell Cell Controller for the Hydrive 1 Vehicle

The paper presents the design of an original control system for a PEM hydrogen fuel cell used in the Hydrive 1 vehicle. The project aimed to improve the reliability and efficiency of the car's power supply system and to extend the functionality of the dedicated controller.

The designed controller eliminates the impact of human error thanks to full automation of the energy management process. The system monitors the voltage of the supercapacitor-based energy storage device and automatically recharges it when predefined thresholds are exceeded, controlling the activation of MOSFET transistors. The implemented solution streamlines vehicle operation and ensures optimal operation of the system during vehicle use, while significantly reducing the power consumption of the control electronics. This leads to more effective use of the energy generated by the fuel cell, which is crucial in the Shell Eco-Marathon competition.

Another key aspect of the solution was the simplification of the controller compared to the sub-optimal factory solution provided by the cell manufacturer. Integrating measurement, control, and safety systems into a single device reduced the number of components, decreased system weight, and increased reliability under track conditions.

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SKN Elektroenergetyków PIORUN

A generator of very short high-voltage pulses using a transmission lines and fast solid-state switches – simulation and experimental model

The goal of the presented project was to develop a simulation and experimental model of a generator producing submicrosecond high-voltage pulses with widths ranging from 100 ns to 800 ns. The designed circuit uses transmission lines in the form of high-voltage coaxial cables and is based on the classic Blumlein pulse generator. An innovation compared to standard Blumlein generator designs is the use of a fast solid-state switch (SiC MOSFET transistor) instead of a spark gap. The project includes the implementation of a practical research and teaching stand with a complete set of components and specialized blocks (including a regulated HVDC power supply, voltage measurement systems, a timer with a control pulse generator and gate drivers), which allow the configuration of a fully functional, modified Blumlein generator with defined voltage and time parameters of the generated pulses.

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AGH Eko-Energia

High-Current Load System for a Wind Turbine

This paper presents the design and implementation of an electronic system serving as the main control and measurement unit for testing the power generated by a wind turbine. Energy dissipation is achieved using a set of high-current lamps with a total power rating of 6.4 kW, switched via transistor-based modules. The system employs an STM32 microcontroller, which performs real-time dynamic optimization of the operating point based on data from temperature sensors and current measurements, while also controlling the cooling system. The controller is equipped with a user interface that enables monitoring of operating parameters and allows selection between automatic and manual load control modes. Thanks to its modular design, the solution can be adapted to other applications, such as determining the maximum power point as a function of battery state of charge, as well as analyzing battery degradation in solar vehicle systems.

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KN BioMetr

Prediction of neurological diseases using artificial intelligence algorithms and mixed reality technology in biomedical signal processing systems.

This project focuses on the prediction of neurological diseases using artificial intelligence algorithms and mixed reality technology in biomedical signal processing systems. Particular attention has been given to Parkinson’s disease, for which early diagnosis is crucial in slowing the progression of the condition and improving patients’ quality of life.

The paper presents the process of acquiring and processing biomedical data, including preliminary cleaning, imputation of missing data, normalization, and selection of relevant features. Based on this, digital biomarkers used in machine learning models were extracted. The proposed solution achieves high classification accuracy, indicating a strong ability to distinguish between study groups and severity scales. The role of Mixed Reality technology as a tool supporting data visualization and interaction with the diagnostic system was also discussed.

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SKN Elektroenergetyków PIORUN

Study of the effect of temperature on the dielectric permittivity of materials used in cable insulation.

The paper presents the fundamental assumptions of the reflectometric method used in cable fault diagnostics, with particular emphasis on the impact of the assumed value of the electrical permittivity of the insulation on the propagation velocity of voltage pulses and, consequently, on the accuracy of the obtained results. Subsequently, the results of laboratory studies on relative electrical permittivity and the dielectric loss factor as functions of temperature and voltage frequency are analyzed for four materials commonly used in cable insulation: polyethylene, silicone, EPR rubber, and polyvinyl chloride. Based on the obtained data, example calculations are provided to illustrate the influence of the type of cable insulation material and its temperature on the propagation speed of probing pulses, as well as the potential measurement discrepancies that may arise if the current cable temperature is not taken into account.

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SKN Elektroenergetyków PIORUN

Control System Design for Water Supply Networks Under Complex Terrain Conditions: A Mountainous Region Case Study

Access to running water is now a fundamental aspect of everyday life. To ensure its convenient and reliable use, cooperation between multiple industries is required, including electrical engineering. Control of water supply systems has become a crucial issue today, as such installations are part of critical infrastructure and require careful design and operation.

The main objective is to guaranty a continuous water supply of appropriate quality to end users. However, designing power supply, control, and automation systems involves numerous challenges, especially under specific terrain conditions. This is particularly relevant for water supply networks located in mountainous areas, where water is sourced from both high-altitude and low-altitude sources and then distributed across regions with significant elevation differences.

In such cases, reliable control systems are essential, taking into account both operational requirements and the specific characteristics of the network. The study presents the design and implementation of a control system developed for a water supply network operating in one of the towns in the Podhale region.

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SKN Elektroenergetyków PIORUN

Numerical modeling of voltage pulse propagation in cables considering the impact of selected insulation material parameters.

The objective of this study is to analyze the influence of selected cable insulation parameters on the propagation velocity of voltage pulses. As part of the research, a numerical cable model was developed, incorporating the relative permittivity of various insulating materials. Simulations were conducted for materials commonly utilized in cable insulation, including Ethylene Propylene Rubber (EPR), Polyethylene (PE), Polyvinyl Chloride (PVC), and Silicone. Furthermore, the study examines the effect of temperature on the dielectric constant variations of these materials. The geometric model and time-domain numerical simulations were implemented in the COMSOL Multiphysics environment using the RF Module. The obtained results enable a comparative analysis of pulse propagation velocities under different temperature conditions and across various insulating media.

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SKNF Bozon

Influence of electric field on the development of grain seeds

The electromagnetic field (EMF) is a physical phenomenon present in nearly every aspect of daily life. Since the concept of interactions was formulated by Michael Faraday, its role has expanded far beyond physics and electrical engineering. Today, EMF is widely applied in medicine, biology, and agriculture. Modern research shows increasing interest in its influence on life processes, particularly in stimulating plant growth and germination. The aim of this study was to assess the effect of the electric component of the electromagnetic field on the dynamics of germination of common wheat caryopses. It was assumed that exposing seed material to an electric field of a specified intensity and duration induces changes in physiology. Particular emphasis was placed on analysing grains with reduced vigour, for which external stimulation shows the greatest application potential. The study was conducted at a field intensity of approximately 4.5 kV/cm in three time variants: 15, 30, and 60 minutes. Germination capacity was verified in accordance with the PN-R-65950:1994 standard, and the analysis of the process dynamics was supplemented with determining indices according to Pieper and Maguire. From an application perspective, the use of an electric field as a stimulating factor may provide an alternative to chemical methods. In the context of increasing restrictions on the use of chemical agents, this technique may find application in modern, sustainable agricultural production systems.

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SOLARIS

The impact of application of RES supply curves reflecting spatial and technological diversity on modeling results of the national power system development

The growing share of electricity generation from renewable energy sources in the Polish power system leads to increased complexity in its balancing, which generates the need for more detailed representation of reality in energy models. Most of the currently used models, employed for developing strategic documents at the national level, treat renewable energy sources in a simplified way, omitting technological and geographical diversity. The aim of this study was to develop supply curves for electricity from photovoltaic installations as well as onshore and offshore wind farms, taking into account technological and spatial factors, and then to implement them in the Polish power system model TIMES-PL. To determine them, data from the PVGIS interface and the JRC ENSPRESO spatial database were used. The data was processed using spatial analysis tools, including QGIS software. On this basis, supply curves were developed that define the installable capacity of renewable energy sources in individual regions of the country, as well as variants of hourly capacity factor profiles reflecting the diversity of operating conditions of installations. The obtained supply curves and hourly profiles were then implemented in the TIMES-PL model to analyze their impact on the results of power system modeling.

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KN Green Energy

Energy security on a local scale

The paper presents an analysis of energy security on a local scale in Polish conditions, in the context of the current and future political and economic situation in the world. The analysis covers the problems faced by the modern Polish energy sector in the context of global warming and the necessity of enviromental protection and deversification of energy supplies, taking into account technical and economic aspects.
The paper ephasizes the analysis of energy security on both a national and local scale. Furthermore, various possible scenarios of energy supply destabilization were analyzed, and comprehensive actions were proposed to ensure energy security on local scale by increasing the energy efficiency of residential buildings and the comprehensive use of renewable energy sources along with energy storage.

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KN Green Energy

Analysis of Selected Solutions for Ensuring Thermal Comfort in Single-Family Buildings

This paper presents an analysis of various selected solutions for ensuring thermal comfort in single-family houses under Polish conditions. The study includes, among other things, an assessment of the feasibility of implementing different types of heating systems permitted by Polish and EU law. Furthermore, selected unconventional solutions utilized in construction and architecture are presented. The conducted analyses also take into account socio-economic and environmental factors, as well as the applicability of various solutions to both older buildings and those constructed in recent years.

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KN Transpeed AGH

Nanofibrous materials with in situ exsolved nanocatalysts as high efficiency electrodes for solid oxide fuel cells in backup power supply applications for AI data centers.

The dynamic development of artificial intelligence is increasing the demand of data centers for stable and continuous supply of electrical energy. Conventional systems do not provide the required reliability and usage of diesel generators is not reconcilable with climate regulations. In response, Bloom Energy is implementing solid oxide fuel cell technology, which offers high power generation efficiency. In contrast to PEMFCs, which require pure hydrogen, SOFCs enable usage of lower purity hydrogen, methane or carbon dioxide. The key challenges remain in high operating temperature and limited catalytic properties of the electrodes.
In the study electrode materials with the perovskite structure Sr0.9Fe(0.8-x)Ti0.1W0.1(M)xO(3-δ) were developed using the electrospinning method. Introduction of transition metals, capable of being reduced to metallic state, into the perovskite structure has enabled the in situ exsolution of metallic nanoparticles, thereby enhancing the catalytic activity. X-ray crystallography revealed, that the oxides crystalize in the Pm-3m space group with nanoparticles, and SEM measurements allowed for the analysis of the material morphology. The obtained results indicate that the developed nanocomposites constitute a promising choice for electrode materials for SOFCs designated for backup power supply to AI data centers.

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KN CarbON

Simulation and modeling of the CO2 absorption process in energy applications

The aim of the study was to develop and analyze a detailed model of the Benfield process used for removing CO2 from process gases, with particular emphasis on energy sector applications. The process model was implemented in the ChemCAD environment, replicating the key components of an industrial installation, including the absorption column, the solution regeneration system, and the closed-loop absorbent circulation. This approach enabled the analysis of the installation's operation under near-realistic conditions. The numerical simulations performed allowed for the evaluation of CO2 removal efficiency and the determination of the impact of key operational parameters on the process performance. For an inlet stream containing 5175 kg/h of CO2, a high degree of separation was achieved, with only 6 kg/h of CO2 remaining in the purified gas. The sensitivity analysis demonstrated a significant influence of operating pressure and absorbent solution concentration on process efficiency, indicating optimal parameter ranges that ensure both high capture effectiveness and favorable energy indicators.

The obtained results confirm the high efficiency of the Benfield process as a CO2 removal technology for process gases in energy applications. The study also highlights the importance of process modeling and simulation as tools supporting the design, analysis, and optimization of gas treatment installations in the context of emission reduction and energy transition.

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KN Green Energy

The Application of Artificial Intelligence in Optimizing the Production of Industrial Energy Systems Using MOF Materials

AI-driven research has successfully identified new metal-organic frameworks (MOFs) for energy applications; however, transforming these “digital blueprints” into mass-produced industrial components remains a significant engineering challenge. This paper focuses on the role of artificial intelligence in bridging the gap between theoretical laboratory successes and large-scale industrial implementations. The implementation of Bayesian optimization in autonomous synthesis loops, often referred to as “autonomous laboratories,” was analyzed to identify optimal production parameters at an unprecedented speed. By using “digital twins” to monitor parameters in real time, it is possible to improve large-scale synthesis processes while reducing resource consumption and shortening lead times. Furthermore, this presentation highlights how AI-driven “process intensification” serves as the final link in the implementation of advanced adsorbent materials in the global energy market.

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AGH Eko-Energia

The electrical power system architecture of the "Perła" solar car

Vehicle-Integrated Photovoltaics (VIPV) support the development of electromobility by improving energy efficiency and extending vehicle range, which helps reduce greenhouse gas emissions. Due to the excessive weight and low flexibility of conventional photovoltaic modules, their use is limited. A solution to this problem is the lightweight and flexible crystalline silicon (c-Si) modules developed by the AGH Eko-Energia, which are laminated in fiberglass and designed for installation on the "Perła" solar car. The applied lamination technology ensures the durability and lightness of the structure, creating potential for using these modules in construction and aviation, thus opening new paths for the commercialization of flexible PV cells. This presentation will focus on the architecture of electrical connections and the integration of modules into the body of a solar car. A method for selecting the MPPT, protective elements, and connecting cables will be presented. Furthermore, a diagram of the module layout on the body will be showcased.

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AGH Solar Plane

Review and comparison of photovoltaic cell technologies for use in solar-powered Unmanned Aerial Vehicles.

This paper presents a review of photovoltaic technologies considered in the context of solar-powered UAVs. Aircraft powered in this way constitute a viable alternative to conventional drone systems, whose range and flight duration are significantly limited by the capacity of onboard energy sources. The integration of photovoltaic cells on aircraft wings enables missions lasting many hours or even multiple days, which is particularly valuable in applications such as search and rescue operations.

Selecting the appropriate cell technology remains a significant challenge. Such cells must meet multiple criteria - they should offer the highest possible efficiency while maintaining low weight, as well as provide adequate mechanical flexibility and resistance to environmental conditions. In student research projects, an additional important factor is their market availability and cost.

The paper discusses third-generation Maxeon cells, which have already been used in the team's designs and tested in terms of efficiency and performance under flight conditions. Since their development, many improved and innovative photovoltaic technologies have emerged, such as GaAs (gallium arsenide) cells and rapidly advancing perovskite cells, which motivated the team to conduct a comprehensive review of available solutions.

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AGH Eko-Energia

Comparative Analysis of Photovoltaic Module Manufacturing Methods for the Solar Car „Perła"

This presentation is dedicated to the analysis and comparison of two methods for manufacturing lightweight, flexible crystalline silicon (c-Si) photovoltaic modules. The project is carried out by members of the AGH Eko-Energia as part of the construction of a solar car that will compete in international solar car races in Belgium. The PV modules, intended for mounting on the vehicle's roof and hood, are handcrafted by team members using advanced composite technologies.
The analysis compares the vacuum infusion method with RTM-Light technology. While infusion was tested on modules in a 1x2 cell configuration, RTM technology is successfully being implemented for larger 2x3 cell structures. The study indicates that the RTM-Light method offers superior process repeatability, which guarantees identical mechanical parameters for all manufactured panels. Additionally, these modules are characterized by a higher quality of finish and visual aesthetics, which are essential for both the vehicle's aerodynamics and its overall presentation.
The choice of RTM technology is optimal in the context of the planned production scaling to a target layout of 2x12 cells. The use of a dedicated metal mold will allow for the highest dimensional precision and durability of the composite structures, which are indispensable during demanding endurance competitions.

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KN Green Energy

Computer-Based Analysis of Energy Efficiency in Single-Family Buildings

The paper presents issues related to improving energy efficiency in single-family buildings in the context of contemporary problems and challenges of the energy sector, as well as the growing role of residential construction as one of the main areas of energy consumption and its potential for reducing energy demand. The key aspects analyzed in the paper include reducing dependence on energy prices and their volatility, as well as limiting building emissions. As part of the work, a concept of a computer-based decision support system was developed to support decision-making in the selection of solutions that improve the energy efficiency of single-family buildings. The system is intended to enable the analysis and comparison of different thermal modernization variants, taking into account both technical and economic aspects. Additionally, the developed system is to include the selection of more efficient and less emission-intensive heating systems, the use of renewable energy sources, energy storage, and the application of intelligent energy management systems using artificial intelligence tools.

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KN FENEC

Waste? Not this time! Or how to feed an SOFC with leftovers.

Biomass is currently one of the more important renewable sources of carbon. It is characterized by a wide diversity of chemical composition, and its thermal processing makes it possible to obtain carbon materials with varied physicochemical properties. As a result, biomass can be treated as an attractive precursor for biochars, which find applications in energy technologies. The proper selection of biomass type and processing conditions allows their use as a solid fuel in solid oxide fuel cells (SOFCs).

This paper presents the results of our own research on the use of selected biomass wastes—glucose, buckwheat groats, and orange pomace—as fuels after pyrolysis. The biomass was subjected to thermal treatment in an inert (N_2) atmosphere over a temperature range of 300–850 °C. In this way, biochars with diverse physicochemical properties were obtained. Their crystalline structure (XRD) and morphology (SEM) were analyzed for both the raw biomass and the produced biochars. The aim of the study was to evaluate the role of gaseous products (CO, CO_2) in fuel oxidation processes, as well as the influence of mineral components of biomass on the reactivity of the obtained materials, and to determine the maximum power achievable from the cell. The influence of the type of biomass on the operating parameters of the electrochemical system was analyzed.

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KN FENEC

Comparison of battery performance characteristics in electric bicycles with fuel cell assistance 'H2 Bike' and 'H2 Rickshaw'

Due to the rising costs of climate change, it is necessary to reduce the consumption of fossil fuels. For this reason, electromobility is being promoted, and electric bicycles, both "urban" and private, are increasingly appearing in cities. They partially replace combustion-powered two-wheelers. Another low-emission vehicle type is the rickshaw, which is very popular in Southeast Asia.

Guided by future forecasts and EU directives promoting green modes of transport, the FENEC Research Group has developed a hydrogen bicycle, the "H2 Bike," and the "H2 Rickshaw." Although both vehicles are fuel-cell-assisted, they employ different technologies: the H2 Bike provides pedal-assist assistance, while the Rickshaw also offers the option of using only the battery as an energy source for driving, without the need to pedal. Our system incorporates a hydrogen-powered PEMFC fuel cell system, designed to extend the vehicle's maximum range. This paper presents and compares the results of experimental tests conducted during urban drives, where both vehicles traveled the same route to Kościuszko Mound. The energy efficiency of the vehicles was characterized, their range was determined, and the required battery charging and hydrogen tank filling times were determined.

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