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AI IS THE FUTURE

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ARTIFICIAL INTELLIGENCE
National Laboratory

ARTIFICIAL INTELLIGENCE
National Laboratory

Dear Reader!

Initiated by the Ministry of Innovation and Technology under the supervision of the National Research, Development and Innovation Office, the National Laboratories Programme was launched with the aim to stimulate research, development and innovation to increase the competitiveness of Hungarian businesses and Hungary as a whole. The Programme was set up in four areas with high economic potential: safe society and environment, healthcare, industry and digitalization, as well as culture and society. National Laboratories concentrate research and knowledge, foster challenge-oriented cooperation and knowledge generation, seek common answers, and carry out research that meets international standards of excellence.

Artificial intelligence (AI) is one of the most promising technologies of our time, which has a profound impact on key areas of business and society from production capacity to logistics and energy supply. The Hungarian government has recognized the revolutionary power of AI, and in 2018 played an important part in establishing the Artificial Intelligence Coalition to bring together market and public organizations. The Coalition drafted the Artificial Intelligence Strategy of Hungary in the following two years.

Coordinated action in AI is essential to internationally competitive basic and applied research as well as innovation. As a joint effort of the National Laboratories Programme and the Artificial Intelligence Coalition, the Artificial Intelligence National Laboratory (MILAB) was established in that spirit as a consortium of eleven universities, research centers, and governmental organizations.

Learn about the diversity areas of MILAB research focusing on AI, a field that will shape not only our present but also our future.

Katalin Sebők
Vice President

National Research, Development and Innovation Office

Welcome to AI!

In today's world, there is hardly anyone who has not experienced directly the inevitable changes that the application of AI can bring to our everyday lives and to economic and administrative processes. But what is artificial intelligence exactly? AI refers to software systems that are able to learn and improve themselves on the basis of input data. AI makes it possible to map parts of human thinking, behavior, and reactions with the help of learning machines, which has an almost unimaginable potential for bringing about efficiency gains in industry, society, and the life of the individual.

The Artificial Intelligence National Laboratory (MILAB) brings together the best research centers and researchers in Hungary. Our aim is to support the implementation of Hungary's Artificial Intelligence Strategy as a pillar of research and innovation as well as to effectively help the translation of results into knowledge-based social capability processes, thus contributing greatly to economic growth.

Practical applications of AI can benefit Hungarian small, medium-sized, and large enterprises in a number of ways: by ensuring that repetitive tasks are performed faster and more accurately, AI supports jobs that allow greater scope for human creativity, thereby increasing competitiveness.

AI research is a key economic focus and a very fast-growing area where, in addition to future hopes, many promising solutions for practical applications have already been identified. In this booklet, we focus on the research work carried out within the Artificial Intelligence National Laboratory. We aim to showcase our activity in as much detail as possible, but in case of any questions, please feel free to reach out to us.

Dr. András Benczúr
Research Director

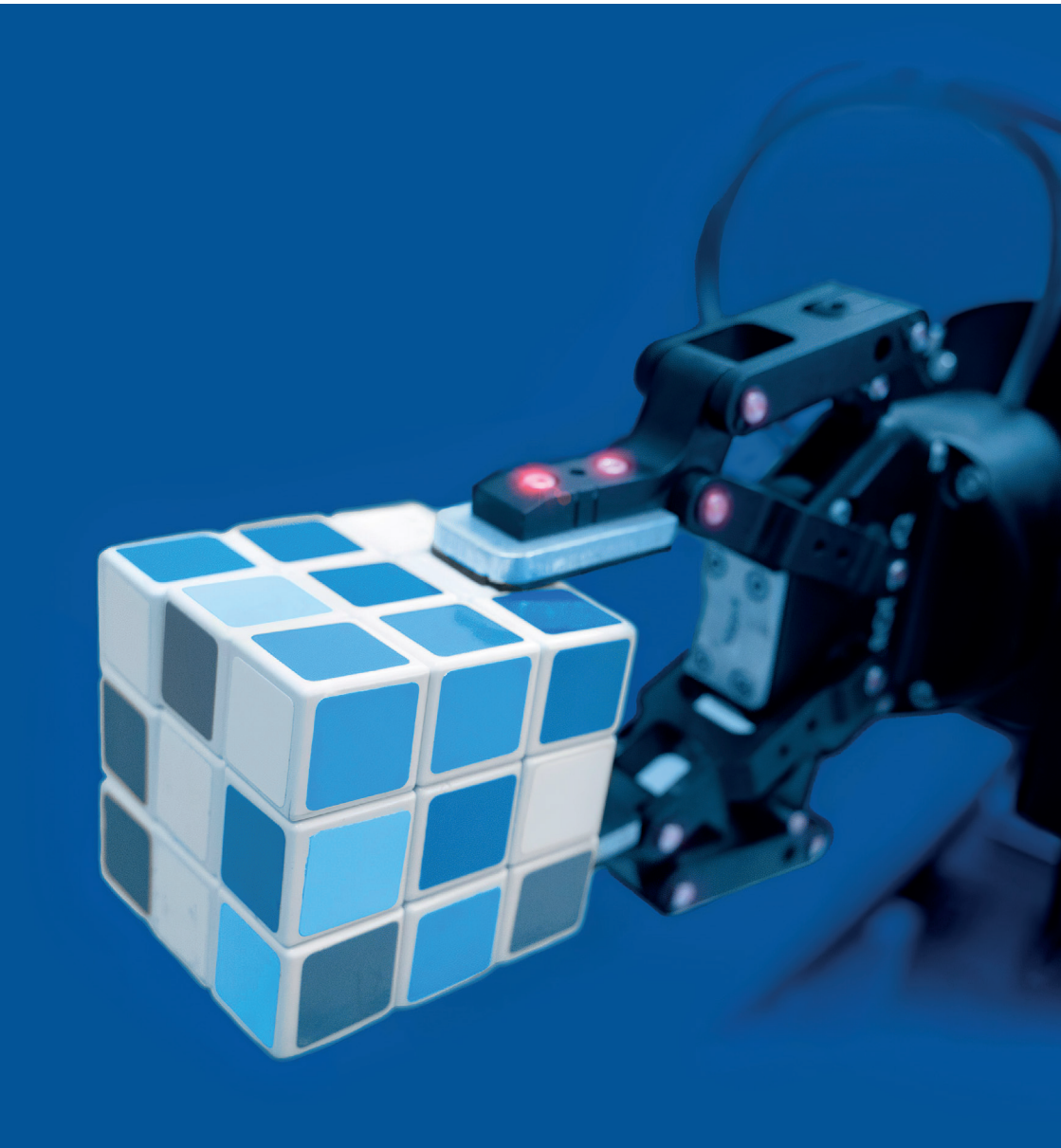
Artificial Intelligence National Laboratory

Dr. András Benczúr received his PhD in applied mathematics in 1997 at the Massachusetts Institute of Technology. As a natural continuation of his doctoral work in randomized algorithms for networks, his attention turned to real-world networks, such as the World Wide Web. In 2006, he was awarded the Yahoo! Faculty Research Grant for his research into Web search engines. Later on, he extended his work to investigating social networks, recommender systems, and smart cities. In 2012, he received the Momentum Grant of the Hungarian Academy of Sciences for research excellence in the area of Big Data. Lately, he has shifted his focus to data-driven methods in healthcare, telecommunications, and industrial IoT as well as cryptocurrency networks. He leads an artificial intelligence research group at the Institute for Computer Science and Control (SZTAKI).

MILAB

The Artificial Intelligence National Laboratory (MILAB) aims to strengthen Hungary's position in the field of AI. The international and domestic environment of AI is characterized by particularly fierce competition for professionals, disruption opportunities, and rapid time to market. The European Union is already making serious efforts to catch up with US and Chinese developments.

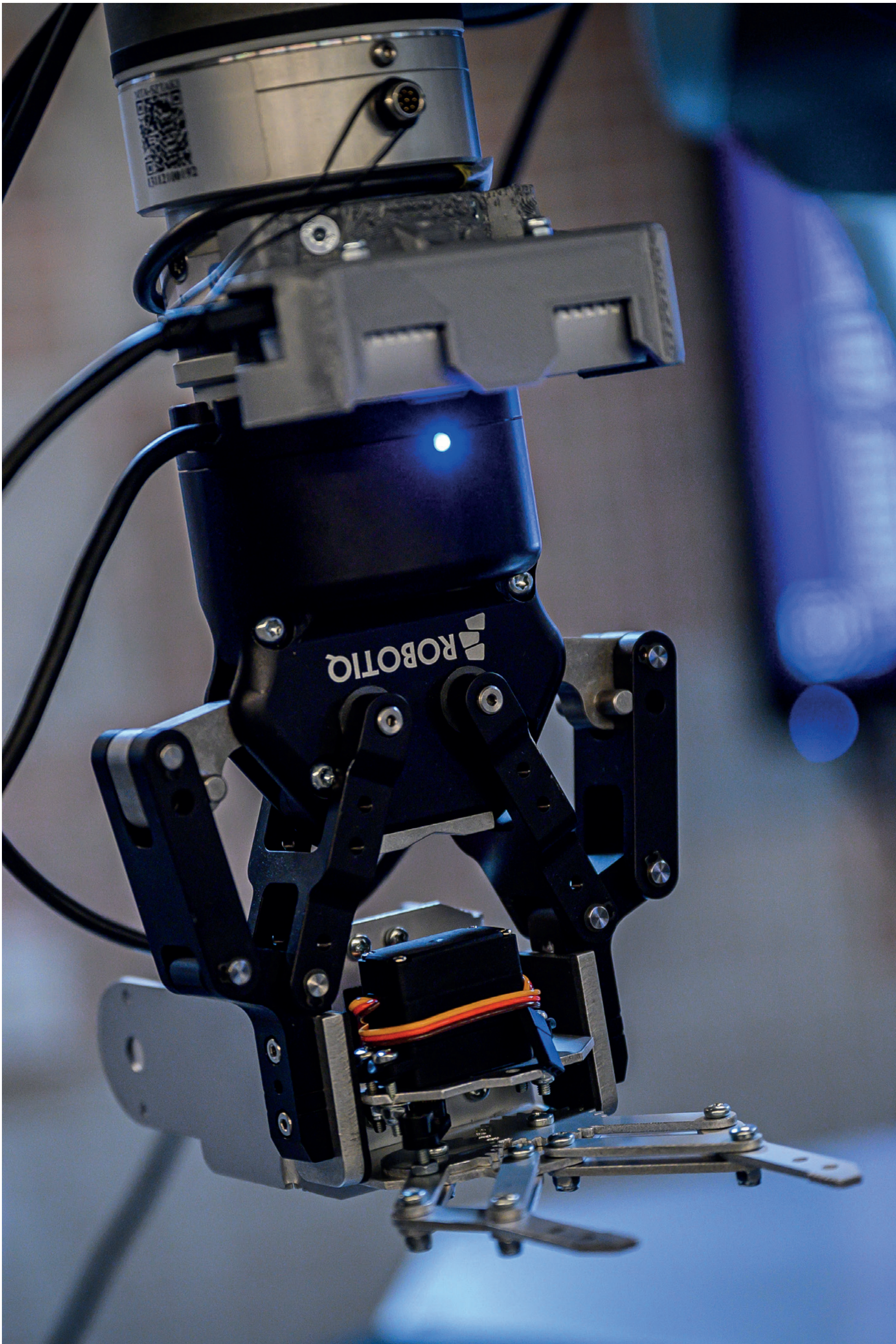
In response to international and domestic challenges, MILAB was created in 2020 with the goal of positioning Hungary in one of the most important R&D&I fields of our time through resource concentration and multiplication, through strengthening the synergy and effectiveness of basic research, applied research, and innovation activities, and through promoting Hungary's participation in large-scale international collaborative projects.



AI

Artificial intelligence is a system that uses mathematics, logic, and algorithms to simulate the reasoning that humans use when they learn and make decisions based on that knowledge.

AI systems provide predictions or perform operations based on patterns from existing data, while continuously improving themselves. AI processes information extremely quickly and accurately, which allows it to be used for complex tasks related to autonomous vehicles, medical diagnostics, industrial automation, and more.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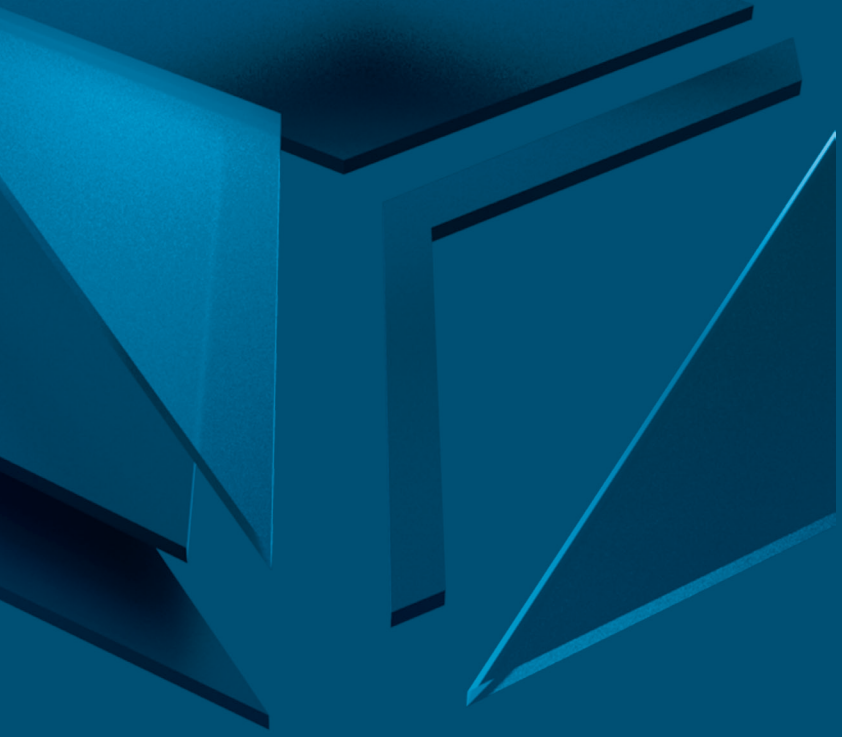
RESEARCH AND APPLICATIONS

Research targeting the foundations of AI is just as important as applying the available knowledge in business, in larger companies or small and medium-sized enterprises in Hungary. Therefore, the Artificial Intelligence National Laboratory makes a point of bringing together researchers and institutions spanning the whole spectrum of AI research starting from fundamental topics, like examining how artificial neural networks learn to solve tasks, to practical applications, such as a chatbot used to book appointments.

AI does not solve problems by itself, but it can be very helpful in well-defined tasks in almost all areas of business and everyday life.

MILAB aims to support Hungarian companies, businesses, and governmental organizations by supplying knowledge and experience in the field of AI.



AREAS OF RESEARCH

The mathematical foundations of AI

How and why does it work? Our research bridges the gap between the theory and practice of machine learning.

Security and personal data protection

Design transparent, verifiable machine learning algorithms, and test the vulnerabilities of AI systems.

Human language technology

The research aims to automate the oral and written forms of human speech.

Machine vision and perception

Our objective is to interpret information from cameras, LIDARs, medical imaging, and other sensors.

IoT solutions for machine learning in smart manufacturing, logistics, and telecommunications

Exploiting the potential of data science, we seek to introduce data-driven approaches in many application areas.

Medical, healthcare applications

We perform AI-based analyses of medical imaging systems and large-scale patient registries to support the diagnostic process and prevention.

THE MATHEMATICAL FOUNDATIONS OF AI

„A few years ago, it became clear that we were on the verge of a new technological revolution in which computers had become capable of learning autonomously, just like humans. The breakthrough came with the development of artificial neural networks modeled to mimic the human nervous system. Like the explosion of computing technology in the 1970s, the machine learning revolution nowadays is also challenging fundamental achievements in research.

Dr. Balázs Szegedy

Before computer science developed into what it is today, its mathematical foundations were essentially laid down first. By contrast, we can say that basic research in machine learning is lagging behind. In order to change this, our goal is to involve Hungary's internationally recognized scientific community in the research on the foundations of machine learning as much as possible. Furthermore, we aim to do everything we can to foster collaboration between the theoretical and applied directions."

Dr. Balázs Szegedy is a world-renowned expert on the mathematical theory that grew out of the Szemerédi Regularity Lemma, which describes the behavior of very large structures using mathematical tools. He has been awarded several ERC grants and the Momentum Grant of the Hungarian Academy of Sciences for his excellence in research. His awards include the following: Paul Erdős Prize (2013), Coxeter-James Prize (2013), Fulkerson Prize (2012), Sloan Research Fellowship (2010), European Prize in Combinatorics (2009), Géza Grünwald Prize (2002), Kató Rényi Prize (1997). He currently leads a research group at the Alfréd Rényi Institute of Mathematics.

AI applications of machine learning and especially deep learning based on advanced mathematics are currently receiving lots of attention. These, coupled with the availability of data and computational capacity, led to a major breakthrough in AI in the early 2010s. However, there is still a lack of knowledge on the mathematical foundations and limitations of deep neural networks.

Certain highly recognized mathematical theories produced by Hungarian researchers, such as nonlinear dimensional reductions, the regularity lemma, and results in graph theory, promise to provide new insights into how AI works. An important goal is to apply the theory to artificial neural networks, which are crucial for AI applications. Another closely related topic is the study of data representations based on information theory, geometry, and topology. MILAB researchers are also investigating the operational guarantees of stochastic optimization and the potential for its incorporation in AI applications.

MACHINE VISION AND PERCEPTION

„Evolution has endowed us with senses that, although amazingly sensitive, are limited in many ways. We can only see a narrow slice of the electromagnetic spectrum, we cannot detect infrasound or ultrasound, and our built-in thermometers are rather inaccurate. Thanks to modern sensors, machine vision and perception are pushing the boundaries of human perception to new modalities and scales. The Machine Vision and Perception area aims to exploit this incredibly rich source of information."

Dr. István Csabai

Dr. István Csabai is a professor at the Department of Physics of Complex Systems at Eötvös Loránd University and a corresponding member of the Hungarian Academy of Sciences. He is involved in research in several multidisciplinary areas where new technologies enable the collection and analysis of large amounts of data. He started working on artificial neural networks and their applications in the early 1990s. His research focuses on understanding complex systems, be it cancer genetics, the man-made Internet, or the large-scale structure of the Universe. In addition to the usual methods of traditional disciplines, modern methods of statistical analysis, data mining and, more recently, machine learning are increasingly being used to understand various phenomena. Professor Csabai has a solid background in these areas and has extensive experience in multidisciplinary research and collaboration with international researchers. He has been involved as a lead or co-researcher in numerous national and international projects and is the author of more than 200 international publications with more than 70 000 citations.

Machine vision, especially in the context of self-driving cars, has been one of the most spectacularly developing fields in recent years. Although some manufacturers already have well-developed systems, safety is still an important area of improvement.

The development and application of machine perception is a major focus in applied research, which includes the fusion of sensor data from different imaging systems (cameras, LIDARs, radars, etc.) and other sensors, the mapping of unknown environments, the preprocessing of measured values, the improvement of their accuracy, and the detection and compensation of false measurement data and biases.

MILAB researchers are aiming to make a huge impact on human health in two critical areas: medical imaging diagnostics, such as the evaluation of mammograms and pathology images, and the analysis and detection of defects in camera images of self-driving vehicles. Moreover, with spreading the applications of such technological developments to manufacturing and agriculture, they seek to enable significant cost reductions. Their other focus areas include the mapping of urban environments for both archaeological and cinematic applications, and space weather forecasting using image-based diagnostics.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MEDICAL AND HEALTHCARE APPLICATIONS

"Over the past decade, the development of medicine has reached unprecedented levels. Modern medical care today is based in part on large randomized prospective clinical trials involving tens of thousands of participants, real-life registries containing detailed data on hundreds of thousands of patients, and personalized medicine, with data from all of these sources forming the basis of professional recommendations. AI can be crucial to future progress in this area by helping to improve patient care and diagnosis, by making the selection of the right treatment easier, and by shortening and optimizing the time to care on a scale that is currently unimaginable.

Prof. Dr. Dávid Becker

The relative or even absolute shortage of doctors worldwide can be reduced with the help of AI, and more and more activities can be automated. For example, during an automatic pre-screening, machines can safely select imaging test results that do not need to be analyzed by a doctor. Another good example is remote monitoring with special devices (e.g. pacemakers and defibrillators) where AI can be used to alert the patient or the doctor to a situation that may require urgent intervention. AI can also help in the selection of therapies: in particular for costly and even risky procedures, AI can help to select patients who are sure to benefit from a given treatment. Of course, no machine learning can or will replace individual, "live" medical interactions during personal encounters between doctor and patient, but the combination of AI and medical thinking will certainly benefit patients everywhere."

Prof. Dr. Dávid Becker is Deputy Director of the Heart and Vascular Centre at Semmelweis University and President of the Hungarian Society of Cardiology. He has played a prominent role in the development of acute myocardial infarction care in Central Hungary. His scientific interests include interventional cardiology, inhibition of platelet aggregation, and the correlation of the occurrence of acute coronary syndromes with meteorological factors.

Researchers from Semmelweis University, Eötvös Loránd University, the Budapest University of Technology and Economics, and the University of Szeged are working on applications of AI in such fields as cardiology, diagnostics, big data processing, and drug discovery.

Their work is centered around building AI solutions for a wide range of medical and healthcare applications, such as diagnostic imaging. They use detailed and high-quality data available in national databases to track digital patient journeys for prevention and effectiveness studies among other purposes. They develop online undergraduate and postgraduate training materials on health applications of AI. Their research and development results support the evolution of transparent healthcare decision-making mechanisms.


SIEMENS

IOT SOLUTIONS FOR MACHINE LEARNING IN SMART MANUFACTURING, LOGISTICS, AND TELECOMMUNICATIONS

„Data acquisition from sensors, IoT devices, and telecommunications is an indispensable element of AI platforms because without data, intelligence capabilities remain untapped. Research on data collection protocols and data analysis techniques for sensors, IoT, and telecommunications can have a profound impact on the performance of AI systems.

Prof. Dr. János Levendovszky

A wide range of AI applications are targeted towards intelligent monitoring and control of large industrial and ecological systems, predictive maintenance, and smart city solutions. However, the optimization of data collection and processing itself requires AI-based algorithms. Extracting relevant data, projecting data representation in high-dimensional space into low-dimensional space, and filtering out anomalies and outliers are possible with new detection techniques based on machine learning. Our goal is to research and develop technologies for sensors, IoT, and telecommunications that could have a direct impact on industrial digitalization and the widespread application of AI in Industry 4.0 systems."

Prof. Dr. János Levendovszky is a Doctor of the Hungarian Academy of Sciences and Deputy Rector for Science and Innovation at the Budapest University of Technology and Economics (BME). His research interests in AI are the following: fitting data series and time series with distributions and stochastic processes, optimization of IoT and WSN protocols, and neural networks and their application in infocommunication and algo trading systems. His research abroad has been conducted in postdoctoral and visiting professorships at the University of Oxford, Katholieke Universiteit Leuven, and the Florida Institute of Technology. In total, he has led nine major international, five industrial, and three domestic IT projects. At the same time, he has been the professional leader of AI research in the Excellence Programme for Higher Education Institutions and the Thematic Excellence Programme as well as the project leader of the BME Competence Center and the BME Center for University-Industry Cooperation.

With the increase of networked machines and IoT, the amount of data available is growing exponentially. The processing and use of this data is an important area of research in AI, and thus also for MILAB researchers.

Machine learning methods allow rules, functions, and decisions to be learned automatically, without human intervention or assistance. More accurate, reliable decisions require resource-intensive analysis of large amounts of data, and the design and implementation of complex optimization and numerical procedures. An important task is to test the robustness of a system incorporating a machine learning procedure: does the inclusion of new training data spoil its properties?

Researchers at MILAB aim to control complex systems with machine learning algorithms (model predictive control – MPC), to teach them the optimal intervention signal, and to provide stability guarantees for the controlled system. Among industrial applications, they seek to investigate how predictive maintenance can be used to trigger periodic maintenance of factory machines to optimize processes, and to work on methods to map and improve real manufacturing processes in the digital space, which will have implications for real-world manufacturing.

SECURITY AND PERSONAL DATA PROTECTION

„Tens of billions of IoT devices are connected to the Internet without adequate protection, leaving them vulnerable, even to being organized into botnets. Security is particularly important for connected autonomous vehicles. Connected IoT devices can gain access to personal data about us, which can be misused. To counter these threats, we are exploring forward-looking AI methods."

Dr. Rudolf Ferenc

Dr. Rudolf Ferenc is Associate Professor at the Department of Software Development, University of Szeged. His research interests include static code analysis, software metrics, quality assurance, design patterns and anti-patterns, and error prediction. He is the leader of the Static Code Analysis group, which is working on the development of tools for code analysis of software in different languages. These tools can be used to compute source code metrics, and detect code duplications and coding violations. He has more than 100 publications in the field, with over 2000 references. He is the leader of several R&D projects helping leading banks and software development companies in Hungary in software quality evaluation, improvement, and architecture recovery. Since 2005 he has been a regular organizer and program committee member of the most important conferences in his research area (ICSE, ICSME, ESEC/FSE, SANER, CSMR, WCRE, ICPC, SCAM, FASE, etc.).

One of the barriers to the widespread uptake of AI stems from the limitations of the technology in its current state.

In line with efforts in the European Union, our particular focus is on eliminating or making the possible failure modes of AI transparent and predictable by developing test environments. Moreover, we put great effort into making the decision mechanisms of models explicit or, if needed, into developing hybrid models and interpretable decisions. Last but not least, we undertake to develop debugging algorithms specific to AI software that can help to detect errors typically made by AI. Increasing reliability this way and incorporating AI into everyday technologies can make it possible to use AI in critical decision situations as well as in cases where reliable human-machine interaction is required.

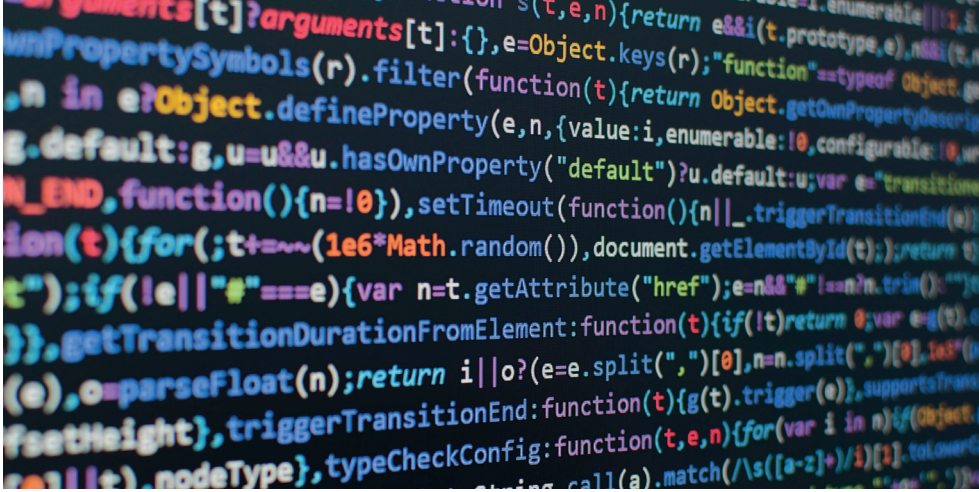
Data is one of the most important resources for AI development. The inclusion of private data in the training of models and its trading and transfer to third parties can only happen if the data is anonymous. However, anonymization can be decrypted by technological and inferential means depending on the context of use. In order to achieve secure data trade and thus AI development that maximizes user rights, it is critical to define new technological and process developments that can ensure the non-decryption of personal data on a broad scale.

HUMAN LANGUAGE TECHNOLOGIES

„AI is able to take over simple, often repetitive subtasks from us in our daily work. Just think how much of our working time is spent on making meeting appointments or retrieving information from company text reports or emails! The aim of language technology is to make text or speech written by humans for humans at least understandable for AI, so that with text and speech pre-analysis, AI can take tedious, repetitive tasks off our shoulders."

Dr. Richárd Farkas

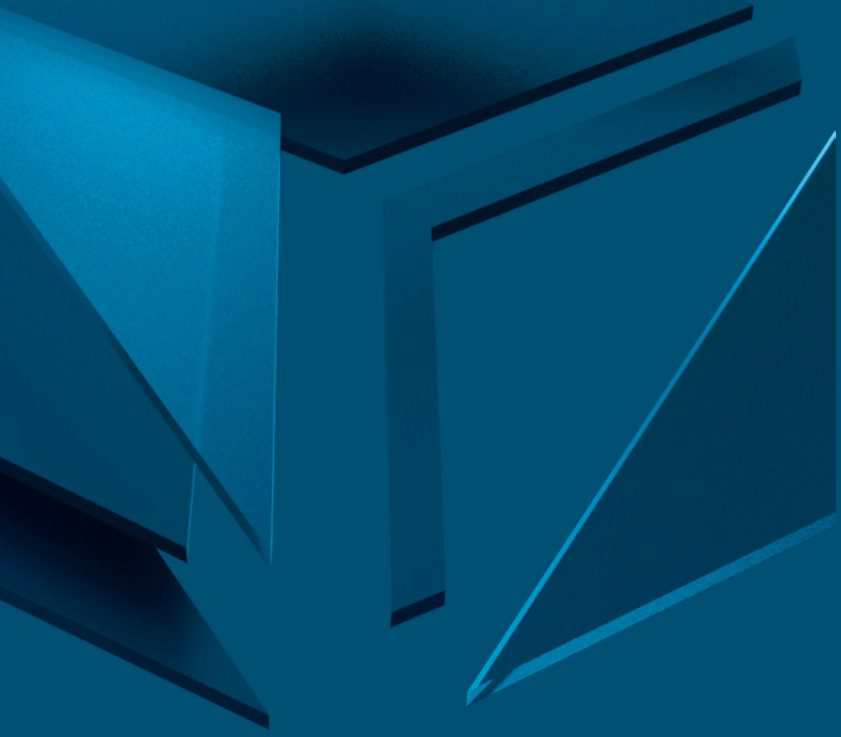
Dr. Richárd Farkas is Associate Professor at the Department of Computer Algorithms and Artificial Intelligence, University of Szeged, and has been developing academic and industrial AI solutions for 20 years. In addition to 2 postdoctoral years in Germany, he worked for 6 years as an AI research engineer at several multinational companies. His main research interest is the development of industrial applications using language technology based on machine learning. He has coordinated the development of applications such as an automatic keyword voter, a CV analyzer, a social media trend analyzer, and a chatbot for domestic and international companies. He is the author of several open-source software applications for the text analysis of the Hungarian language. Currently, his main focus is on building a technological bridge between academic research results and real market needs.



The development of solutions for the automatic analysis of Hungarian texts and speech is a priority of national interest. Our goal is to combine corporate and academic efforts to create solutions for processing Hungarian-language content, which will bring a new level of automation to services in the digital age.

Machine learning of spoken and written text is one of the fastest growing areas of AI internationally. By adapting and further developing existing technologies for the Hungarian language, we have the opportunity to accelerate the digitalization of Hungarian businesses, institutions, and services. We can automate processes in which Hungarian-language texts have to be processed or communication with Hungarian users is needed.

Our research focuses on the computer understanding of the meaning of sentences. To this end, we are developing neural language models (such as BERT and GPT-3) and solutions for several Hungarian language applications (question answering, conversational robots, emotion recognition, entity recognition, etc.).



AN OPPORTUNITY NOT TO BE MISSED

MILAB aims to contribute to the competitiveness of Hungarian enterprises with the knowledge gained in the field of AI, and to the development of the Hungarian industry with the help of digitalization.

The opportunity is open to everyone. AI is no longer the future, it is no longer just a difficult thought experiment: there are many inspiring examples and best practices for its use in business, economy, healthcare, manufacturing, or even agriculture.

By bringing together the best universities and research centers in Hungary, MILAB can help Hungarian SMEs to understand, implement, or even develop AI.

ARTIFICIAL INTELLIGENCE

MANUFACTURING

01

MANUFACTURING

Production optimization has long been a concern for most companies and factory managers. Nowadays, AI offers a wealth of opportunities for the manufacturing industry, which is a major component in our country's economy.

Research under the MILAB umbrella is aimed at increasing efficiency, whether it is a robotic arm or machine maintenance. We can save a lot of wasted resources and downtime by avoiding periodic checks and only checking instruments right before they fail instead. We can reduce risk by designing modifications in virtual space that only appear in actual production after testing, or save human resources by entrusting material handling in the factory to autonomous vehicles.

ARTIFICIAL INTELLIGENCE

CUSTOMER SERVICES

02

CUSTOMER SERVICES

Understanding real customer needs and serving them in an efficient, personalized way is becoming an increasingly important part of company operations. However, personalization is very expensive and cannot be scaled without the right technology. The effective application of AI offers a myriad of solutions to various business challenges.

When properly harnessed and combined with modern language technology knowledge, the huge amount of data assets that companies have can be fed into scalable and constantly evolving (learning) applications. These applications provide companies with disruptive technologies that enable them to address business challenges at a whole new level.

MILAB's knowledge enables the deep analysis, processing, and leveraging of customer data and interactions to understand and serve existing and potential customers more accurately and efficiently than ever before. Which company would not want to create a personalized human-machine interaction based on the sentiment analysis of its clients, with unlimited scalability?

ARTIFICIAL INTELLIGENCE

HEALTHCARE, LIFE SCIENCES, PHARMACEUTICAL INDUSTRY

03

HEALTHCARE, LIFE SCIENCES, PHARMACEUTICAL INDUSTRY

How can peak performance be best timed in sport? What is behind the sudden cardiac death of an athlete? How can a heart attack risk calculator be adjusted for domestic conditions? How can a costly surgical procedure be further optimized?

Healthcare is one area where AI is no longer just the future. It is being used in an increasing number of areas and with increasing efficiency today. And yet, it still holds unimaginable potential.

Every minute, a massive amount of health-related data is generated not only by equipment in hospitals but even thanks to the sensors of such personal gadgets as smartwatches, which AI can help to process and understand. With AI, we can improve our devices and our health.

Our work revolves around problems like how to detect autism earlier, with even fewer resources, and how to screen out false positive diagnoses. We research the recognition of Parkinson's disease based on voice and we are working on finding the best way to estimate who can successfully perform a high-cost procedure. Furthermore, we are involved in automating patient information and admissions, and in looking into how to use AI to refine drugs based on available data.

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AGRICULTURE AND ANIMAL HUSBANDRY

04

AGRICULTURE AND ANIMAL HUSBANDRY

Agriculture and animal husbandry have always occupied an important place in the Hungarian economy. This should also be the case in a digital age where ever greater efficiency can be achieved with fewer human resources, while reducing the burden on the environment and businesses.

Today, it is no longer unthinkable to use a mobile phone to monitor the development of individual members of a cattle herd, or to detect early signs of lameness in cattle or even coughing in piglets. Using AI, we can detect pneumonia in time from the electrical conductivity of milk, and we can also monitor yields using satellites.

By solving well-defined problems, AI can help reduce waste, bridge the gap caused by the overall labour shortage in the sector, and make the future more predictable.


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CONFIDENTIAL DATA AND CRITICAL INFRASTRUCTURE

05

CONFIDENTIAL DATA AND CRITICAL INFRASTRUCTURE

Protecting the growing volume of increasingly sophisticated data is a key issue not only at the level of AI, but also in terms of the critical infrastructure needed for the daily operation of individuals, companies, or even entire countries.

Blackmail viruses and cyber-attacks are not only found in action movies; they are also increasingly common in the real world and can cause more and more damage due to technological dependency. Researchers aim to use AI to enhance the protection of corporate or even personal data.

Another important development direction is the indecipherability of AI learning data, which is essential for many diagnostic and therapeutic applications. Last but not least, the protection of the increasingly popular smart home is just as important.

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