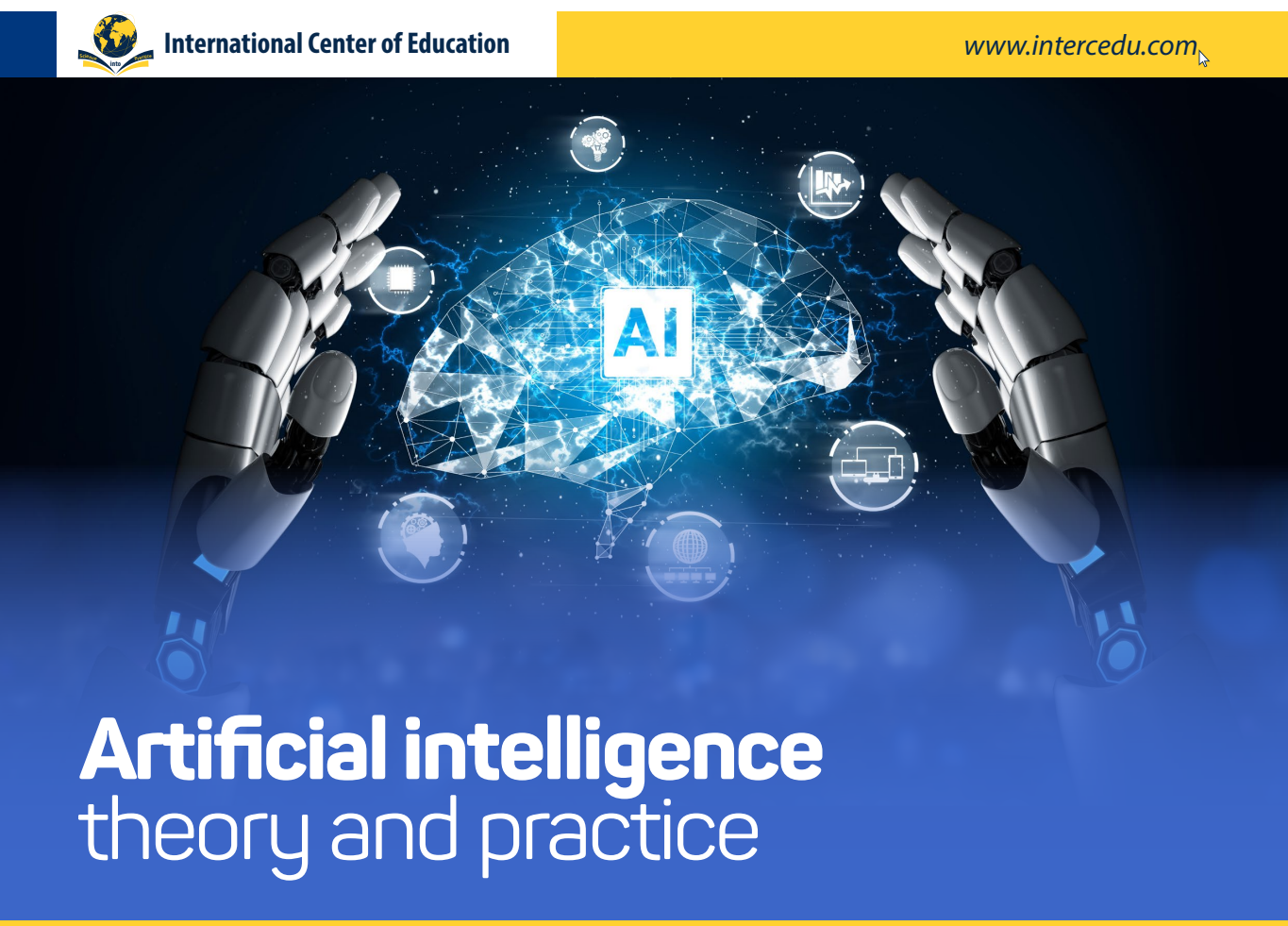


Artificial intelligence
theory and practice

Doc. Ing. Ladislav Hluchý, CSc. · Institute of Informatics SAS, p. r. i., Bratislava

Dr. h.c. mult. prof. Ing. Štefan Luby, DrSc. · Slovak physicist, Chief scientific editor of INTERCEDU, j.s.c.

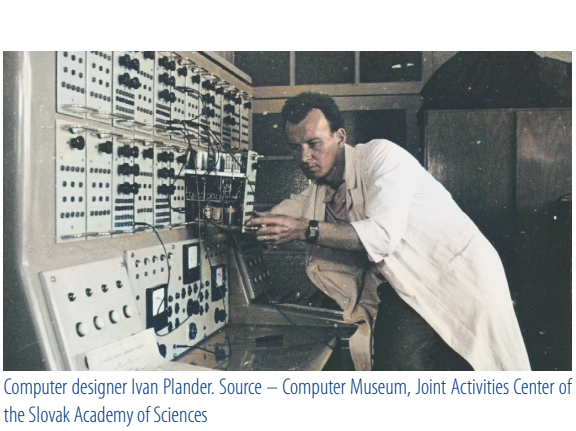
1. Motivation – prologue

In the summer of 2023, the European Academy of Sciences and Arts (EASA), based in Salzburg, signed with INTERCEDU j. s. c. with headquarters in Pezinok Memorandum on cooperation. One of the topics of cooperation is the development of artificial intelligence (AI). The protagonist in this area is the president of EASA himself, prof. Klaus Mainzer, philosopher and historian of science. At the signing of the Memorandum, he gave a lecture on new directions of technology development, including AI, and under his leadership, the EAVU expert group elaborated the road map Digitization, artificial intelligence and social impact, published in a Slovak translation on the INTERCEDU website **[1].**

From left: Prof. Dr. Klaus Mainzer, President of the European Academy of Sciences and Arts in Salzburg and Prof. Štefan Kassay, DrSc. President of INTERCEDU at the signing of the Memorandum of Cooperation.

The UN first resolution on AI adopted in March 2024 **[2]** is an important step for the further development. The UN calls for AI to benefit for all countries, respect human rights, and be safe and trustworthy. UN further appeals to reduce the digital divide between the rich and poor world. The developing world must be provided with technologies and opportunities to use the benefits of AI, e.g. in healthcare, in prediction of floods, helping farmers, training the workforce, etc. The resolution underlined the hot topic of developing competent legislation in the field of AI.

Slovakia is not newcomer to AI. Already before 1990, attention was paid to artificial intelligence at the Institute of Technical Cybernetics of the SAS, whose director was academician Ivan Plander. After the chaotic reorganization of the Institute by the first post-revolutionary SAS Presidency, the current SAS Institute of Informatics was created after further mergers. Under the leadership of doc. Ladislav Hluchý, a member of EAVU and his successors as directors, it demonstrated remarkable viability in the acquisition of EU projects and in applications of informatics including AI products on a broad social basis.


Computer designer Ivan Plander. Source – Computer Museum, Joint Activities Center of the Slovak Academy of Sciences

The aim of this article is to draw attention to the technical assumptions and ethics in the field of AI, to briefly summarize the theses outlined in the EAVU expert report and to compare them with the tasks with which one of the European leaders in this field – the team of doc. Hluchý – responds to the AI current development.

2. Directions of AI according to the EASA roadmap

The large capacity of computers and databases in recent years has made it possible to implement machine learning and workforce education with large volumes of data, leading to breakthroughs in AI applications in industry, economy and social infrastructure. It is necessary to base it on responsible AI, which is a challenge in technology and engineering, but also in ethics and humanities. For AI to be useful, its algorithms must be transparent and explainable. **Explainable AI is considered the next stage of development.**

In the following the roadmap summarizes AI activities mainly in the USA – in the Computing Community Consortium (CCC) and in the Association for the Advancement of Artificial Intelligence (AAAI). It mentions the German plan in the AI, the focus of the European Laboratory for Learning and Intelligent Systems (ELLIS) and the group of experts of the European commission that recently proposed the current definition of AI:

"Artificial intelligence refers to systems designed by humans that, given a complex goal, act in the physical and digital world by sensing their environment, interpreting collected structured or unstructured data, reasoning about insights derived from that data, and deciding on the best actions to take to achieve of the given goal."

Next, according to the EASA roadmap, we will summarize the application areas of AI, which include the main spheres of human existence in the context of the Academy's mission. The use of AI in defense is not discussed here.

***a.* Medicine and health care:**
Healthy life, active aging, remote care, personalized medicine, digitization of medical expertise, managing pandemics, etc.

***b.* Renewable energy and green economy:**
"Green economy" is a priority of strategic interventions to be implemented from the funds of the European Recovery Plan. The advantages and disadvantages of renewable energies, hydrogen, nuclear energy and fusion energy must be considered. For Europe, they must be combined into a "hybrid" energy system. This also includes building efficiency, regulation of heating, cooling and ventilation systems.

***c.* Sustainable innovation:**
Conservation of strategic raw materials, recycling and waste management, smart agriculture and services, resilient and flexible systems with zero errors.

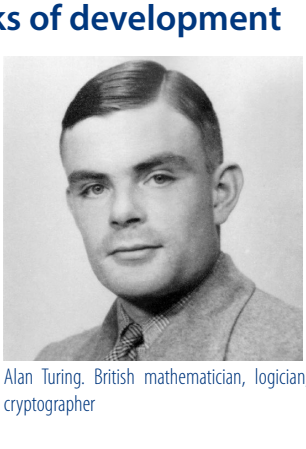
***d.* AI and robotics in the home:**
Household management including smart devices and home robots, enriching knowledge and answering questions, for example through chatbots, etc.

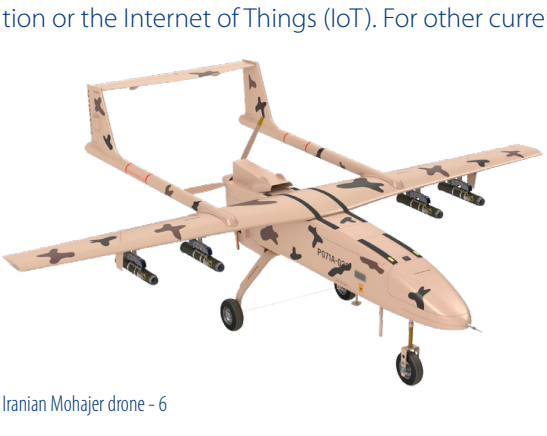
***e.* Digital sovereignty and human autonomy:**
In April 2019, the European Commission published ethical guidelines for trustworthy artificial intelligence. The starting points are human autonomy, self-control, justice, in accordance with European philosophical and traditions, as well as EASA values. Freedom of expression must be protected against attempts to suppress dissent or abuse of freedom of expression and to promote intolerance and hate.

***f.* Cultural heritage for Europe:**
We consider both tangible and intangible cultural heritage. Based on 3D scanning, cultural heritage is moving towards a digital future. We currently have 15% of the world's cultural heritage available in digitized format. This also includes deciphering ancient languages, restoring ancient texts etc.

3. Artificial intelligence – technical and ethical frameworks of development

If we leave aside the futurological theater play of K. Čapek RUR, we can locate the roots of the formation of AI to 1950, when A. Turing published article **[3]**. Further progress was linked to new software and hardware solutions. However, considering the mission of this article, we have to make a big leap to around 2013, when a new wave of basic research on AI chip technology began, resulting in the third development stage in 2017 (e.g. **[4]**). Trends can be divided into two categories – server and edge applications. The second of them operate in loco without the need for a constant connection to the Internet. This includes e.g. speech recognition or the Internet of Things (IoT). For other current works, we refer to **[5, 6]**.


Alan Turing, British mathematician, logician, cryptographer


Iranian Mohajer drone - 6

However, from the point of view of the commercialization of AI applications, the ethical dimensions of AI deployment and the preparation of the public are no less important. And all the more so because the media ranks AI among similar cataclysms such as climate change or nuclear war! The development of AI cannot in any case be left in the hands of powerful technology companies, regardless of equality, transparency and employment **[7]**. Great dangers stem from cyberterrorism and military robots with varying degrees of autonomy that must remain under the control of a human operator. However, it is clear that if any power starts developing AI weapons, a global arms race with catastrophic prospects must follow. At the same time, the authors **[8]** draw attention to a new wave of „hype" that has already saturated in nanotechnology and is moving to AI, where it will cause a lot of misinformation and conspiracies. Therefore, I present the sober opinion of an expert[1] who answered my question about trends in AI as follows:

"In essence, this is another level of learning systems. AI cannot create anything new, it can process existing information very quickly. In order for this to be true, the hardware structures of computers must be adapted to it. For this, new chips are being developed, which, in addition to huge internal memories, abound with built-in optimal algorithms for processing stored data. The rest depends on the implemented software, which is always oriented to a specific type of tasks. Universal software does not exist. A number of leading manufacturers of computer systems in the world are engaged in the development of chips for AI, and at least 10 unique concepts are known."

---

[1] Doc. Ing. V. Áč, CSc., leader of the development of integrated circuits at the former TESLA Piešťany factory and later an employee of several private companies.

Experts in AI ethics are irritated by the word autonomous **[9]**. It suggests that such machines can address a moral agenda, which is mislead.

The discussion about our future in the era of AI is taking place in Slovakia as well. Their platform is also SAS Media Monitoring. I will at least mention the results of the survey on AI from March 2024 **[10]**: AI will require intensive retraining towards IT and analytics. The focus is already on finance, law and human resources. Call centers should disappear first. AI can partially replace various admission interviews. The quantification of changes in job opportunities seems not very reliable, but it is clear that some jobs will disappear and new ones with higher qualifications will be created. According to the European Commission, AI could also replace creative work, but it is questionable what the Brussels administration imagines under this term.

4. Research and applications of AI at the Institute of Informatics SAS p. r. i.

II SAS has a broad scope in the field of AI and a significant position within the Slovak Republic, which can be characterized by the following selected topics:

1. Chat GPT
2. Face recognition
3. Prediction of photovoltaic energy production
4. Computer vision in the serverless cloud
5. Diagnosis of breast cancer
6. Classification of energy levels in nanostructures
7. Optimizing of airline revenue
8. The influence of the environment on energy equipment
9. Evaluation of insulators in distribution networks
10. Classification of wood species using hyperspectral images
11. Artificial intelligence in sports.

On the basis of detailed documents, we will convey eleven above mentioned topics.

Ad 1 Chat GPT, Principal investigator: Štefan Dlugolinský

CHAT GPT
Semantic
Web
search
idea
data
information
results
articles
sources
practical
technical
reading
published

ChatGPT is an AI using neural networks to generate natural language text based on input text stimuli. It is based on the technology of generative pre-trained transformers (GPT). It has no consciousness and no ability to think logically. Its capabilities are limited to patterns that it „learns" from training data without any real understanding.

Current ChatGPT models have a capacity of 1.75×10^{11} parameters in the free GPT-3.5 version and an estimated capacity of more than 10^{12} parameters in the paid GPT-4 version. Model parameters refer to variables that are adjusted during the training process in order to reduce the error measured by the loss function. These parameters can affect the accuracy, speed and overall efficiency of the model. The number of machine learning parameters in a model is an indicator of its complexity and capabilities. In general, more parameters allow the model to capture more detailed and complex patterns in the data it is trained on, leading to better performance. In the case of ChatGPT, it is better „understanding" of the text and more accurate answering of questions. The training of models takes place on a huge amount of text data, in which the model identifies patterns, relationships and grammar of the language, which allows it to better „understand" the input and generate more relevant answers. When generating answers, the model takes into account learned patterns, but the quality of the answers is not always guaranteed. The model often „invents" facts. We call it hallucinating. This requires additional mechanisms for quality control, but also for filtering inappropriate content.

Another important factor is the size of the context window. It can be thought of as a memory in which the model stores the content of the ongoing interaction with the user. If the interaction exceeds the size of the window, the model loses access to the oldest parts of the conversation. This limitation can affect the consistency of the model in long conversations or complex tasks. Currently, the trend is to increase the size of this window. ChatGPT-3.5 indicates the size of its window 4K tokens, ChatGPT-4 version already 128K tokens. (A token is a small unit of text ranging in size from one character to an entire word.) The largest known window so far has Google's Gemini 1-5 model, which is up to 1 million tokens in size. However, this model uses audio and image tokens in addition to text tokens, allowing it to engage in image conversations, e.g. in creative collaboration. It is therefore a multimodal model that can work with different modes of data. Multimodality in conjunction with a very large window is a significant milestone.

In the latest version of ChatGPT-4, it is possible to generate visual content from textual stimuli through the integrated DALL-E tool. Users can enter descriptions of scenes, objects, or situations in natural language, and the model will generate images that visually represent those descriptions. This process opens up new possibilities for creative industries such as graphic design, advertising, film and video production, or even for educational purposes where it can help visualize complex concepts.

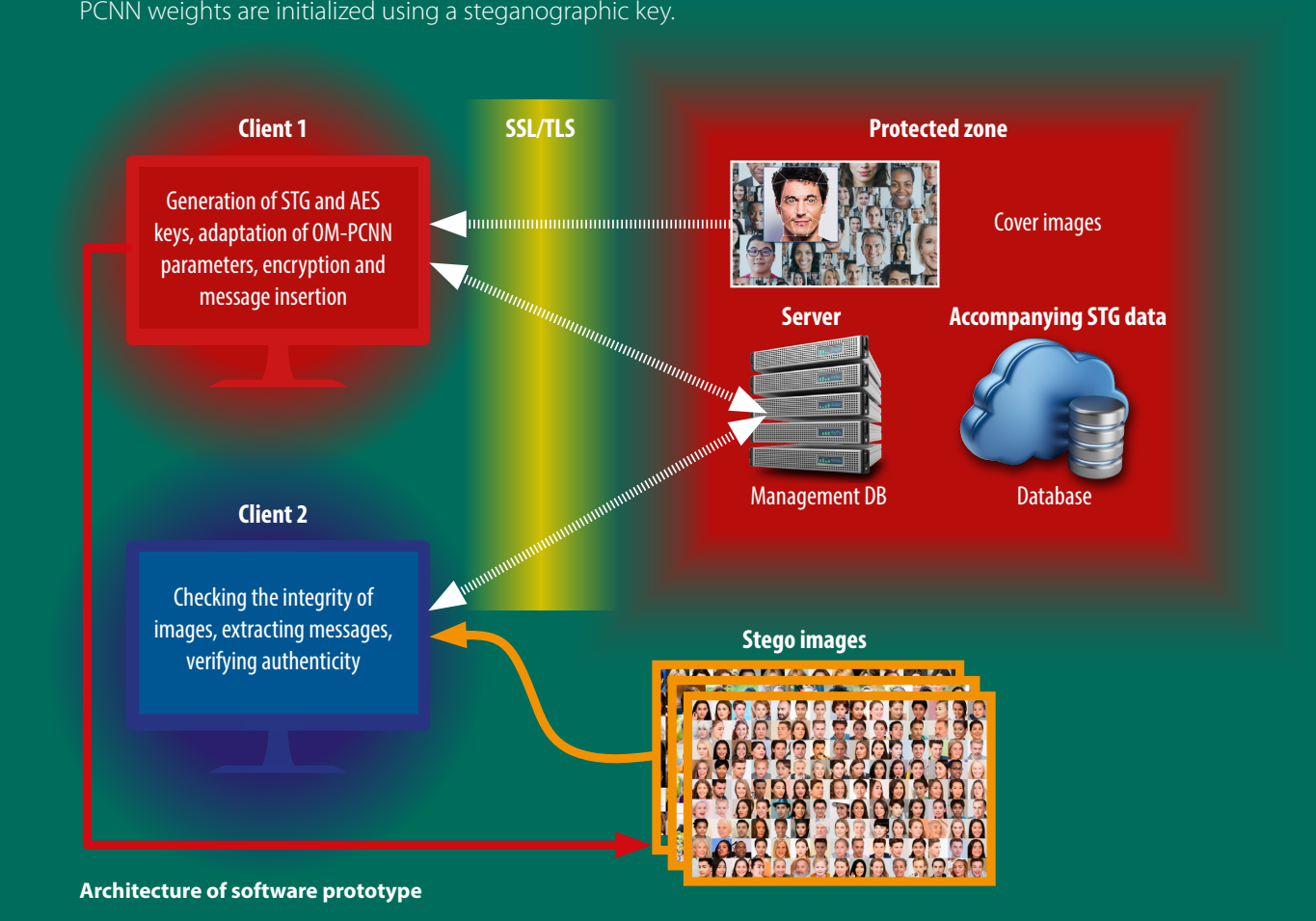
In today's era of digital transformation and growing interest in artificial intelligence, ChatGPT is becoming a key tool in many industries, from software development to customer support, marketing, and education. In the field of customer support, it can automate answers to frequently asked questions, improve the speed and efficiency of services, and while providing customers with a personalized experience. In marketing and communication, it can generate attractive content for social media, blogs or advertising campaigns, helping brands to increase their reach and awareness among people. In the field of education, it can help create personalized learning materials and provide personalized feedback to students, thereby increasing learning efficiency.

Its ability to generate coherent and contextually relevant text opens up new possibilities for automation and human-machine interaction. On the other hand, this and similar technologies bring various risks, e.g. their abuse, because they allow very quick shortcuts to results that are very similar to those created by human activity, or are indistinguishable from reality. By being able to replace many human activities these technologies have and will have a great impact on society. If until recently we were talking about industrial revolutions, then we are witnessing a new AI revolution. Future developments are likely to focus on improving the model's ability to understand more complex questions, improving personalization and adaptation to specific user needs, as well as monetizing models tailored to specific tasks. At the same time, emphasis will need to be placed on the development of robust ethical frameworks and transparency to ensure that the potential risks of these technologies do not outweigh their benefits. The development and implementation of such technologies requires a multidisciplinary approach that includes not only technical knowledge but also a deep understanding of ethical, social and legal aspects.

Ad 2 FaceControl - complex communication device for innovative management of production and support processes in industry.

Project of regional development 313012P897
Recipient: Apis Co. Ltd.
Partners: Ardaco, j.s.c., II SAS p. r. i.,
Principal investigator: Radoslav Forgáč.
Duration: 1. 3. 2019 – 31. 10. 2020

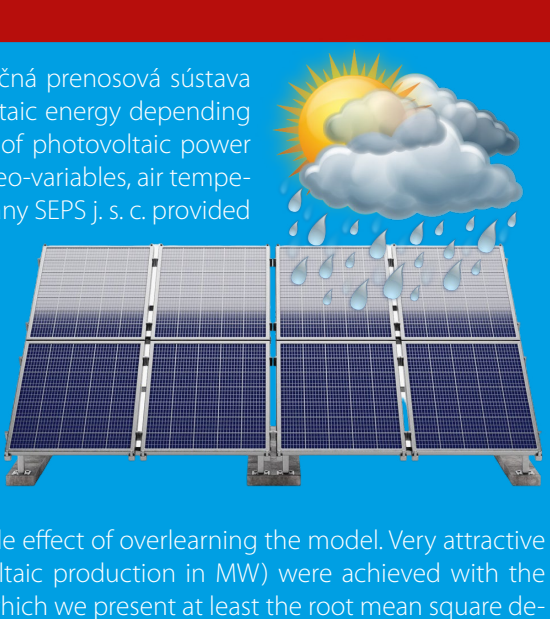
The main goal of the Face-Control project of the II SAS was to complete the prototype of a software module for verifying the authenticity of face images using neural networks and steganography. The result of the solution is a proposed model of image-steganography and the creation of a software prototype for verifying the authenticity of images. The image steganography model is based on inserting and extracting messages using position matrices that are generated by the OM-PCNN neural network. The software prototype (Fig.) is based on the proposed image steganography model, symmetric encryption using AES-256 and SHA-2 cryptographic hash function with 512-bit fingerprint. In order to increase the security of the steganographic model, the OM-PCNN weights are initialized using a steganographic key.


Client 1
Generation of STG and AES keys, adaptation of OM-PCNN parameters, encryption and message insertion
SSL/TLS
Protected zone
Cover images
Server
Accompanying STG data
Management DB
Database
Client 2
Checking the integrity of images, extracting messages, verifying authenticity
Stego images

Architecture of software prototype

Ad 3 Estimator of Slovak photovoltaic energy (FVE) production based on installed capacity, location, time and weather variables

Recipient: SEPS j. s. c.
Problem solver: II SAS p. r. i.,
Principal investigators: Ladislav Hluchý, Peter Krammer.
Duration: 1. 3. 2023 – 15. 10. 2023



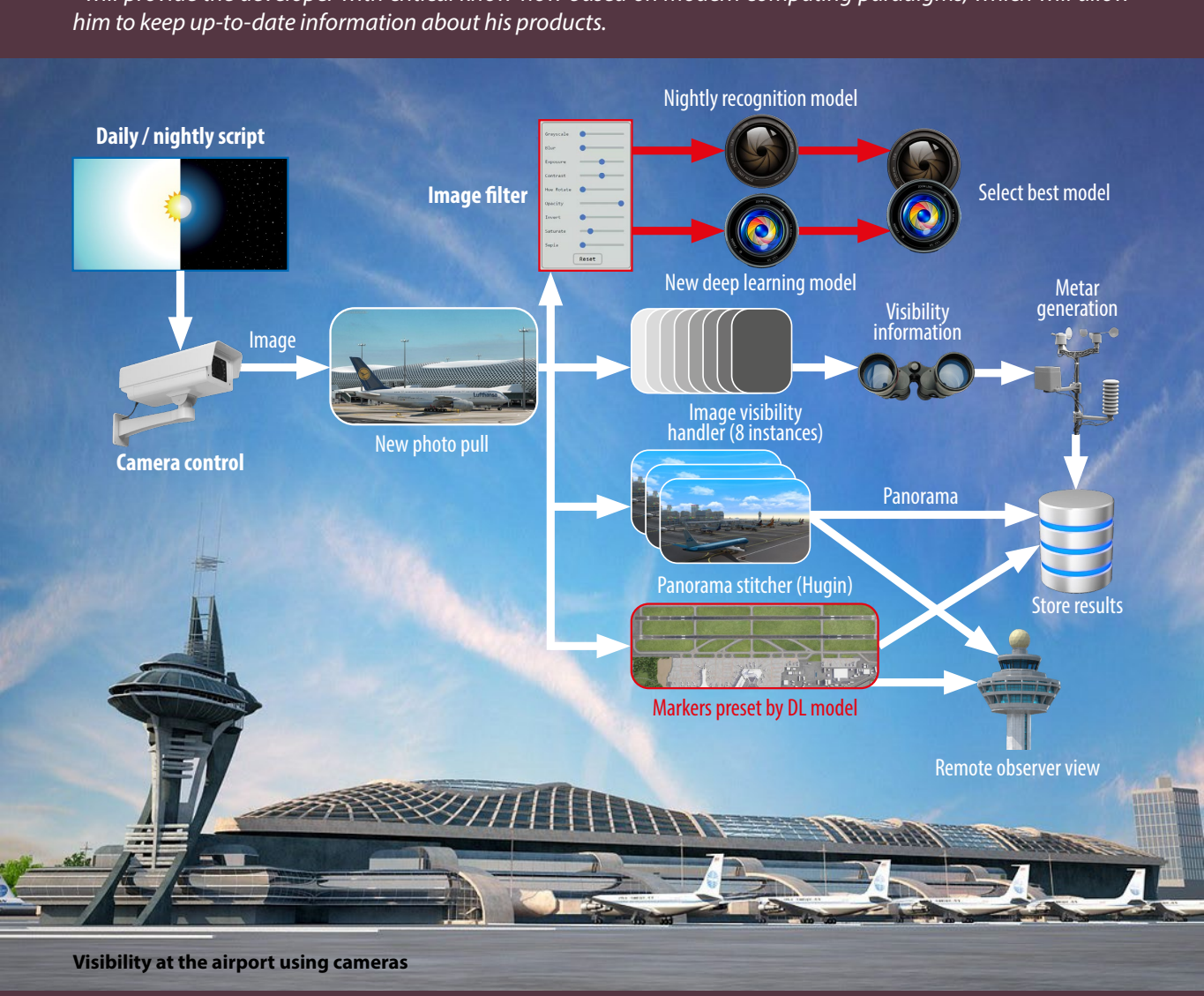
Project SEPSPP23_004, assigned by the Slovenská elektrizačná prenosová sústava j. s. c. is aimed at modeling the rate of generated photovoltaic energy depending on the related quantities. The aim is to estimate the level of photovoltaic power supplied to the electricity grid. In the modeling, mainly meteo-variables, air temperature and relative air humidity were considered. The company SEPS j. s. c. provided the project with data for 2 years, measured with a period of 15 minutes for 18 available locations in Slovakia. Due to the relatively low volume of data for individual sites, neural network models were not used, but regression tree models. The key phase of the project was the identification of highly relevant input attributes derived by non-linear transformations from the original input variables. 20 regression trees were used to model the performance in each of the locations. The bagging technique was used in the modeling, which significantly suppresses the undesirable effect of overlearning the model. Very attractive results (calculated from the modeled quantity of photovoltaic production in MW) were achieved with the models created in this way, represented by ten metrics, of which we present at least the root mean square deviation of 1.4503 and the mean relative error of 2.5860. All project outputs (with the exception of the provided data) are available for download from the II SAS website **https://www.ui.sav.sk/w/sepspp23_004/**

Ad 4 Computer vision in the serverless cloud

Project ICONTROL APVV, 2024
Principal investigators: Ladislav Hluchý, Ondrej Habala.

In the project, we designed and developed a meteorological application of airport visibility based on computer vision methods and the Function-as-a-Service paradigm **[1]**. The application has been used by its developer and operator (MicroStep-MIS) for several years at several airports, albeit as a monolithic system without the use of cloud or serverless computing. It is now trying to transform it into a serverless application, which:

- *allows the developer to modularize the application, potentially offering several different deployments with different requirements, functionality and cost,*
- *enables application deployment without the customer having to invest in hardware and maintenance,*
- *allows the application to be developed into a completely different functionality and even domains,*
- *will provide the developer with critical know-how based on modern computing paradigms, which will allow him to keep up-to-date information about his products.*



Visibility at the airport using cameras

Architecture of the visibility measurement application at airports

An important element of the safety of all types of transport is good visibility. Visibility measurement is therefore a relevant issue for air transport throughout the flight, but especially when the aircraft is maneuvering on or near the ground. Air accidents caused by bad weather account for almost 50 % of all cases and the main cause of weather-related accidents is reduced visibility. There are special sensors for measuring visibility at airports **[2]**, but they are usually expensive to acquire, coverage is often insufficient and they can measure visibility only at the exact measuring point.

Another approach to determining visibility is based on research into remote and automatic visibility observation using camera images **[3,4]**. This approach solves all the above problems, the cameras required are cheaper than dedicated sensors, can cover a larger environment and are often already present at airports and can be commissioned to measure visibility. Visibility measurement using cameras involves the immediate processing of a large number of images from various sources with image recognition and automation of modeling processes, as well as the application of multiple parallel functionalities and control mechanisms. Therefore, a more sophisticated and highly flexible information infrastructure is needed.

In our system, camera images are the basis for a remote observer to estimate visibility using reference points. In the automatic version, images taken during good visibility are used to construct reference objects. Then, during the measurement, the system determines which reference objects are visible and which are not, and can decide on visibility conditions based on this information. This system can track line of sight according to aviation rules for human observers, which is more advantageous than other arbitrary solutions. Since the response speed of the system depends on the capacity of the underlying infrastructure, it can be increased by expanding this infrastructure. It is possible to achieve duration of visibility measurements of one minute or even less in critical situations – and by changing the duration requirements, resources and costs can be saved when short duration is not needed.

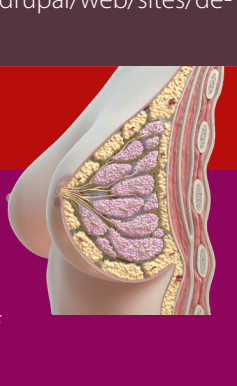
The processes of our application are shown in the picture above. Daytime and nighttime imaging camera configurations differ because there are differences in the visibility reporting process by weather observers during day and night. Overall, the cameras mimic manual observations. The technologies used in the original application had to be modified to fit the Function-as-a-Service infrastructure in order to run using the OpenWhisk system **[5]**. Image data are obtained using the ONVIF standard. The user interface is provided through a web application server integrated in the IMS software [6]. The user interface for IMS is built using industry-proven standards: HTTP/HTTPS protocol, HTML and XML formats, JavaScript and AJAX technologies, making it suitable for cloud deployment. The IMS system is also available via a web browser. The core IMS server software also enables deployment at the edge and in the cloud.

References

[1] Chowhan, K.: Hands-On Serverless Computing: Build, run and orchestrate serverless applications using AWS Lambda, Microsoft Azure Functions, and Google Cloud Functions, Packt Publishing, 2018, ISBN 978-1788836654.
[2] Burnham, David C., Edward A. Spitzer, Thomas C. Carty and Deborah B. Lucas, "United States Experience Using Forward Scattermeters for Runway Visual Range", Report No. DOT/FAA/AND-97/1, March 1997.
[3] Bartok, J.; Ivica, L.; Gaál, L.; Bartoková, I.; Kelemen, M. A Novel Camera-Based Approach to Increase the Quality, Objectivity and Efficiency of Aeronautical Meteorological Observations. Appl. Sci. 2022, 12, 2925. https://doi.org/10.3390/app12062925
[4] Bartok, J., Šišan, P., Ivica, L., Bartoková, I., Malkin Ondík, I., Gaál, L. Machine Learning-Based Fog Nowcasting for Aviation with the Aid of Camera Observations. Atmosphere 2022, 13, 1684. https://doi.org/10.3390/atmos13101684
[5] The Apache Software Foundation, OpenWhisk Incubation Status - Apache Incubator, available at https://incubator.apache.org/projects/openwhisk.html
[6] MicroStep-MIS, IMS4 Remote Observer, available at https://www.microstep-mis.com/drupal/web/sites/default/files/datasheets/IMS4\%20Remote\%20Observer.pdf

Ad 5 Diagnostics of breast cancer

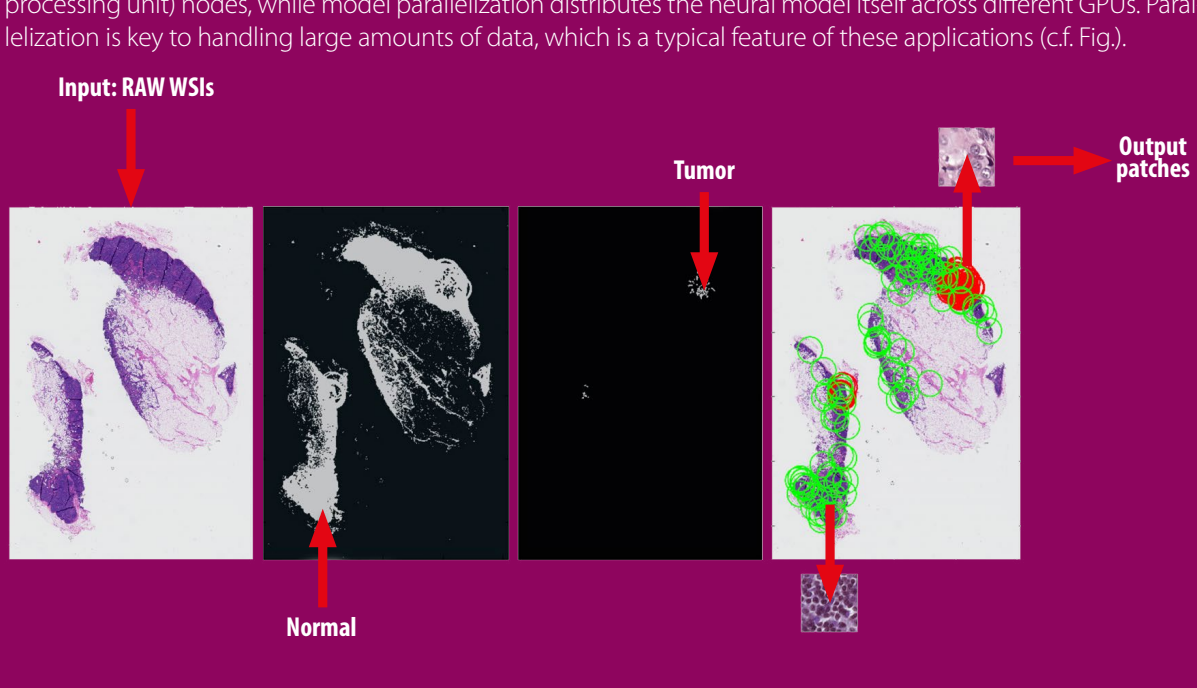
Principal investigators: Ladislav Hluchý, Martin Bobák.



AI methods have a significant impact on various sectors, including medicine. The application of such approaches, especially deep learning, in the analysis of histopathological images and the use of high-performance infrastructure to handle the computational and storage requirements allows a significant improvement in the efficiency and accuracy of the methodology.

Histopathology deals with the microscopic examination of tissues to study the manifestations of diseases such as cancer. The digitization of these samples, known as Whole Slide Images (WSIs), enables the application of deep learning techniques to automate and improve diagnostic processes. Convolutional Neural Networks (CNNs) are particularly effective in analyzing these images, performing tasks such as tumor detection, nuclear segmentation, and mitoses quantification. CNNs are trained to identify regions in WSIs where tumor tissue is likely to be present, reducing the need for manual annotation by pathologists and increasing the efficiency of the diagnostic process. Nuclei segmentation from histopathology images helps quantify cellular characteristics that are crucial for diagnosing and understanding disease progression. Due to the pyramidal structure of WSIs, images are analyzed at multiple resolutions. Initial analysis often involves background filtering using methods such as Otsu thresholding, followed by detailed inspection of higher-resolution slices for more accurate diagnosis.

The integration of high-performance computing (HPC) with deep learning is essential to handle the massive amounts of data and computing power required to process WSI images. HPC infrastructure allows data and computing tasks to be distributed across multiple nodes, which significantly reduces the time needed to train and infer deep learning models. Data parallelization involves distributing the dataset across multiple GPU (graphics processing unit) nodes, while model parallelization distributes the neural model itself across different GPUs. Parallelization is key to handling large amounts of data, which is a typical feature of these applications (c.f. Fig.).



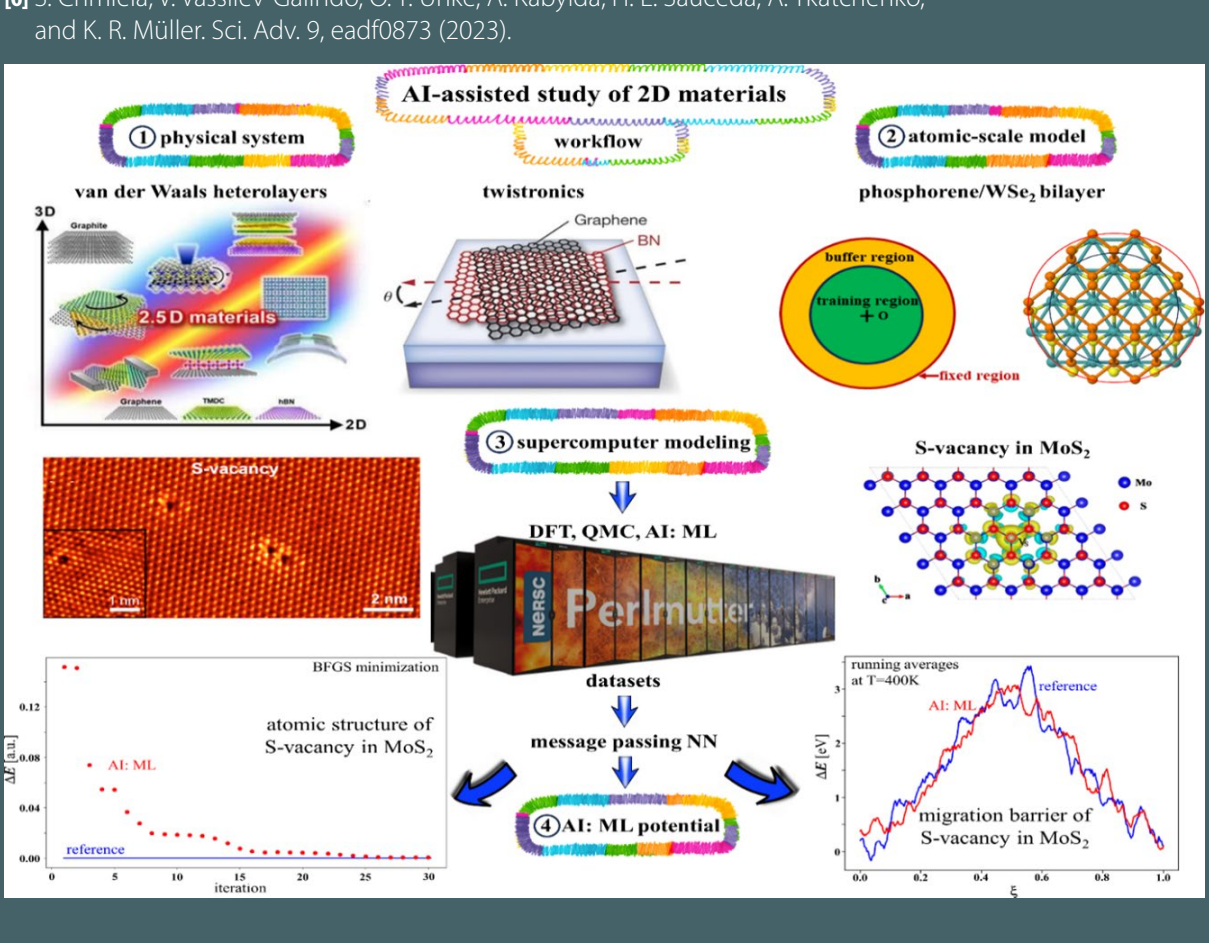
Ad 6 AI-assisted computer modeling of 2D materials

Projects: 2D-QMC, APVV 2021
TREX, H2020, 2020 - 2024
Principal investigator: Ivan Štich, team: Ján Brndiar, Adam Hložný.

Two dimensional (2D) materials **[1]** are a new class of materials whose thickness may be reduced down to a single-atom. Nobel prize in physics was awarded for their pioneering studies **[2]** and they currently belong to the most studied materials. 2D materials have already revolutionized science and provide ample opportunities for technological breakthroughs due to their unique electronic, optical, thermal, spin, and magnetic properties **[1]**. In addition to the laboratory research, computer modeling represents an alternative valuable window which science can open onto 2D materials. Two examples being study of structural defects and the so-called twistronics **[3]**, see Fig. On the computer 2D material can be prepared as defect-free or with a specific defect, for instance S-vacancy in monolayer MoS2, and the effect of the given defect on the structural and electronic properties can relatively easily be understood. Advances in 2D materials are fuelled by new developments in van der Walls (vdW) heterostructure engineering and materials design. Two monolayer systems may be stacked upon each other and allow them to interact via very weak vdW interaction. Then the so-called "proximitizing" can induce their positive properties into each other. For instance, spin or magnetic properties can be induced from a layer with strong spin or magnetic properties into the other layer which does not possess them. In addition, materials can be stacked at different angles allowing tweaking of another parameter, the twist angle, in the field of twistronics. Computer modelling in materials science typically requires to model the coupled electrons-ion system, where normally the former is fully quantum and the latter classical. The most prominent modelling method is the Density Functional technique or DFT **[4]**. The DFT accuracy often is not sufficient and more accurate and numerically expensive methods may be required. A numerically very efficient are stochastic sampling methods, such as Quantum Monte Carlo (QMC) **[5]**. With the current techniques, codes, computer hardware – supercomputer Permutter at Lawrence Berkeley National Laboratory in our case, it is very hard to push the QMC calculations to sizes significantly exceeding ≈1000 electrons. Yet, modelling of twisted bilayers with Moire patterns having periodicities of 5 – 10 nanometers or structural defects which deform the lattice around them to fairly large distances, may require tens of thousands of electrons to be explicitly included. In this situation brute force methods need to be replaced by smarter, AI-driven techniques. The system is trained on a spatially much smaller system, see Fig., and the machine-learning (ML) potential **[6]** trained on these datasets via a two-step training process (DFT–>QMC) may then be transferred to model the much larger system at the ultimate QMC accuracy. Such an approach was used in modelling the structural defects in 2D materials (structure and migration barrier) and is being used in modelling the twisted bilayers in twistronics, Fig. AI and ML approaches specifically may also be applied if time evolution of systems is required on very long time-scales.

References

[1] M. Zeng, Y. Xiao, J. Liu, K. Yang, L. Fu, Chem. Rev. 118, 6236–6296 (2018).
[2] https://www.nobelprize.org/prizes/physics/2010/summary/
[3] E. Gibney, Nature 565, 15–18 (2019).
[4] R. O. Jones, Rev. Mod. Phys. 87, 897–923 (2015).
[5] W. M. C. Foulkes, L. Mitas, R. J. Needs, and G. Rajagopal, Rev. Mod. Phys. 73, 33–83 (2001).
[6] S. Chmiela, V. Vassilev-Galindo, O. T. Unke, A. Kabylda, H. E. Sauceda, A. Tkatchenko, and K. R. Müller. Sci. Adv. 9, eadf0873 (2023).



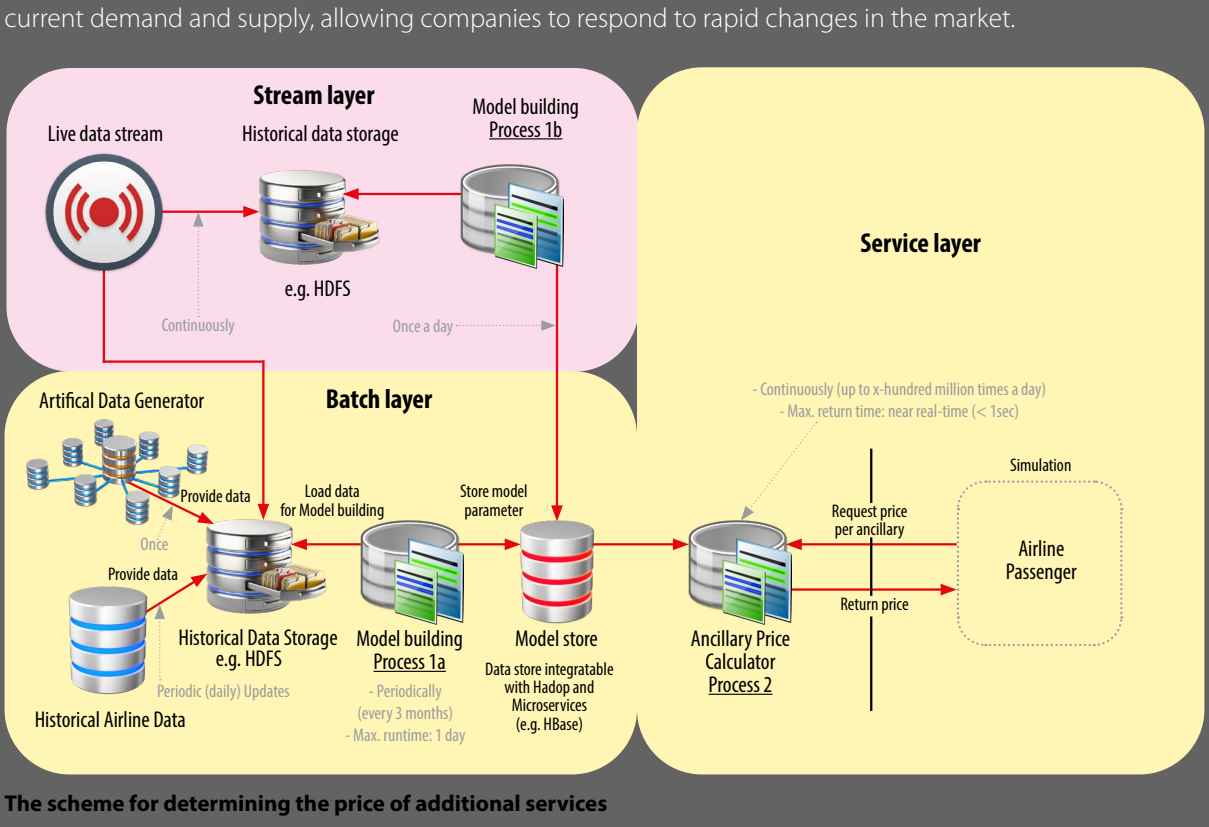
Ad 7 Optimazing airline revenue

Principal investigators: Ladislav Hluchý, Martin Bobák.

The use of AI in airline revenue management, specifically in the area of ancillary pricing, brings significant benefits. Ancillary pricing includes all additional fees that passengers pay in addition to the basic ticket price, for example for baggage, seat selection or access to lounges. The deployment of AI in this area enables the personalization of offers and the optimization of prices in real time.

AI systems can analyze vast amounts of historical passenger data, including their previous purchases, preferences and demographics. This information is used to predict customer behavior and identify hidden patterns, which makes it possible to optimize offers and their prices. Advanced machine learning models such as neural networks and random forests are used to determine the optimal prices of additional services, considering factors such as seasonality, competitive prices and economic trends.

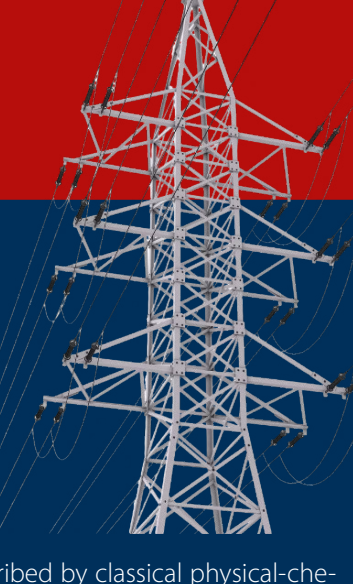
AI also makes it possible to tailor offers to individual passengers based on their preferences and purchase history. Personalization increases the likelihood that passengers will accept an offer, increasing the airline's overall revenue. In addition, AI systems process data in real time and adjust prices of additional services according to current demand and supply, allowing companies to respond to rapid changes in the market.


Stream layer
Live data stream
Historical data storage
e.g. HDFS
Model building Process 1b
Continuously
Once a day
Service layer
Batch layer
Artifical Data Generator
Provide data
Load data for Model building
Store model parameter
Once
Provide data
Historical Data Storage e.g. HDFS
Model building Process 1a
Model store
Data store integratable with Hadop and Microservices (e.g. HBase)
Periodic (daily) Updates
Periodically (every 3 months)
Max. runtime: 1 day
Historical Airline Data
Continuously (up to x-hundred million times a day)
Max. return time: near real-time (< 1sec)
Simulation
Request price per ancillary
Return price
Airline Passenger
Ancillary Price Calculator Process 2

The scheme for determining the price of additional services

Ad 8 Analysis of the environmental impact on energy industry equipment using artificial intelligence and cloud computing methods

Project APVV 20-0548
Recipient: Institute of Informatics SAS, p. r. i.,
Principal investigator: Marcel Kvassay.
Duration: 1. 07. 2021 – 31. 12. 2023



The main goal of the ARIEN project was the design and verification of an innovative method for determining the degree of environmental pollution for energy needs, using data from the Slovak Hydrometeorological Institute. The method was based on advanced artificial intelligence techniques and has not yet been used in the Slovak energy sector. It made it possible to effectively prevent breakdowns on 110 kV to 400 kV power lines due to voltage jumps.

The use of artificial intelligence for the design of the methodology was a logical choice, because the processes of the spread and fall of impurities in the air and their chemical interactions have not yet been satisfactorily described by classical physical-chemical models due to their complexity. However, neural networks required large amounts of training data, and therefore the second goal of the project was to design a methodology to obtain a sufficiently robust set of synthetic data for their training and testing. The new methodology made it possible to replace the usual process according to the canceled standard STN 33 0405, which was logistically, technically and time-consuming, with a new innovative procedure using available information processed by the most modern methods.

The established plan for the outputs and benefits of the project is considered to be fulfilled by the researchers. The valuable conclusion is that in today's situation, when there are much stricter rules for air polluters than when the former standard ČSN 33 0405 was functional, the four degrees of environmental pollution are no longer justified. Levels of pollution III and IV in the sense of this standard arise only in exceptional circumstances and for a short time, and do not represent a more permanent characteristic of the measured location. This knowledge will be used when updating the European standard for SR and the project partner VUJE, j. s. c. assumes that he will actively participate in the preparation of this new Slovak standard. There is therefore a realistic assumption that the valuable scientific knowledge and results achieved in this project will be used and benefited in many ways in the coming years.

Ad 9 Assessment of the insulators in distribution networks using artificial intelligence methods

Project APVV 20-0548
Recipient: Institute of Informatics SAS, p. r. i.
Investigators: Marcel Kvassay, Radoslav Forgáč, Miloš Očkay.
Duration: 1. 07. 2021 – 31. 12. 2023

The assessment of insulators on high-voltage masts in distribution networks is currently an actual problem due to the needs of analysis and diagnostics in the field of energy industry. One of the ambitious options for identifying faults on insulators in distribution networks is the analysis of acoustic emissions.

The aim of the research at the II SAS was to use artificial intelligence methods to identify warning signals that accompany damaging processes of insulators, thereby eliminating dangerous conditions on high-voltage lines. Partial discharges on insulators (Fig.) belong to these phenomena and can result in serious insulator failures and distribution network outages.

Project partner VÚJE, j. s. c. designed and implemented a monitoring system of real operation, which allows obtaining different types of data to detect phenomena contributing to the degradation and subsequent failure of insulators. One of the modules of this system enables the recording of acoustic emissions, i.e. sounds that the insulator emits during operation.

The acoustic sound signal from high-voltage masts contains a large amount of different sound information, as well as a significant amount of noise. By creating synthetic acoustic data with similar characteristics, it was possible to significantly expand the set of data for the purpose of applying neural networks.

Partial discharges have specific acoustic manifestations and can be detected. The acoustic data obtained from the monitoring module represents a large set of audio files. Due to the fact that it was necessary to look for a specific pattern in the course of the acoustic wave in the data, neural networks were used for this purpose, which detected the investigated phenomena in the visual representation of the acoustic wave.

Ad 10 Research on the application of artificial intelligence tools in the analysis and classification of hyperspectral imaging data

Project EF of regional development 313011BWC9
Recipient: Technical University in Zvolen (TUZVO)
Partners: Institute of Informatics SAS, p. r. i., principal investigator Ladislav Hluchý.
VUJE, j. s. c.
The beginning: 01.02.2022

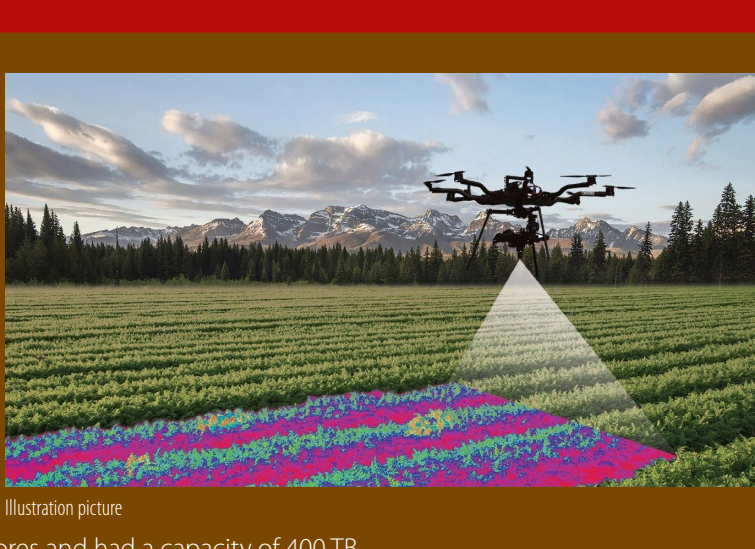


Illustration picture

The goal of the researchers from II SAS in the HYSPED project was the preparation of a cloud infrastructure for data collection and the design of models based on artificial AI for the classification of tree species using hyperspectral images as part of aerial photography of overhead power lines in the locations of Visolaje, Sverepec, Závada and Počarová. During the implementation of the project, 28 flights were made and 15 TB of data was obtained for further processing. The input data for the classification models were generated by the solvers from TUZVO. The cloud infrastructure was represented by the open software cloud platform OpenStack, which provided 756 CPU cores and had a capacity of 400 TB.

Research on classification models was focused on pixel and object classification methods. The combination of a balanced dataset, extensive augmentation, a custom-designed model and an extensive learning process resulted in classification accuracies exceeding 99% for all, even sparsely represented woody species. Another approach for the classification of hyperspectral data, developed within the HYSPED project, uses the proven GoogleLeNet model. The inception module of the original model has been improved. The mentioned model took part in a Kaggle competition focused on the classification of hyperspectral images, specifically the detection of chaff rust on images of winter wheat. The model placed second among 27 teams (https://kaggle.com/competitions/beyond-visible-spectrum-ai-for-agriculture-P1).

The output of the HYSPED project from II SAS is a study of modeled dependencies in data and validated models with the support of cloud infrastructure for the detection and classification of woody plants at the TRL 5 level.

Ad 11 Artificial intelligence in sport, Martin Šeleng, Štefan Dlugolínsky

II SAS also provided a study of the possibilities of applying AI in sports. We select essential data from it.

Automated generation of statistics from sports events

Currently, only the largest sports organizations (FIFA, EUFA, ITF, F1) use advanced technologies for the automated generation of statistical outputs. Through AI algorithms, machine learning and computer vision, our goal is to generate advanced statistical data fully automatically and in real time, which many sports federations and clubs currently do not have.

Automated game analysis

Game analysis is performed by video analysts in team sports. The work requires professional capacity and special equipment, and that is why it is not usually performed even in professional clubs. By automating and replacing the work of the video analyst through the system, the data will also be available to clubs and coaches for whom it is currently unrealistic to obtain this important information from matches.

Automated evaluation of qualitative indicators of the training process

The training process is the most important part of the educational and development process of youth. The training process is rarely monitored and subsequently evaluated. With the help of algorithms of artificial intelligence, machine learning and computer vision, the automated system can fully automatically evaluate selected quality parameters of the training process and provide them to coaches and sports managers in real time or immediately after the end of training units.

Adaptation of the product to the specifics of the largest collective sports - football, basketball, ice hockey, volleyball, handball

The current version of the product is adapted primarily to ice hockey. To adapt the product for other collective sports, research and development of new algorithms and models will be required.

Procedures for completing tasks

To fulfill the stated goals, it is necessary to solve partial research and development tasks such as identification of the properties of the object - the player: left-handed, right-handed, shirt color, number, identification of individual actions of the individual, such as holding the puck/ball and others. The details can be read in the full document of the II SAS, which established an ambitious program for the correct improvement of sports performances, contrasting with the health-harmful practices of using illegal support means.

Conclusion

The mentioned topics are far from exhausting the program of II SAS in the field of artificial intelligence. During the writing of this study, our public learned about his participation in the EC-funded international project Artificial intelligence for the European Open Science Cloud (AI4EOSC), which is focused on researching new technologies for AI **[11]**. It is in accordance with the characteristics of the Institute that we mentioned in the introduction.

Keeping the public informed about AI advancements is of the utmost importance. This area is becoming an object of concern driven by the catastrophic visions of the tabloid media. There is no doubt that AI products will cause changes in the labor market. Some occupations will disappear, others will be created. It was already the case in the first industrial revolution, when Ludists broke machines, and in the information revolution of the era of the massive advent of computers. Similar to AI today, there were fears that computers would take over society. In the Journal of Irreproducible Results, satirical articles were published about how computers plotted against humanity at their congresses. Arno Penzias, Nobel laureate for the discovery of cosmic background radiation, which is a witness to the Big Bang, explained the matter in his famous book **[12]**:

- **Unlike computers, the human brain generates ideas. Computers are just fast calculators that push their own buttons.**
- **To construct an intelligent computer = to understand the secret of thinking.**

Therefore, it is not relevant to consider a turning point beyond which the development of AI will continue beyond human control. On the contrary, it is possible to express pleasure that AI is also being developed professionally in Slovakia, and of course not only in SAS, but also in universities, especially in SUT and in research institutes.

On the basis of the documents of II SAS supplemented and processed by S. Luby.

References

[1] https://intercedu.com/projects/eavu-articles/63.
[2] Resolution on Steering Artificial Intelligence towards Global Good, Faster Realization of Sustainable Development, GA 12588, 21. 03. 2024.
[3] A. Turing, Computing machinery and intelligence, Mind, 49, 1950, 433 – 460.
[4] H. Momose, T. Kaneko, T. Asai, Systems and circuits for AI chips and their trends, Jap. J. Appl. Phys., 59, 2020, No. 050502.
[5] Y. Wang, L. Zhang, W. Zhang, The development and application of artificial intelligence chips, IEEE International Conference on Advances in Electrical Eng. and Computer Applications (AEECA), Dalian, China, 2022, 689 – 696.
[6] E. Darney, A review on AI chip, Recent Research Reviews J., 1(1), 2022, 99 – 109.
[7] C. Cookson, Editorial, Finantial Times, 6. 9. 2018.
[8] F. Seifert, C. Fautz, Hype after hype: From bio to nano to AI, Nanoethics 15, 2021, 143 – 148.
[9] A. Etzioni, O. Etzioni, Incorporating ethics into artificial intelligence, J. Ethics, 21, 2017, 403 – 418.
[10] M. Žofčin, Pripraví nás AI do dvoch rokov o prácu? Zive.sk, 15. 3. 2024, prevzaté do Monitoringu SAV.
[11] SAV je kľúčovým hráčom v oblasti využitia UI vo vede a priemysle, Tlačová správa 29. 4. 2024, https://www.sav.sk
[12] A. Penzias, Ideas and Information, W. W. Norton & Co.,New York 1999, 228 pp.

Prof. **Štefan Luby,** DrSc.

Researcher at the Institute of Physics of the Slovak Academy of Sciences and professor of physics at the Slovak University of Technology in Bratislava. He has worked on semiconductors, thin films of metals, silicides and resistive materials, resistor sensing and reliability of integrated circuits. In the field of electromigration research he founded a scientific school. His current research interests are in nanoscience and nanotechnology with a focus on nanoparticles, multilayers, graphene, supercrystals and applications of these structures. He is also involved in modelling social phenomena such as population migration, spread of diseases, etc. using physical methods and theories. His research has been carried out in Slovakia and at universities and research centres in Germany, Italy, USA, Japan and Greece. His publications include more than 400 papers, 15 books and chapters, 9 patents and 18 non-fiction books. He has received honorary doctorates, prizes and medals in Germany, Japan, Hungary, the Czech Republic and Slovakia.

Doc. Ing. **Ladislav Hluchý,** CSc.

Graduated from the Faculty of Electrical Engineering of the Slovak Technical University in Bratislava. As a researcher he worked at the Institute of Technical Cybernetics of the Slovak Academy of Sciences and its successor organizations – the Institute of Computer Systems of the Slovak Academy of Sciences and nowadays at the Institute of Informatics of the Slovak Academy of Sciences. The last two institutes he headed as director. Under his leadership, both organizations ranked among the top two or three most successful SAV institutes in winning European Union projects, including the success story category project. He is known as an expert in grid computing and derived applications and is currently a pioneer in the development of artificial intelligence in Slovakia. He has successfully supervised 11 PhD students. According to WOS, he has published more than 160 papers and self-evidently chapters in books. He has been involved in the European Grid Initiative, Institute of Electrical and Electronics Engineers, and is a member of the European Academy of Sciences and Arts. He is an honorary professor of Óbuda University in Hungary. He has been awarded for his achievements at home and abroad.