Dennis Gabor Memorial Year

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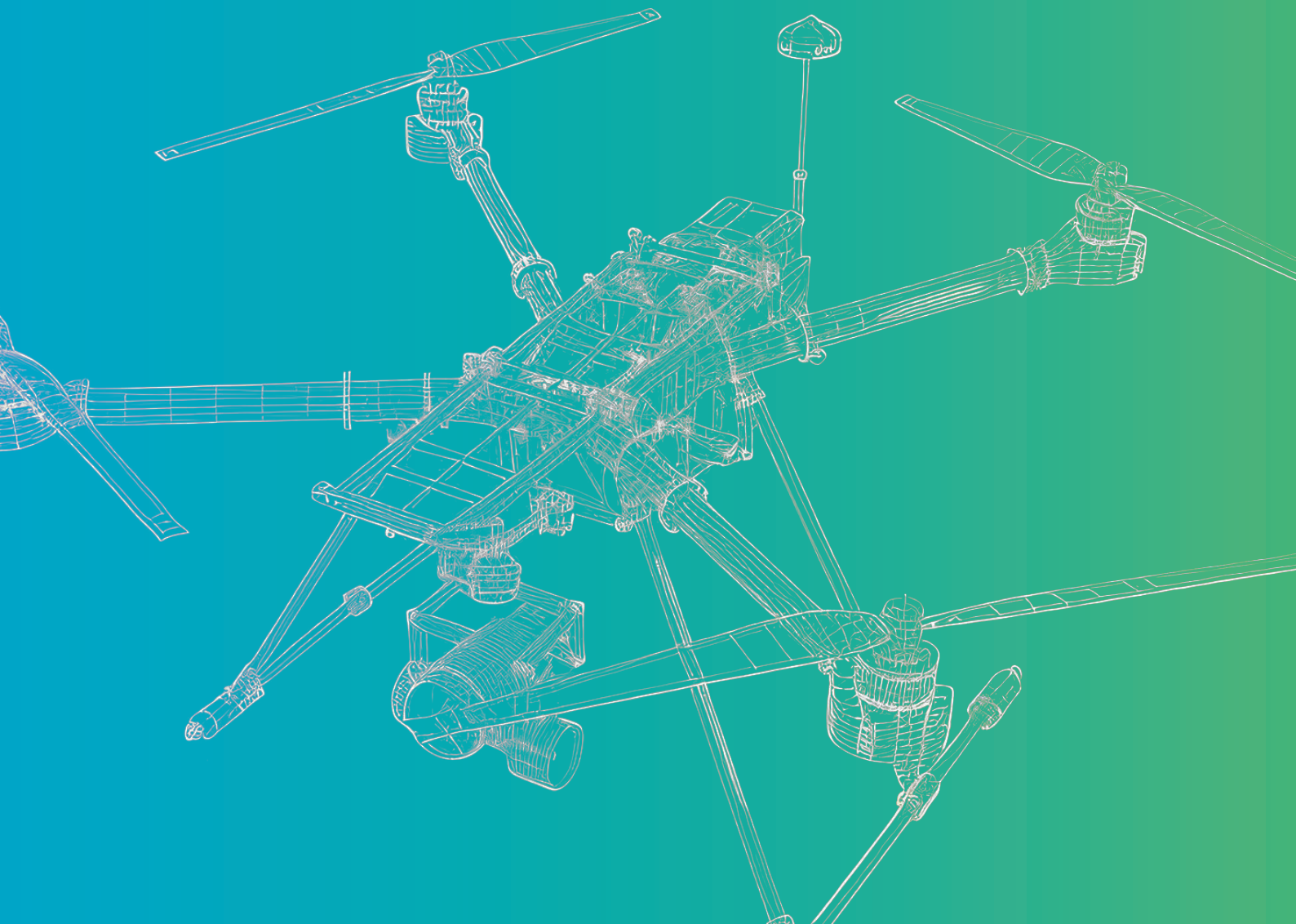
FDFV2026

THE FUTURE OF DRONEDATA
THE FUTURE OF VISION

ABSTRACT VOLUME



FDFV2026

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DENNIS GABOR UNIVERSITY

DIGITAL HORIZONS

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10:10-12:10 PLENARY PRESENTATIONS (PLENARY SESSION CHAIR / DÉNES GÁBOR TEREM)

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- **Biró Lóránt** - Information Security Awareness Training at the Gábor Dénes Association
- **Ruttler Violetta** - Drone Resilience at the European Union
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- **István Fazekas** - Less Guesswork, More Accuracy: Drones in the Era of Digital Twins
- **Veronika Kozma-Bognár** - The Role of Virtual Reality in Drone Education
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SESSION CHAIR: JÓZSEF BERKE

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- **Marcel Berzéki** - Comparative Analysis of Multispectral Drone Surveys
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PLENARY SESSIONS

DRONE TECHNOLOGY AND IMAGE PROCESSING AT DENNIS GABOR UNIVERSITY

Prof. Dr. József Berke[1]
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Abstract: The integration of drone technology and unmanned aerial vehicles (UAVs) into remote sensing workflows has fundamentally changed the methodology for collecting and analyzing high-resolution data. The presentation primarily presents the latest scientific results of the Department of Drone Technology and Image Processing of Dennis Gabor University (DGU). The research focuses on hypertemporal UAV imaging recorded in different spectral ranges, the evaluation of raw sensor data based on mathematical algorithms, and data fusion procedures. The presentation describes in detail the methods developed by DGU researchers, which combine the basic algorithms of image sensors, entropy-based examinations, and image structure analyses with classification supported by artificial intelligence (AI). Model-based results that address the challenges of multitemporal aerial imagery processing and data fusion, improving the accuracy of automated target detection, will be presented. The presentation will also cover validated practical applications – including precision crop protection, environmental geospatial information technology and complex vegetation analysis, demonstrating the direct industrial and environmental applicability of theoretical informatics research conducted at Dennis Gabor University.

Keywords: UAV data fusion, entropy, spectral fractal dimension, GDE, vegetation analysis, environmental protection

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LATEST GEOAI TECHNOLOGIES OF NV5: GEOAGENT, ENVI AGENT AND ENVI DEEP LEARNING

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Abstract: GeoAI is the integration of artificial intelligence (AI) with geospatial data and technologies to analyze and solve spatial problems. As GeoAI continues to reshape how geospatial insights are generated, delivered, and used, NV5 Geospatial [1] has a clear vision that spans the full progression of geospatial work, from desktop level actions to enterprise scale execution.

The latest ENVI Deep Learning 4.0 release [2] introduces an open ecosystem for AI model integration based on the Open Neural Network Exchange (ONNX) standard, which enables organizations to develop, reuse, and share models across platforms. ENVI Deep Learning supports object detection, pixel segmentation, and grid classification, with GUI and API access covering labeling, training, and inference, to ensure both usability and technical rigor.

To extend capabilities from analysis to operational execution, NV5 recently introduced GeoAgent [3], an agentic AI geospatial orchestration platform that enables automated data discovery and analysis through natural language interaction. Hosted by NV5 and powered by the Model Context Protocol (MCP), GeoAgent is a configurable, multi-tenant Software-as-a-Service (SaaS) solution, with user management, secure data access, tool customization, and AI auditability. It is designed for organizations with enterprise-scale processing needs and repeatable workflows that operate within broader system contexts.

At the desktop level, NV5 has introduced IDL and ENVI Agent [4]. These agentic partners enable natural language interaction for IDL scripting and the planning and execution of complex remote sensing workflows in ENVI. IDL and ENVI Agent are Desktop based, AI integrated extensions for Visual Studio Code (VSCode) that enable agent style workflows by combining GitHub Copilot's Large Language Models (LLMs) for reasoning with Model Context Protocol (MCP)-based tool integration of IDL and ENVI, orchestrated and hosted by VSCode.
These latest GeoAI technologies, part of NV5's broader suite of GeoAI services and solutions [5], demonstrate how innovative GeoAI technologies can further streamline end-to-end

geospatial processing, by reducing the time from data collection to decision-making through faster discovery, efficient processing, and improved productivity.

Keywords: GeoAI, Geospatial workflows, Earth Observation, Deep Learning, ONNX, Agentic AI, Model Context Protocol (MCP)

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PRACTICAL APPLICATIONS OF POINT CLOUDS, BIM ANALYSIS, AI-BASED POINT CLOUD CLASSIFICATION

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Abstract: Today's modern laser scanners can capture a millimeter-accurate digital replica of reality in a matter of minutes, which we call a point cloud. This digital dataset enables a wide range of applications: we can create 2D floor plans and 3D models from it, which are integral parts of BIM processes, or even integrate them into facility management systems, where we can supplement existing data with spatial information. During the presentation, concrete examples will be used to demonstrate the capabilities of the Leica Cyclone 3DR point cloud processing software for 3D tracking of construction work, comparing it with plans, identifying and documenting deviations, and monitoring construction progress.

Keywords: BIM, AI, Point Cloud Classification

SHALLOW WATER DRONE APPLICATIONS AND TOOLS

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Abstract: In this presentation, we will briefly review the

- application areas of various surface (USV/ASV) and underwater drones (UUV, ROV),
- their most important design considerations,
- their most important onboard equipment, and
- their typical sensors (payloads).

The aim of our presentation is to provide assistance to those who are thinking about acquiring such systems to support their shallow water diving, hydrological, hydrographic, environmental research or nature conservation activities, or archaeological work.

Keywords: ASV, USV, UUV, ROV, Sonars, Navigation

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1. UNMANNED AERIAL SYSTEMS (UAS) AND APPLICATIONS

PREDICTIVE SYSTEM FOR ANALYSIS AND ASSESSMENT IN INFORMATION PROCESSING

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Abstract: Since the massive spread of the drone technology is still developing new and further more surprising capabilities are discovered almost daily. The next step is the growing autonomy in operations. The drones as a self-guided, autonomous flying systems – beside of their almost classic functions – might carry out different new missions. Up to know the information collected by them had to be transmitted to the operational center where it had to be processed to be analyzed and assessed as part of the decision-supporting process. [1] This information processing and the whole procedure – in spite of using artificial intelligence (AI) may be too long. There might be circumstances which need immediate decision to avoid lethal outcomes. [2] What if the information processing, the analysis and assessment as a supporting function are deployed on a reconnaissance drone? The functions deployed on the drone might have a new function. It might have predictive capabilities to set up the dynamic ranking of the possible consequences based upon the current assessment. This function brings a higher level of operative decision-making support for the human decision-makers. this new supporting system may be used in disaster management, in military operations and many other fields. [3]

Keywords: autonomy, information-processing, prediction

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DRONES AND SPACECRAFT IN EARTH OBSERVATION: CAPABILITIES, LIMITS, AND TECHNOLOGY TRANSFER

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Abstract: The aim is to compare drones and spacecraft as Earth observation platforms with particular attention to their operating environments, system design logic, mission suitability, and the potential for technology transfer between the two domains. Drones and spacecraft are built for very different operating conditions, so similar mission goals lead to different engineering solutions. Drones are optimized for atmospheric, low-altitude, local missions, where mobility, fast deployment, recoverability, and direct interaction with the environment are key advantages. Spacecraft are designed for launch, vacuum, orbital motion, radiation, and long autonomous service, which makes reliability, redundancy, and lifetime planning central design priorities. Propulsion, power use, remote sensing, communications, materials, and missions are different. Drones are limited by endurance, payload mass, weather sensitivity, and airspace constraints, but they are flexible, repairable, and relatively inexpensive. Spacecraft provide wide-area or global coverage, persistent observation, navigation, and communications services, but they are costly, difficult to service, and constrained by launch and orbital requirements.

Technology transfer between the two domains is valuable. Space engineering contributes robust autonomy, fault-tolerant design, and long-life subsystem thinking, while drone development contributes lightweight sensors, compact electronics, AI, and faster development cycles.

In Earth observation, drones are especially valuable in the civil sector because their high spatial resolution and flexible local data collection support applications such as agriculture, infrastructure inspection, and disaster management. Spacecraft, by contrast, enable continuous and repeated monitoring of large areas in meteorology, environmental protection, and strategic applications, making it possible to track changes over time Drones and spacecraft are not competing but complementary observation systems. Drones are more effective for high-resolution, flexible, local-scale monitoring, while spacecraft are better suited for continuous, repeated, and large-area observation. The strongest technology transfer does not occur through direct hardware reuse, but through shared methods in autonomy, sensing, power management, and system-level design.

Keywords: outer space. atmosphere, drone, spacecraft, technology transfer, Earth observation, remote sensing, autonomous systems, communication systems, orbital dynamics

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THE IMPACT OF NON-DRONE CONTROLLER USE ON UAV CONTROL AND HANDLING COMPETENCE

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Abstract: The aim of this study was to examine whether previous video game experience, especially routine controller use, provides a measurable advantage during the initial acquisition of drone piloting skills. The field experiment involved three equally sized groups: PC gamers, console gamers, and a non-gamer control group. The comparison was based on pre- and post-flight questionnaires, flight log analysis, image-based evaluation, and the assessment of flight time, error rate, and altitude control. Based on previous literature, video game experience was expected to improve visual information processing, reaction time, and spatial orientation, all of which may support UAV operation [1]–[3]. The results largely confirmed this assumption. Participants with gaming backgrounds approached the task with greater confidence and completed it faster and with fewer errors than the control group. Console players achieved the best flight times overall, while the PC group performed most accurately in task execution and photographic results. In contrast, the control group showed clearly weaker performance in both speed and precision. The findings suggest that prior gaming experience, particularly familiar and reflex-like controller handling, can offer a real practical advantage in the early learning phase of drone control. At the same time, the limited sample size indicates that these results should be further validated in larger-scale studies.

Keywords: UAV, drone control, video game experience, controller use, cognitive skills, field experiment

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APPLICATION OF UAV IN RESEARCH AND EDUCATION AT THE UNIVERSITY OF SOPRON

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Abstract: We have been dealing with UAVs, as a platform for different sensors in our various research projects for twenty years at the University of Sopron. While our research interests have not been changed much in the past two decades – we primarily examine individual ecosystems or their components in forested and natural environments – technological development has been very significant during this period. Starting from independently built and assembled devices, we have now reached fully operational boxed products. During this period, significant development has also occurred in terms of certain sensors; while previously the traditional RGB cameras were the most important payloads, today these have undergone very significant development in themselves, and have been supplemented with other passive and active sensors. In terms of passive sensors – in addition to RGB cameras – we have obtained significant experiences using multispectral and thermal cameras, and in terms of active sensors, laser scanners are the ones that are of paramount importance in our research. In the framework of the presentation, we would like to present a cross-section of our research, during which we conducted various surveys in forest and natural areas, in leaf-on and leaf-off conditions, from which we produced orthophoto mosaics, various surface models, digital terrain models, digital surface models, and 3D models, effectively supporting research tasks. Based on the research tasks so far, we also predict future research directions and opportunities. In addition to the research, the drone pilot training launched at our University two and a half years ago and the related experiences will also be presented.

Keywords: drone, forest, orthophoto, DTM, DSM, 3D-model, drone-pilot

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CROSS-PLATFORM INFERENCE OF UAS OBJECT DETECTION SYSTEMS

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Abstract: Unmanned Aerial Systems (UAS) are increasingly used in applications such as environmental monitoring, infrastructure inspection, and illegal waste detection, where reliable object detection is essential. In these scenarios, system performance depends not only on the underlying deep learning model, but also on the computational environment in which inference is executed. This highlights the need for structured evaluation approaches that consider both model behavior and platform-specific characteristics.

This study examines how a YOLOv8-based object detection model can be evaluated across multiple execution contexts, including a local GPU workstation, an embedded edge device, and a cloud-based CPU environment. A unified inference and benchmarking pipeline are proposed to support consistent comparison across platforms using identical data and model configurations.

Recent works have introduced composite metrics that combine accuracy with system-level factors such as inference time, resource usage, and energy consumption. In contrast, in this study I examine a different approach by evaluating two complementary metric sets: detection performance (e.g., accuracy-related measures) and execution characteristics (e.g., latency and throughput), allowing clear interpretation of platform-dependent behavior.

In addition, a lightweight model modification is considered using a brightness-derived RGB index (BI) as an additional input channel. This enables preliminary analysis of potential trade-offs between detection performance and computational cost within the same evaluation framework.

The proposed approach provides a structured basis for cross-platform comparison in UAS object detection and contributes toward establishing a foundation for future industrial deployment scenarios, including both edge-based onboard systems and vendor-mediated integration pathways, as well as extensions toward multispectral data processing.

Keywords: UAS, object detection, YOLOv8, inference benchmarking, edge computing, cross-platform evaluation, neural network modification

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2. DRONES IN HUNGARIAN AND EUROPEAN EDUCATION AND SECURITY

INFORMATION SECURITY SURVEY OF DRONE DATA AT DENNIS GABOR UNIVERSITY

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[3]Professor, Dennis Gabor University, berke.jozsef@gde.hu

Abstract: Nowadays, the use of unmanned aerial vehicles (UAV) is becoming more widespread, and thanks to continuous development, they have become decisive in more and more application areas. Although the rapid development of drones creates many new application opportunities, they also carry significant risks if they are not used consciously. All this highlights the need to pay special attention to raising public awareness. Within the framework of the Information Security Complex Research Program at Dennis Gabor University, a nationwide questionnaire survey was conducted in 2025, which examined the application practice of drones and drone data, as well as their information security aspects, with the participation of more than 3,000 people. The questionnaire contained a total of 61 questions with nominal and ordinal scales. To group the responses in an objective way, we used hierarchical, agglomerative cluster analysis (farthest neighbour method with squared Euclidean distance calculation) to determine which attitude groups could be distinguished. A total of 5 groups were created, which significantly reflect the age groups. Based on the processing of the questions and the above-mentioned groups, it can be said that the younger age group has already encountered drones at events - while this is not typical for the other age groups. Those between 30 and 40 years old do not have information about the drones application areas, unlike those between 50 and 60 years old, who have already heard about the most areas. During learning new technological tools, the age group over 60 usually needs help, but it is typical for all age groups that they only learn the new technological tool that they definitely need. When asked whether they would make the image data available for any educational, research or commercial purposes, most people answered no, unanimously and regardless of age group. The results obtained during the entire survey provided the basis for the development of the information security awareness portal of Dennis Gabor University.
Project no. TKP2021-NVA-05 has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the TKP 2021 funding scheme.

Keywords: drone, information security, survey, questionnaire

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DRONE-BASED INNOVATIVE SOLUTIONS AT THE SZOLNOK CAMPUS OF THE UNIVERSITY OF PUBLIC SERVICE LUDOVIKA

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Abstract: The Szolnok Campus of the Faculty of Military Sciences and Officer Training at the University of Public Service Ludovika (UPS) serves as a strategic hub for the air force officer training of the Hungarian Defence Forces. Beyond its primary educational mandate, the institution maintains a robust research and development profile, centered on the innovative applications of Unmanned Aerial Systems (UAS). This paper aims to present the drone technology research conducted at the Szolnok Campus, which addresses contemporary challenges in modern warfare and aviation safety.

Recent developmental projects span several interdisciplinary fields. A primary research direction involves the design of drone-based meteorological measurement platforms and forecasting models, which facilitate more accurate local prognoses through vertical atmospheric profiling. To enhance operational capabilities, the application of drones as communication relay points was investigated, ensuring the continuity of data transmission even in the absence of critical infrastructure. Furthermore, innovations in flight safety focus on the automated, UAV-based detection of Foreign Object Debris (FOD) on runways, thereby minimizing the risk of human error. The research portfolio also includes powertrain optimization, which directly improves system operational reliability by increasing energy efficiency and flight endurance.

The presented innovations exist in close symbiosis with the modernization of officer training, ensuring that future air force officers become proficient in the tactical and technical potential inherent in unmanned systems during their commissioning. These results not only enrich scientific discourse but also contribute directly to maintaining the technological superiority and operational safety of the Hungarian Defence Forces.

Keywords: air force officer training, Unmanned Aerial Vehicles (UAV), meteorology, aviation safety, FOD detection,

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EDUCATION OF DRONE TECHNOLOGY AT DENNSI GABOR UNIVERSITY

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Abstract: Nowadays the drone technology is one of the most dynamically developing technological areas. The development of unmanned vehicles has accelerated significantly in the past decade. Devices previously used primarily for military purposes have become indispensable in many areas of the economy and science. Their application is no longer limited to the technical implementation of data collection but has become a complex system that includes the development of sensor technology, the processing of big data, and the application of analysis methods based on artificial intelligence.

The operation of drones, the planning of data collection, the processing and analysis of data, and their legal use require complex, interdisciplinary knowledge. Higher education plays a decisive role in ensuring that drone technology becomes a tool that generates really social and economic value, thereby contributing to increasing innovation and ensuring the supply of highly qualified professionals.

Dennis Gabor University (previously Dennis Gabor College) has been engaged in education related to remote sensing, GIS and image processing for more than 30 years. In the field of drone technology, our institution was the first to launch the master's degree in Computer Science Engineering with a drone technology specialization in 2023. Currently, in addition to Hungarian, our MSc in computer science engineering and in business informatics programs can be enrolled in English. The aim of our training is to train professionals who are capable of using unmanned aerial vehicles (UAVs), comprehensively planning operations, and interpreting and practically utilizing the related data collection and data processing processes. The related educational materials are published at several training levels and in different courses, with particular attention to real-world practical applications and project-based learning. The education of drone technology, led by Department of Drone Technology and Image Processing, is closely linked to the research and development activities at the university, which enables the integration of the latest technological solutions and methods into education. Experience so far shows that our training contributes to the acquisition of high-quality, marketable knowledge by students, with particular attention to

the processing and practical application of drone data in various industrial and research areas.

In our presentation, we will present the training structure of Dennis Gabor University related to drone technology, the methodology of theoretical and practical education at multiple training levels and majors, and the results achieved. We will review how the subjects and training elements build on each other, ensuring gradual, competency-based knowledge development for students. We will also discuss the significance of the talent development activities in our Talent Support Center, as well as how the educational process supports the development of students' independent problem-solving skills and professional thinking.

Keywords: drone technology, education, computer science engineering MSc, business informatics MSc, Talent Support Center, projektwork, remote sensing, GIS, image processing, artificial intelligence

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DRONES AND RESILIENCE IN THE EUROPEAN UNION

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Abstract: Act LXXXIV of 2024, the European CER Directive, and the NIS2 Directive together form a new regulatory framework that fundamentally transforms the way we think about the security of critical organizations and makes it clear that physical and digital protection can no longer be treated in isolation from one another. This presentation examines ways to enhance the resilience of critical infrastructure from the perspective of unmanned aircraft systems (UAS), building on theoretical and legal frameworks. The “all-hazards” approach defined by the Critical Entities Resilience (CER) Directive highlights that modern threats—particularly hybrid and chain-reaction effects—require complex, multidimensional responses that go beyond the toolkit of traditional physical security.

This research demonstrates how drone technology can support the threefold functions of prevention, detection, and response in the protection of critical infrastructure. The use of UAS systems enables real-time surveillance of large or hard-to-reach areas, rapid situational awareness, and increased efficiency in operational responses to incidents. In addition, they contribute to risk analysis and resilience planning, particularly in the integrated protection of supply chains and physical-cyber systems.

The presentation emphasizes that drones should not be viewed as a standalone solution, but rather as complementary elements of complex facility protection systems—including manned guarding, security technology, and security protocols. Fitting into the concept of complementary policing, the use of UAS technology facilitates cooperation among state, market, and civilian actors. The explosive development of drone technology also opens up new opportunities for the private security sector. Drones are not only suitable for increasing territorial coverage but also for modernizing the work of personnel and making it more efficient through the use of smart tools.

Overall, the use of unmanned aerial vehicles offers an innovative and cost-effective means of enhancing the resilience of critical infrastructure, while also raising regulatory, data protection, and operational challenges that warrant further research.

Keywords: private security, resilience, asset protection, critical infrastructure protection, facility security, security awareness

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3. DRONE-BASED DATA COLLECTION AND ARTIFICIAL INTELLIGENCE IN ANALYSIS

A NON-INVASIVE UAV-BASED METHODOLOGY FOR INVESTIGATING FUNGAL FAIRY RINGS IN PANNONIAN GRASSLANDS

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Abstract: The development of drone technology provides new opportunities for observing ecological patterns in grasslands that are often difficult to detect from ground level. The aim of this work is to present a repeatable UAV-based methodology for the non-invasive detection, documentation and subsequent ecological assessment of fungal fairy rings in meadows and pastures. The approach is based on visible-spectrum UAV imagery, orthophotos generated from aerial photographs, and repeated field and aerial observations throughout the vegetation period. The methodology focuses on flight altitude, timing of data acquisition, light conditions, vegetation state and the effects of grassland management. Based on field experience, an altitude of approximately 40 metres provides a practical balance between image detail, flight safety and the comparability of repeated surveys. Fairy rings were most clearly visible in early spring, especially in March and April, when vegetation contrast was high. By early summer, and particularly after mowing or drought periods, the circular patterns became less distinct or disappeared from the aerial images. UAV-derived orthophotos, however, revealed several fairy-ring structures that were not clearly recognizable from ground level. The proposed methodology therefore offers a practical basis for spatially monitoring fungal fairy rings and supports their ecological interpretation as persistent grassland structures. This drone-based approach ultimately leads to the broader ecological question addressed by Balogh et al. (2026): the role of fungal fairy rings as ecosystem engineer structures in Pannonian grasslands.

Keywords: drone data; fungal fairy rings; orthophoto; non-invasive monitoring; Pannonian grassland; vegetation pattern; UAV imagery

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INVISIBLE TRACES IN THE AIR: DRONES AS EMERGING EVIDENCE CARRIERS IN THE DIGITAL DOMAIN

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Abstract: The rapid proliferation of unmanned aerial vehicles presents new challenges and opportunities in the field of drone forensics. The telemetry, navigation, sensor, and control data generated during drone operation form a complex digital trace system capable of supporting event reconstruction, incident interpretation and evidence-based decision-making. Rather than focusing on data extraction techniques, the presentation examines drone-related events through a data-reconstruction-oriented analytical lens. It explores how different categories of drone incidents foreground distinct patterns of data generation, and how these data types can contribute to subsequent forensic interpretation. The examined domains include accident and malfunction reconstruction, the post-event analysis of criminal drone use, the assessment of border-security and airspace-intrusion incidents, and the interpretive potential of data produced during regulatory or authority-driven test flights. Since the field of drone forensics currently lacks universally accepted standardization, the systematic mapping of its investigative domains represents scientific value in its own right. Moreover, comparing drone-generated data with other sensor and RF data sources opens new avenues for reconstruction that extend beyond the boundaries of traditional digital evidence analysis. The presentation outlines a conceptual framework that views drones as autonomous, data-producing objects—systems whose forensic value extends far beyond current practice and calls for new approaches to the evaluation of digital trace ecosystems.

Keywords: Drone forensics, Digital trace systems, UAS/UAV incident reconstruction, Sensor and RF data fusion, Forensic data prioritization, Airspace and security incidents

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THE CHALLENGES OF INTEGRATING VIRTUAL REALITY (VR) AND UNMANNED AERIAL VEHICLES (UAVS, DRONES)

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Abstract: The integration of virtual reality (VR) and unmanned aerial vehicles (UAVs, drones) opens up new possibilities in industrial, defense, educational, and civilian applications, particularly in the areas of remote-controlled operations, real-time surveillance, and human-machine interaction. The aim of this study is to explore the current challenges arising from the combined use of VR and drone technologies, with a particular focus on dynamic VR solutions and the cybersecurity protection of related peripheral devices.

The analysis highlights that the dynamic, immersive interfaces of VR-based drone control systems significantly increase operational efficiency, while also generating complex technical challenges. Real-time data streams, high-resolution video streams, and the integration of information from multiple sensors impose significant computational and network loads, which can lead to scalability and latency issues. Dynamic VR solutions — such as motion tracking and haptic feedback-based controls — offer new interaction paradigms, but they also increase system complexity and the potential for errors.

From a cybersecurity perspective, VR-drone integration is particularly risky, as the two technologies together create an expanded attack surface. The sensor-based operation of VR systems, their collection of biometric data, and their network connections enable new types of attacks, such as sensor spoofing, data manipulation, or identity theft. At the same time, drones' communication channels and control systems are also vulnerable, particularly in cases of weak encryption, inadequate authentication, or outdated software, which could allow for control takeover or the manipulation of data streams.

Peripheral devices — such as VR headsets, control interfaces, communication modules, and IoT-based sensors — pose additional security challenges. These devices are often integrated into heterogeneous architectures, which makes it difficult to apply uniform security standards and increases the risk of supply chain vulnerabilities. Since VR systems can essentially be interpreted as IoT devices, traditional IT threats — such as data leaks, malware, and network attacks — are directly applicable to these environments.

The study emphasizes that the safe operation of combined VR and drone systems requires an integrated, multi-layered security strategy. This includes end-to-end encryption, real-time anomaly detection, a “security-by-design” approach, and ensuring forensic readiness. According to our findings, future research should prioritize the secure adaptation of dynamic VR interfaces and the standardized protection of drone ecosystems to ensure reliable and resilient digital operations.

Keywords: virtual reality, dynamic VR, UAV, immersive interface, security-by-design

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EVALUATION OF CLASSIFICATION ALGORITHM EFFICIENCY USING UAV IMAGERY

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Abstract: Remote sensing is widely regarded as one of the most effective approaches for monitoring aquatic vegetation [1]. The aim of our study was to assess the surface cover of the Kísérleti-tó, located in the Kis-Balaton, for the year 2024, thereby extending our previous research [2]. The primary objective was to differentiate open water surfaces from the vegetation present on them using multispectral remote sensing data. Aerial data acquisition was conducted using a DJI Mavic 3 Multispectral UAV; the ultra-high-resolution imagery was processed, and alignment was performed utilizing Agisoft Metashape. During preprocessing, the study area was restricted to open water surfaces, which were manually delineated and extracted from the ortophoto using Adobe Photoshop. By excluding the influence of terrestrial vegetation, the complexity of the classification task was significantly reduced. Three classes were defined for the classification: open water surface, floating vegetation, and background. Multiple classification algorithms were applied, and their results was evaluated using the Kappa statistic. In general, higher surface coverage was observed during warmer months with increased solar radiation. Based on the comparison, the Support Vector Machine algorithm achieved the highest accuracy (99.34%), followed by Maximum Likelihood (97.63%), Mahalanobis distance-based classification (96.28%), and Minimum Distance (95.16%). The Parallelepiped algorithm showed lower, yet still acceptable results (89.1%). The high accuracy values can primarily be attributed to the suitable spectral separability of the classes, consistent with findings reported in the literature [3]. The reflectance values of open water and vegetation differ significantly, especially in the Near-InfraRed range, enabling reliable separation [4,5]. Additionally, the distinct spectral characteristics of the background contributed to increased overall accuracy. Our results demonstrate that, with appropriately prepared data and a purposefully defined study area, multispectral remote sensing methods can be effectively applied for detailed and accurate analysis of surface cover in aquatic environments.

Keywords: UAV, remote sensing, image classification, algorithm, Kappa statistic

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DRONE FORENSICS AI-PIPELINE: RECONSTRUCTION OF INCOMPLETE TELEMETRY AND AUTOMATION OF EVIDENCE INTEGRITY

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Abstract: With the proliferation of Unmanned Aerial Vehicles (UAVs), the forensic analysis of flight data has become a critical necessity. The objective of this research is to develop an automated digital forensic pipeline based on open-source components capable of detecting and flagging data loss, intentional manipulation, and anomalies caused by GPS spoofing.

The relevant literature has identified the fundamental forensic and methodological challenges of storing and preserving drone data. LSTM-based models have established a theoretical foundation for machine learning-driven telemetry correction. This presentation integrates these findings into an end-to-end workflow, augmenting it with the sequential predictive capabilities of modern transformer architectures.

The core of the system is a hybrid LSTM-Transformer model that interpolates missing data points by considering physical flight constraints and weather data. The study incorporates a multi-level validation layer that detects manipulation through correlation analysis of IMU and GPS data. The workflow is orchestrated by the n8n engine, utilizing open-source tools for Big Data-based processing. The integrity of the evidence is guaranteed at every analysis step by an SHA-256 hash function, ensuring the integrity of the digital chain-of-custody. The output of the research is an ISO 27037 compliant, LLM-assisted expert report, which can be directly utilized in legal and evidentiary proceedings.

Keywords: drone forensics, UAV telemetry, LSTM-Transformer, data reconstruction, digital evidence, n8n automation, GPS spoofing, ISO 27037

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4. UAV IMAGE PROCESSING: OBLIQUE AND MULTISPECTRAL TECHNOLOGIES

APPLICABILITY OF MULTISPECTRAL SENSORS IN THE FIELD OF FIRE DETECTION

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Abstract: The objective of my research is to examine the effectiveness of advanced remote sensing technology, specifically multispectral sensors, in the field of fire and smoke detection. A common technical characteristic of traditional optical smoke detectors is that the sensor typically needs to come into direct contact with an accompanying phenomenon of fire, such as smoke or heat, to trigger an alarm. In facilities operating fire alarm systems, additional challenges can arise from the significant number of sensors, the often complex technical installation requirements, and the potential increase in false alarms due to visual disturbances. My research is directed towards the theoretical validation of the feasibility of a technical solution that utilizes multispectral sensors to make fire detection simpler and faster. During an experiment, I performed smoke and flame texture imaging using a DJI Mavic 3 Multispectral drone to subject the recordings from the green, red, red edge, and near-infrared (NIR) bands to image classification procedures following image pre-processing. The goal is to detect the presence of flame and smoke in a verifiable manner at the early stage of a fire without direct sensorial contact. The methodology was based on imaging performed under real-world, on-site conditions, pre-processing the resulting image data in Photoshop and ENVI software environments (modeling), and then analyzing the results of various image classification procedures in ENVI.

Throughout the workflow, I paid special attention to preserving the radiometric integrity of the image data. For spectral classification, I examined the usability of various algorithms, including supervised (e.g.,Maximum Likelihood) and unsupervised (e.g., IsoData, KMeans) methods. I intend to present the professional issues of the applicability of multispectral technology in preventive fire protection in relation to the results achieved.

Keywords: multispectral, smoke detector, fire alarm system, supervised classification, unsupervised classification

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INVESTIGATING THE TRACEABILITY OF YOLO MODELS

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Abstract: The presentation introduces a research project whose primary objective is to investigate the traceability of leaked YOLO object detector models using black-box and whitebox methods. The research presented examines not only behavior-based and parameter-level watermarking solutions, but also addresses data authenticity, the assurance of AI pipeline integrity, and the preservation of dataset integrity.

The presentation describes the research's multi-layered approach. On the dataset side, data provenance is included, together with cryptographic authentication and digital signature mechanisms associated with images, annotations, models, and logs. It also discusses the applicability of steganographic markings embedded in image training data, as well as visual watermarks placed on a subset of the images. The black-box investigations follow two directions: first, a method in which the watermark acts as a secret trigger influencing model behavior; second, an approach in which verification is based on a separate output class. In parallel, the white-box approach examines the use of fingerprint embedding in the neural network based on parameter regularization, without modifying the model architecture.

The central question of the presentation is to what extent the presented layers of data and model protection are suitable for tracing leaked YOLO models, while origin verification and ownership proof also appear as related application areas.

Keywords: machine learning, object detection models, intellectual property, cybersecurity

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EXAMINATION OF UAV IMAGES MADE WITH OPTICAL AXES OF DIFFERENT INCLINATION

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Abstract: Most UAV-based imaging traditionally relies on vertical-axis optical captures, which are primarily suitable for accurately mapping the horizontal structures of the surface. However, vertical or near-vertical surfaces, such as the sides of tree canopies, artificial or natural walls, appear only partially, incorrectly, or not at all in nadir images. Oblique images mitigate these errors and deficiencies because they provide lateral geometric information, thereby reducing the shortcomings arising from nadir imaging (Vacca et al., 2017). In my thesis, I examined how UAV images captured from an area with diverse vegetation at different optical axis angles affect the information, models, and accuracy obtainable during photogrammetric processing, in comparison to each other and to nadir-only images.

The research related to my study is not only investigating whether oblique mode recording is useful, but also at what camera tilt angle, at what flight altitude, and with what degree of overlap setting it provides the best results for different surface types.Based on previous studies, camera tilt angles between 20° and 45° from nadir best assist in improving the model and the point cloud density. The selection of the appropriate camera tilt angle strongly depends on the properties of the area to be surveyed. In highly contoured areas with many steep or vertical high surfaces, the use of oblique imaging is essential to ensure the desired result. (Kyriou et al., 2021; Agüera-Vega et al., 2024)

Keywords: UAV, oblique, nadir, camera tilt angle

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COMPARATIVE ANALYSIS OF OBLIQUE IMAGING

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Abstract: The rapid spread of UAV-based photogrammetry has opened new possibilities for the survey of protected wetlands {1}. However, the direct comparison of consumer and industrial-grade drones - both widely available today - under identical field conditions appears relatively less often in the literature {2}. I present such a comparison through the example of a survey carried out at the Kis-Balaton area. Two oblique imaging systems of different categories were examined in two consecutive years (2025 and 2026): the DJI Mavic 3 Multispectral, a compact gimbal-controlled consumer platform, and the DJI Matrice 300 RTK industrial drone equipped with the Share UAV PSDK 102S V3 oblique camera system. Data acquisition followed the same flight plan in both years, and processing was carried out in a unified environment using Agisoft Metashape. The spatial comparison was performed in QGIS using the DEM of Difference (DoD) method. The results show that the industrial system provides systematically higher geometric accuracy and point cloud density, but this advantage is not uniformly distributed across the surface. On homogeneous reed area the two systems yield nearly identical results, while around wooded and shrubby areas the industrial system proves clearly superior {3}. Remarkable that both systems performed reliably under windy conditions as well. This suggests that a higher number of images and stronger block geometry can compensate for uncertainty arising from platform micro-movements. Based on my research, device choice is more task-dependent than category-dependent. The consumer platform is better suited to flat-area surveys with multispectral data needs, while the industrial system offers added value where high-precision 3D reconstruction of detail-rich terrain features is required. The combined use of the two systems can provide an effective methodological basis for the long-term study of complex wetland habitats.

Keywords: UAV photogrammetry, oblique imaging, wetland survey, DEM of Difference, Kis-Balaton, Agisoft Metashape

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5. MULTISPECTRAL, LIDAR AND SLAM TECHNOLOGIES IN PRACTICE

AERIAL AND MOBILE LIDAR-BASED SURVEYING IN RAILWAY DESIGN PROJECTS

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Abstract: The surveying of railway infrastructure increasingly relies on high precision digital spatial data that provides a reliable foundation for design and reconstruction projects. This presentation introduces two advanced data acquisition technologies: the DJI Matrice 300 drone equipped with the L1 LiDAR sensor, and the VMX mobile LiDAR platform mounted on a railway measurement vehicle. Drone based surveying offers extensive area coverage and excellent elevation information, while the VMX system captures millimetre level detail of the track environment and railway facilities. The combination of these two methods results in a complete, high resolution 3D model. The presentation also outlines the processing workflow, including the use of DJI Terra and Metashape for data refinement, as well as integration within AutoCAD Map3D, where slicing large LAS datasets enables memory efficient handling. The workflow presented provides fast, accurate, and unified spatial data that serves as a robust basis for all engineering disciplines involved in railway design.

Keywords: GIS, LiDAR, point cloud, terrain model

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COMPARATIVE STUDY OF VEGETATION INDICES BASED ON MULTISPECTRAL DRONE IMAGERY

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Abstract: Drone technology has become a key tool in remote sensing, GIS, agriculture and environmental monitoring over the past decade. Unmanned aerial vehicles (UAVs) enable high-resolution, time-flexible data collection, which provides a reliable description of the condition of the studied areas. The use of drones is becoming increasingly important in precision agriculture, where exploring the heterogeneity of crop populations is essential. Vegetation indices can be used to identify stress effects, such as water shortage, nutrient deficiency or the presence of plant diseases. This allows for targeted interventions, reducing production costs and environmental burden. The aim of our research is to compare discrete and non-discrete (RGB-based) vegetation indices derived from multispectral drone images to monitor the development of maize during the vegetation period. For our measurements were performed with a DJI Mavic 3 Multispectral drone at flight altitudes of 80 and 120 meters. During the analyses, we also evaluated the correlation, statistical distribution and data content of the indices.

The results indicate that while NDVI cannot be effectively replaced, certain index pairs show a high degree of substitutability: GNDVI and IRGBVI indices showed 81–85% agreement, while OSAVI and MVARI indices showed 80–84%. Increasing flight altitude resulted 4–9% divergence in data trends. It can be said as a results that based on the data content and the close correlation, specific RGB-based indices can enable cost-effective drone technology to provide reliable data for precision agricultural practices.

Keywords: multispectral remote sensing, vegetation indices, precision agriculture, UAV technology

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THE INSTABILITY OF RESPONSIBILITY IN AUTONOMOUS SYSTEMS

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Abstract: The operation of drone systems unfolds within a distributed decision environment in which multiple actors contribute to a single outcome through distinct logics. Sensors generate data, algorithms process inputs, human operators make decisions, and legal frameworks subsequently assign meaning to the resulting action. Although these elements form a continuous chain, they do not constitute a unified interpretive system. This paper focuses on situations in which all components of the system function in accordance with their respective operational logic, yet the resulting outcome deviates from expected behaviour. Such deviation cannot be explained as technical failure. It emerges from transformations of meaning that occur along the interpretive chain. The analysis identifies three recurring points of instability. The first arises at the boundary between data acquisition and algorithmic processing, where the contextual integrity of input information may be altered. The second occurs in the relation between algorithmic output and human decision-making, where generated results are integrated into a different interpretive frame. The third appears between operator action and legal evaluation, where executed decisions and their regulatory assessment do not correspond in meaning. These configurations are not exceptional cases but recurrent structural patterns inherent to system operation. Current compliance and audit practices are not equipped to detect such conditions, as they remain oriented toward technical conformity and formal rule adherence. The paper argues that the legal and operational assessment of drone systems remains incomplete without examining the interpretive chain through which outcomes are produced. Identifying these divergences is not only a matter of system performance but directly affects the attribution of responsibility, as it determines how outcomes can be interpreted within a legal framework.

Keywords: Drone systems, interpretive chain, legal responsibility, algorithmic decision-making, human machine interaction, data processing, compliance, structural divergence, meaning intelligence, MÉDÉSZet, audit

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COMPARATIVE ANALYSIS OF DRONE CAMERAS BASED ON ORTHOPHOTOS

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Abstract: Drone-based photogrammetry has undergone significant development in recent years and has now become one of the defining tools of GIS data collection. As the technology becomes more accessible, there is an increasing demand for comparative analysis of the quality of orthophotos and the performance of the applied camera systems. The aim of this research was to conduct a comparative analysis of four different drone camera systems – DJI Mavic 3 Multispectral (M3M), DJI M30, and Zenmuse L1 and P1 applied on DJI Matrice 300 platform.

Data collection took place in the Kis-Balaton region within a short time interval, ensuring almost identical environmental conditions. The orthophotos were produced according to a uniform workflow using the Agisoft Metashape software, which included image alignment, point cloud generation, digital terrain model creation, and orthophoto production. In order to ensure comparability, all datasets were processed with the same processing parameters.

The study revealed significant differences in the performance of desktop and mobile processing platforms. In addition, it was an important methodological decision not to apply correction procedures (e.g. color correction, contrast optimization, noise reduction) during image preprocessing, as these could have distorted the objective comparability between camera systems.

Based on the results, it can be concluded that the Zenmuse P1 camera system provided outstanding detail and accuracy, while the Zenmuse L1 system could achieve better results with further optimization. The DJI Mavic 3 Multispectral RGB capabilities make it primarily suitable for vegetation monitoring tasks, while the DJI M30 can be evaluated as a balanced, general-purpose solution.

The research points out that choosing the right tool and processing strategy is crucial in drone orthophotography, and depending on the study goals, there may be significant differences in terms of both quality and processing efficiency.

Keywords: drone, orthophoto, DJI, Metashape, photogrammetry

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NAVIGATION OF UNDERWATER DRONES WITH EKF-BASED SLAM METHOD

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Abstract: One of the biggest challenges in underwater robotics is precise navigation. The presentation examines the navigation problem of underwater autonomous vehicles (AUVs), with particular attention to the EKF-based SLAM approach. In the underwater environment, global positioning (GPS) is not available, and sensors operate with significant noise and distortion, resulting in a complex state estimation problem. The presented model applies an Extended Kalman Filter-based SLAM algorithm implemented in a simulation framework, which simultaneously estimates the robot's state and environmental landmarks. The aim of the study is to analyze estimation stability and noise sensitivity in different scenarios. The results show that EKF-SLAM provides stable and consistent estimation under medium noise levels; however, in the case of highly nonlinear dynamics and high measurement noise, linearization errors significantly affect convergence.

Keywords: drone, AUV, navigation, SLAM, EKF, GPS-denied, underwater drone, Artificial Intelligence, noise sensitivity

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6. DRONE TECHNOLOGY IN ENERGY AND INDUSTRIAL OPERATIONS

DETECTION OF ELECTRICAL CONNECTION FAULTS USING DRONE IMAGERY

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Abstract: In this day and age, electrical networks and industrial electrical equipment play a crucial role in our daily lives. One only needs to consider that the vast majority of our household, industrial, and IT devices are powered by electricity. Consequently, it is essential to possess the electrical engineering knowledge required for the safe and efficient operation of these systems.

The objective of this presentation is to provide a comprehensive overview of high-voltage electrical networks, as well as the various types of electrical connections used in the industry and their most common points of failure. Identifying connection faults is of paramount importance, as malfunctioning electrical networks can lead to severe accidents; by detecting and correcting these errors, such incidents can be prevented.

During the presentation, I will demonstrate data and footage captured via drones, which are processed by a custom-developed database management application.

In the concluding part of the presentation, I will discuss the future development potential of the system, showcasing how it can be expanded and enhanced to ensure more efficient data management and broader usability.

Keywords: UAV technology, database, software, development, measure

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RADIOMETRIC DISTRICT HEATING DIAGNOSTICS AND THE METHODOLOGY OF "DHIM" (DISTRICT HEATING INFORMATION MODELLING) FOR EFFICIENT NETWORK MANAGEMENT

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Abstract: This presentation aims to enhance the efficiency of Hungarian district heating services by introducing an innovative diagnostic workflow based on high-resolution aerial thermographic data collection. The methodology is built on radiometric data fusion and dynamic software post-processing. The latter enables the thermal normalization of datasets captured under varying environmental conditions, ensuring data consistency and comparability across the entire network. A key element of the process is precision range filtering, which, by focusing on peak temperatures and anomalies, can detect subtle thermal variations even in deep-buried pipelines. Practical results demonstrate that ground-level validation of anomalies detected from the air is required to ensure localization accuracy within 1 meter, thereby radically reducing the costs of exploratory excavations. Finally, the study introduces the "District Heating Information Modeling" (DHIM) concept, which integrates these validated diagnostic data into GIS and CAD systems via centimeter-accurate orthophotos, providing a robust foundation for predictive maintenance.

Keywords: radiometric thermography, district heating network, DHIM, thermal normalization, ground-level validation, network loss, GIS integration

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AUTOMATED SITE SURVEILLANCE AND CRITICAL INFRASTRUCTURE PROTECTION: THE SYNERGY OF SKYBASE AND DJI DOCK

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Abstract: The protection of modern industrial facilities and critical infrastructure is no longer conceivable without advanced technological support. The rising costs of manned guarding services, combined with the critical importance of rapid response times, have accelerated the adoption of automated drone solutions. This presentation introduces the integrated application of the Hungarian-developed SkyBase on-premise drone platform and DJI Dock "drone-in-a-box" technology in the field of corporate security systems.

The backbone of the presented solution is the hardware of DJI Dock, enabling autonomous drone take-off, precision landing, and rapid charging even under extreme weather conditions. Built on this foundation, the SkyBase software control layer integrates the drone as an active, intelligent sensor into existing surveillance ecosystems (VMS/BMS).

Key topics of the presentation:

- **Immediate Response:** How the system can deliver live video feeds to the dispatch center within 30 seconds of an alarm event (e.g., perimeter intrusion) without human intervention.
- **Data Sovereignty:** The importance of 100% on-premise operation in eliminating cybersecurity risks compared to cloud-based solutions.
- **Operational Efficiency:** The role of automated patrol routes and machine vision-based analytics in reducing the workload of on-site security personnel.
- **Scalability:** Coordinated management of multiple docks and drones across large-scale facilities such as logistics centers, solar power plants, and industrial sites.

Through practical use cases, the presentation demonstrates that automated drone technology is no longer a futuristic concept, but a cornerstone of modern security infrastructure, ensuring faster incident response and a high level of regulatory compliance.

Keywords: Autonomous drones, drone-in-a-box, DJI Dock, SkyBase, physical security, critical infrastructure protection, on-premise security systems, VMS integration, machine vision, automated surveillance.

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THE FUTURE OF DRONEDATA
THE FUTURE OF VISION


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