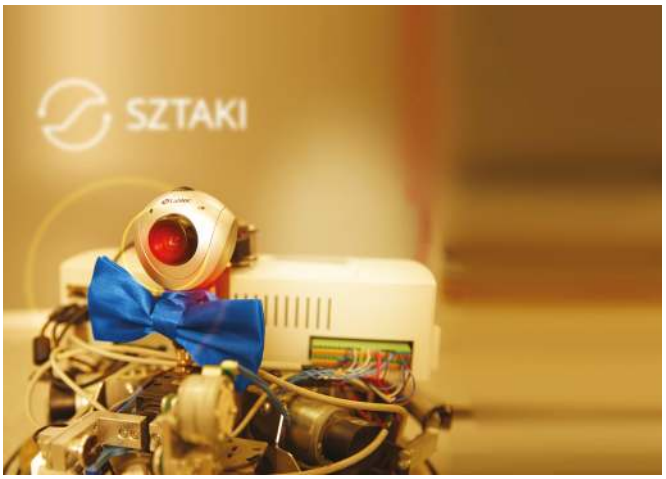
SCIENCE & INNOVATION

ELKH INSTITUTE FOR COMPUTER SCIENCE AND CONTROL

2020 / 2021

SZTAKI.HU/EN

TABLE OF CONTENTS



COMPETENCIES

SCIENTIFIC, INDUSTRIAL AND GOVERNMENTAL RELATIONSHIPS

OUR SOCIAL RESPONSIBILITY

WELCOME

According to the mission of the Institute for Computer Science and Control (SZTAKI), articulated in 2016, "relying on its strong – and characteristically focused – basic research activities, SZTAKI generates new results while utilising a framework of widespread domestic and international cooperation, and facilitates their applications to the benefit of the sustainable development of the economy and society, and, at the same time, avails in its fields of activity to preserve and, as far as possible, to raise the Hungarian scientific-technical culture to a higher level. Our strategy mirrors the statement above, and also our motto, "Excellence in science and innovation".

From the establishment of the Institute's legal predecessor in 1964, until the 31st of August 2019, it belonged to the Hungarian Academy of Sciences. It has belonged to the Eötvös Loránd Research Network ever since. We have kept our basic mission, but we review it from time to time and amend it if necessary. The External Advisory Board of the Institute consists of such prominent personalities as János Csirik, László Pap, Stépán Gábor, Jürgen Beyerer, Hendrik van Brüssel and Paul Van den Hof.

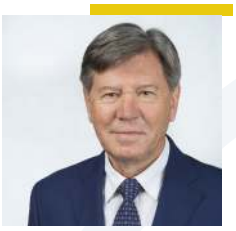
In 2001, we were awarded the title of EU Center of Excellence, and in 2017, under the leadership of

SZTAKI, the German Fraunhofer Society and the two faculties of BME established the internationally recognized Centre of Excellence in Production Informatics and Control, EPI CoE. We have participated in 45 projects in the EU's 7th Framework Programme, in nine cases as consortium leaders, while we manage six of our 27 projects won so far in the H2020 Framework Programme.

With the results of its basic research activities, the Institute contributes to the work of the Centre of Excellence in Vehicle Technology Research (J3K) founded by the Hungarian Academy of Sciences at the Széchenyi István University in Győr, which is also supported by Audi Hungaria and the city of Győr. In addition to Győr, we also operate a site in Kecskemét.

Under our leadership, the Industry 4.0 National Technology Platform Association has been established and now operates, and we are a member of the 5G and Artificial Intelligence Coalitions. We have regular educational activities in many higher education institutions and also contribute to their PhD schools as supervisors. We have further strengthened our innovation activities, primarily with EPIC InnoLabs Nonprofit Kft.

László Monostori
DIRECTOR



József Bokor
DIRECTOR OF RESEARCH

Mariann Kanizsainé Dörnyei
DIRECTOR OF FINANCE

Róbert Lovas
DEPUTY DIRECTOR

An autonomous robot of the SZTAKI SmartFactory research platform.

COMPETENCIES

COMPUTER SCIENCE & ARTIFICIAL INTELLIGENCE

Recommendation systems that know our taste all too well. All-knowing smartphones. Machine translation. Self-driving cars. Computers that beat the best Go players in the world. In the background of most solutions, we find huge computing power and gigantic databases to teach machines.

APPLICATION AREAS OF OUR LABORATORY:

Modelling and prediction of human behaviour by using large amounts of data

Machine perception, visual object detection by big data

Data based optimisation of physical and manufacturing procedures, predicting errors

Support of autonomous transportation by behaviour prediction and sensor fusion

MACHINE LEARNING

Recommendation systems that know our taste all too well. All-knowing smartphones. Machine translation. Self-driving cars. Computers that beat the best Go players in the world. Many technologies from early science-fiction have become real already – maybe not entirely in their originally imagined form but far overcoming their predicted field of use.

In the background of most solutions, we find huge computing power and gigantic databases to teach machines.

The goal of SZTAKI is to mathematically analyse and research the practical use of such systems. We aim to present our interdisciplinary research with the practical applicability of theoretical results, such as autonomous vehicles, machine vision, manufacturing processes, human behaviour, medical diagnostics and biological problems. We combine the work of mathematicians and engineers: research is experimental by nature; however, due to the large amount of data, procedures have to build upon deep understanding of the theory of algorithms and probability.

SENSORY DATA

Due to advanced computer networks and the spread of IoT (Internet of Things: network connected devices), we have an exponentially growing amount of data from heterogeneous devices, all coming with device specific data structures and noise.

Machine learning methods allow such systems to learn rules, functions, and decisions automatically without human intervention or help. More accurate, reliable decisions require resource-intensive analysis of large amounts of data, and the design and implementation of complex optimization and numerical procedures.

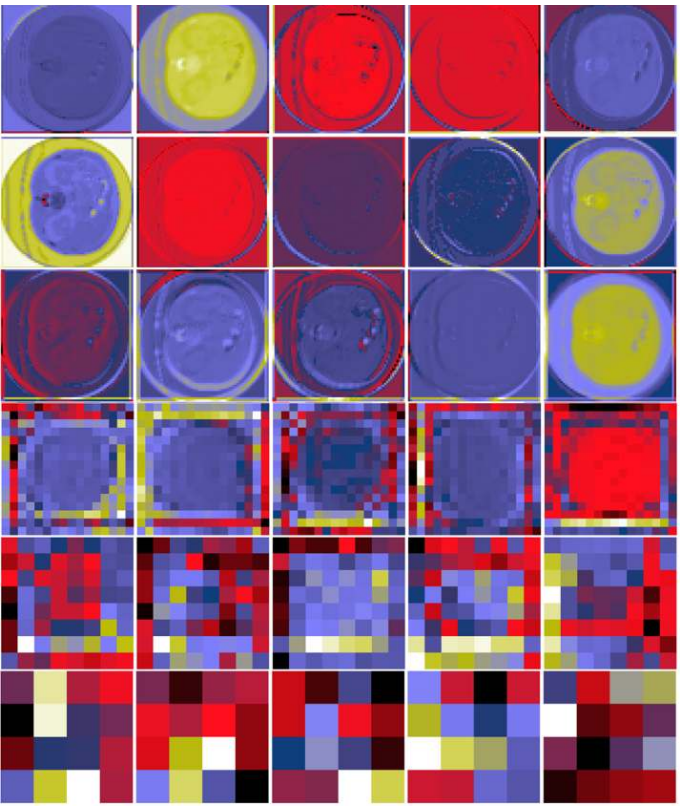
We also examine the robustness of machine learning methods: does the involvement of a new training spot degrade the qualities of such a method?

We research the control of complex systems with a machine learning algorithm, teaching the optimal intervention signal, while providing stability guarantees for the controlled system.

MACHINE LEARNING ON VISUAL DATA

We model with a mixture of complex data types, multimodal or highly diverse attributes, spatial, temporal and numerical data, time series and image content. Sensor fusion involves the combined use of visual and motion sensors, data from control systems, the mapping of unknown environments, the preprocessing of measured values, the improvement of their accuracy, and the detection and compensation of erroneous measurement data and distortions. We wish to significantly contribute to the preservation of human health in two critical areas: medical imaging and the analysis of camera images of self-driving vehicles. We also wish to increase performance and quality in manufacturing and agriculture.

Reference projects

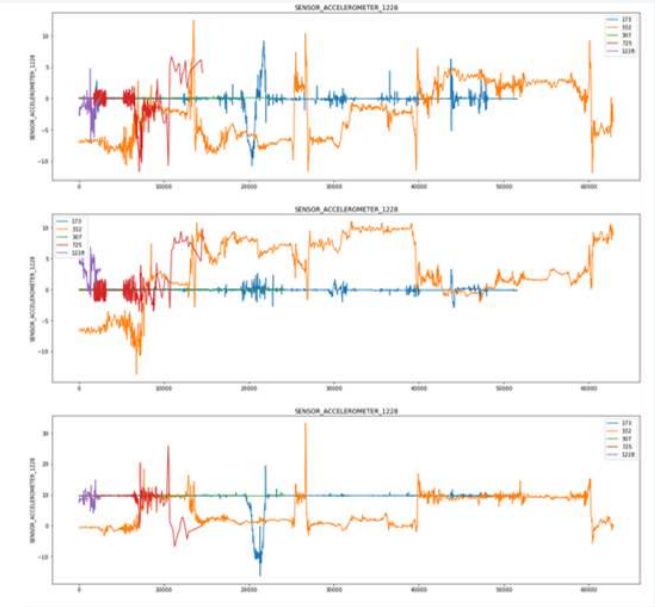


HEALTHCARE APPLICATIONS

Lung cancer diagnostics are emphasised applications (GINOP-2.2.1-18-2018-00004). Unfortunately, lung x-rays are not effective enough to detect suspicious masses of tissue - that requires CT imaging, in which case the diagnosis is made by the expensive involvement of radiologists. We develop an image analytics software that is effective at recognising malignant tumors in CT images. In another of our applications, in cooperation with **ELTE Department of Genetics**, we predict ageing control proteins in humans, using state-of-the-art AI methods. The paper summarising our results was released in the prestigious Scientific Reports journal.

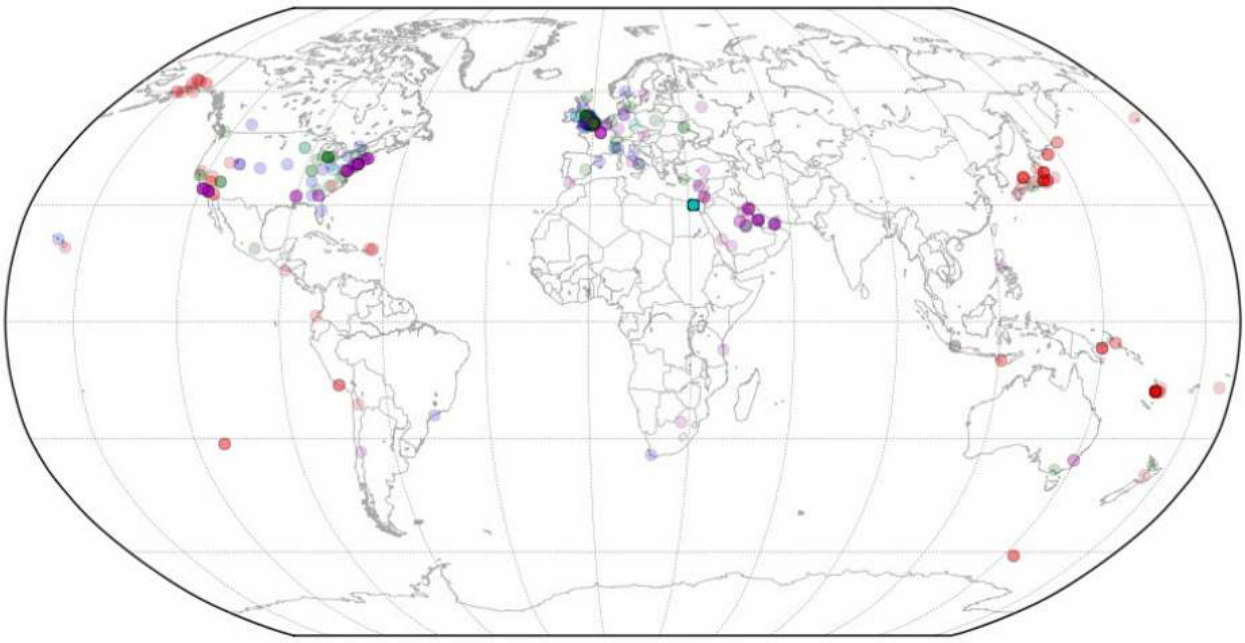
TELECOMMUNICATIONS

In collaboration with **Ericsson Research Hungary**, we conducted research to predict mobile session loss by examining time series of several radio parameters. Our method extends the so-called time warping solution to several time series, using the natural distance metrics given by the Fisher information matrix. We use our results to research technologies beyond 5G. Such technologies will require far more complex AI based rules, error detection systems and mechanisms than even 5G does.



SOCIAL AND FINANCIAL NETWORKS

We have provided OTP Bank with new forecasting methods based on machine learning for tasks including credit card default prediction. An examination of the network characteristics of the Lightning Network layer above Bitcoin revealed that, with the current level of usage and transaction fees, central nodes are not sufficiently incentivised to forward payments. For this reason, orders of magnitude higher transaction fees or turnover would be required, assuming financially rational behaviour of the main intermediary nodes. Our results have proven that the Lightning Network – and some other smaller payment channel networks – probably only work with the goodwill of a few enthusiastic nodes. Examining the topology of the network, we also found that payment channels do not provide strong protection for the anonymity of their users. **Our research was quickly noticed by the crypto-economic community. Cornell researcher Emin Gün Sirer commented it on Twitter, while German and Chinese journals also cited our results.**



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AUTONOMOUS VEHICLES

In the road vehicle production industry, the focus of development and production has been shifting away from advanced driver assistance systems (ADAS) towards fully autonomous vehicle control. The latter control approach removes the human factor, i.e., both human intelligence and fallibility, from the operation of the system. However, due to the reliability requirements set for ADAS, and the complexity of such systems, high-level control autonomy cannot feasibly be reached by taking incremental development steps alone; the development and use of brand new control solutions are necessary and such solutions are sought and developed at SZTAKI.

Our research and development activities

REAL TIME VEHICLE CONTROL

Autonomous vehicle control systems rely on building blocks that, besides classical and advanced control engineering methods, also implement **artificial intelligence (AI) based procedures.** By adopting such a mixed control engineering approach, autonomous vehicles can be coached toward taking appropriate decisions and manoeuvering securely even in complex transport and traffic situations.

The know-how derived from research carried out at SZTAKI is based on the combination of control engineering techniques and AI. Such combined methods are applicable for real time vehicle control tasks, as well as for validation and verification procedures.

SENSOR FUSION AND BIG DATA

With the burgeoning of intelligent transport systems, and the steady rise in levels of vehicle automation, also considering the growing number of solutions that rely on intelligent electronic devices, more and more information sources now provide information on the transport environment. The fusion and processing of data received from these sources can be used to optimise transport networks.

The difficulty of the above data analyses lies in the volumes of the data-sets (i.e., in Big Data); it is of great importance that these data-sets are processed appropriately. At SZTAKI, we have developed an effective methodology that facilitates model-building for transport networks; in particular, it ensures high precision in extracted models, and reliable forecasting of evolving traffic conditions.

MACHINE VISION OF VEHICLES

Images from cameras that work within the visible spectrum give a lot of information about the environment – in the same manner as our own eyes do – and have an important role in the control of autonomous vehicles in the same manner as we rely on our sight in our locomotion. Such vehicles usually combine images from multiple cameras (to gain stereoscopic distance estimates, for example) and use artificial intelligence algorithms and powerful computers. SZTAKI researchers had been working on a vision system based on industry cameras and graphical processors that can be used onboard autonomous vehicles. Virtual reality based simulation environments are a necessity in the development of such hardware/software prototypes. SZTAKI has built **world class solutions** also in this regard.

VISION BASED NAVIGATION (UAV, UGV)

Traditional positioning using a ground-based coordinate system is not always a viable solution. For example, a submarine examining the corrosion of an oceanic oil rig won't be able to use GPS because it doesn't work under water, yet on-site cameras may support the navigation of the submarine. Viewing cameras don't have information of distances though, so sensor fusion and environment databases are the only viable solutions for 3D navigation. At SZTAKI, we demonstrated navigation based control of underwater vehicles and aircraft. We built a complete navigational architecture for underwater vehicles and tested its operation in environments. In the **VISION H2020 project**, we developed relative vision based navigation algorithms for **ONERA's unmanned aircraft** that can deliver the aircraft to the designated runway even in the event of a GPS failure.

FAULT-TOLERANT AND SAFE RECONFIGURATION

The safe and reliable operation of systems (e.g., of autonomous vehicles) presumes and heavily relies on advanced control methods and algorithms. Such methods and algorithms must per se be capable of handling the tasks associated with a system's normal operation (e.g., path tracking), but effective handling of sudden faults (e.g., sensor faults) and critical situations (e.g., imminent risk of collision) is also an important and indeed critical requirement. These specific demands paved the way towards the conception of safety-critical functionality, of fault tolerance, and reconfigurable control design paradigms.

In our research, we aim to **form adequate control hierarchies for the above purposes.** For instance, a supervisor controller placed higher in the control hierarchy can monitor the operation of the subordinate controllers that had been designed for local contexts. Furthermore it can harmonize their operation via the scheduler algorithm. To facilitate the appropriate application of reconfiguration procedures, **we have developed methodologies, as well as algorithms for such hierarchical control systems**.

CONTROL OF COMPLEX AERO-SERVO-ELASTIC SYSTEMS

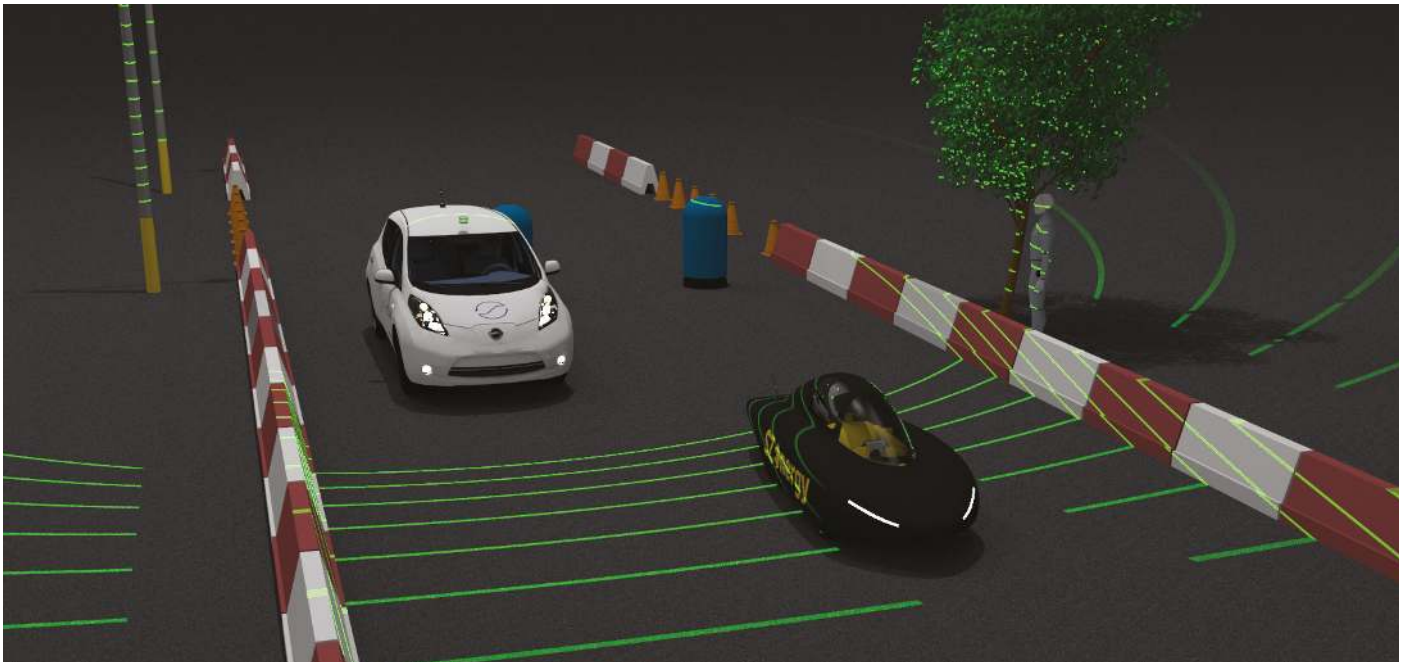
Within the design process of aeroplanes, the design of their mechanical strength and the design of their control systems were two separate, fairly uncoupled subprocesses, just untill recently. So, for instance, the tuning of aeroelastic behavior of the aeroplane during flight tests, such as the reduction of wing flapping, was only possible passively by incorporating extra weight, i.e., the weight of the structural stiffeners.

However, aeroelastic behavior can be controlled actively by aerodynamic surfaces. In the **H2020 FLEXOP** project, we developed mathematical modelling procedures that can be used to produce low-complexity models that are more suitable for control design. As a continuation of the project, the **FLiPASED** project explores ways to take advantage of the aeroelastic behavior of a wing to create some what different, flexible wing shapes in different flight phases to minimize fuel consumption.

COORDINATED TRANSPORT

As integration of vehicle and transport control areas tightens, engineers responsible for the design of autonomous vehicles also need to concern themselves with the dynamic and control characteristics of the traffic environment and the infrastructure surrounding these vehicles. At the Institute for Computer Science and Control (SZTAKI), we investigate how the increasing presence of autonomous vehicles is **going to affect the transport networks** within certain relatively small areas, e.g. within and near junctions, or along short segments of road, on the one hand, and, on the other hand, within larger areas, e.g. within an urban district, or over a motorway section.

We have developed a methodology that is capable of exploring the control strategy of autonomous vehicles, the characteristics of the traffic they are immersed in, as well as the spatio-temporal relationships and communication connections between surrounding vehicles. The results – obtained through the use of this methodology – are expected to indicate and provide guidance on how the widespread use of autonomous vehicles is going to change transport in general, and more specifically, how it is going to alter the way vehicles are used. In an urban context, the driver's aim is to drive the vehicle through junctions in an energy-efficient and safe manner, and in a highway context to overtake in a similar manner; while in a motorway context, it is important to decrease congestion, and to facilitate and secure intended high-speed driving manoeuvres. **At our Institute**, in order to achieve the respective aims with autonomous vehicles, **algorithms are being developed that not only control simultaneously the actuators of the transport network (e.g., traffic lights, variable message/traffic signs) and the movement of the autonomous vehicles, but also control them in a coordinated fashion**. To this end, we investigate how infrastructure devices within or linked to transport systems, cutting edge communication technologies (e.g., V2X), and high-performance computing capacities (e.g., cloud computing, parallel computing solutions) can be efficiently applied for the purpose.



Graphical simulation of a road scene with an autonomous car immersed in it. The white car – marked with the SZTAKI logo – is equipped with a LiDAR, and uses it to perceive the road environment, which includes another car, as well.

Our solutions

A production car enhanced with autonomous capabilities developed at SZTAKI.

CONTROL OF AUTONOMOUS CARS

At our Institute, we have been researching, developing and testing route-planning methods that take into account all three of the following circumstances at the same time: the relief of the area around the vehicle platform, the traffic situation within the area, and the restrictions that currently apply there to the platform. As it turned out, such methods **can lower the fuel consumption of a vehicle platform by 5 – 10 percent compared to the case when the vehicle platform is driven by an average human driver**.

A successful technical demonstration of SZTAKI's autonomous vehicle was held at the opening event of the ZalaZONE test track. GPS-based tracking of a pre-selected trajectory was accomplished there by the autonomous car. The tracking was supported, i.e., made more precise, by the real time spatial information gathered by the on-board LiDAR sensor. This information was used for the purpose of obstacle avoidance, as well: randomly placed obstacles along the planned trajectory were successfully avoided by the autonomous car.

COLLISION AWARENESS

We developed solutions to avoid collisions of unmanned aerial vehicles. These solutions can identify the exact time of the collision and can choose a safe direction of evasion, using only visual sensors. For the first time in the world, SZTAKI demonstrated camera-based avoidance for fixed-wing, unmanned aircraft in a real flight experiment.

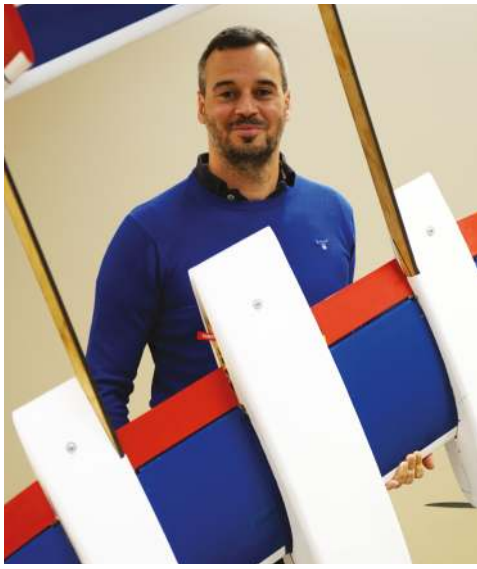
EMERGENCY NAVIGATION

We developed and tested a system based solely on visual information and on-site navigation sensors that can support the autopilot with enough information for safe landing, even after the ILS or GPS based solutions, common in civil aviation, have malfunctioned.

CONTROL THEORY IN ACTION – MIDAIR AND ON ROADS

Together with our European partners, we have researched and implemented control theory methods on the avionics system developed by SZTAKI, which are able to control the flexible behavior of the aircraft wing so that the external observer seems more rigid and aerodynamically less resistant. This opens up new possibilities in aircraft design, enabling 8 percent fuel savings or a 25 percent increase in payload for next-generation passenger aircraft. For the first time in the world, SZTAKI demonstrated the camera-based avoidance of fixed-wing, unmanned aircraft in a real flight experiment.Jointly with our industrial partners, we demonstrated a convoy of trucks moving on the road in a tightly-controlled formation. The trucks shared vehicular data of pre-defined types among themselves i.e., within the convoy and **were capable of keeping the specified following distance without driver intervention**.

The experimental aircraft, right before take-off.
Photo: F. Vogl / TUM



Bálint Vanek, leader of the Aerospace Guidance, Navigation, and Control Group

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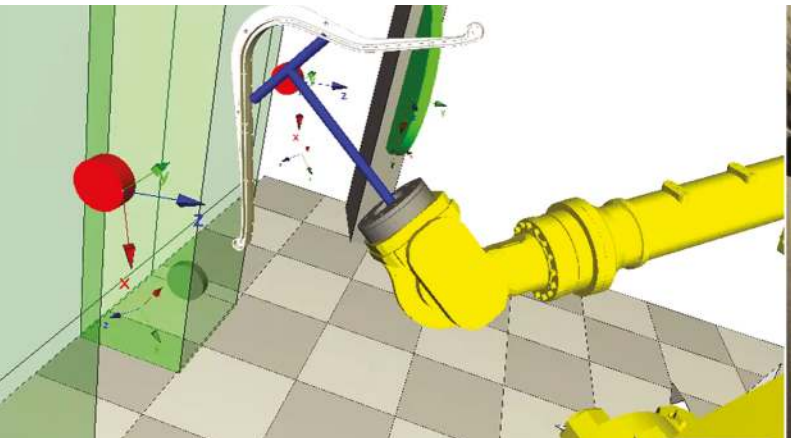
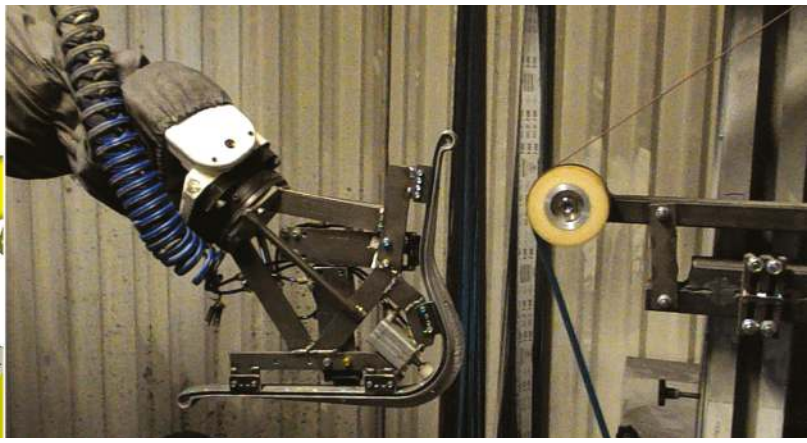
CYBER-PHYSICAL PRODUCTION SYSTEMS

Converging and mutually interacting research in manufacturing science and technology, computer science including artificial intelligence, as well as information and communication technologies resulted in what is now termed Cyber-Physical Production Systems (CPPSs). These systems – where material, energetic, informational, and financial processes are inseparably connected – consist of autonomous and cooperative elements and sub-systems that are linked within and across all levels of production, from processes through machines up to production and logistics networks. CPPSs are the main technological driver of the 4th Industrial Revolution, frequently referred to as Industry 4.0..





Digital twin model and real environment of robotic grinding.

The main traits of CPPSs are the intelligence and smartness of its elements, their connectedness that enables harnessing data/knowledge and services available via a network (including the internet), as well as responsiveness, a continuous interplay and mapping between the status of physical system components and their virtual counterparts. In CPPSs, the importance of digital twins, which provide passage between the real and virtual worlds of manufacturing, is hard to overestimate.

Robotisation of individual tasks in production systems becomes the norm, while a huge amount of data, and hence information, is rapidly produced, resulting in an ever-increasing complexity of information processing and decision-making. Meanwhile, the time window for making decisions becomes shorter day by day, and thus the humans in charge find themselves in new, unprecedented situations. Social and environmental impacts of such

systems are so significant that the seemingly opposing factors of effectiveness and sustainability have to be reconciled all along their life-cycle. Both long- and short-term global and local interests of production need to be harmonised, while also responding to new requirements such as adaptive situation awareness, robustness, self-organisation, transparency and interoperability.

Analysis, design, and control of cyber-physical production systems require a new approach that integrates the need for high-level fundamental research with the urgent demands of industrial implementation. Research, specifically in the fields of computer and manufacturing sciences, industrial engineering, operational research, data analytics and artificial intelligence should produce state-of-the-art toolsets for modelling, simulation, data processing and problem solving. Application conditions of these tools and technologies are created by modern computational infrastructures, such as cloud and edge computing. Seeking scientifically inspired solutions to industry's complex challenges is a main driving force for our innovation activities. Our main competencies are the following:-

Design and operation of cooperative and adaptive production and logistics networks; management of distributed energy systems.

Implementation of Digital Twins for dynamic analysis, optimisation, technical surveillance and real-time control of manufacturing and logistics systems.

Exploration of theoretical foundations and support of industrial implementations of stochastic machine learning methods, considering compliance with existing background knowledge.

Robust, resource- and energy-efficient management of manufacturing and logistics.

Synchronisation of cyber-physical production systems' services in view of the standardisation issues of cloud-based services.

Human-centered manufacturing optimisation, support of human–machine workflow, especially in robotics.

Participation in initiatives which go beyond the application of current toolsets of cyber-physical production systems, and have the potential to create new mechanical–economic conditions of profitable manufacturing, such as circular economy; production as a service; "living" production systems and biological transformation on manufacturing.

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Our services

DEMONSTRATION SYSTEMS FOR CYBER-PHYSICAL MANUFACTURING AND LOGISTICS

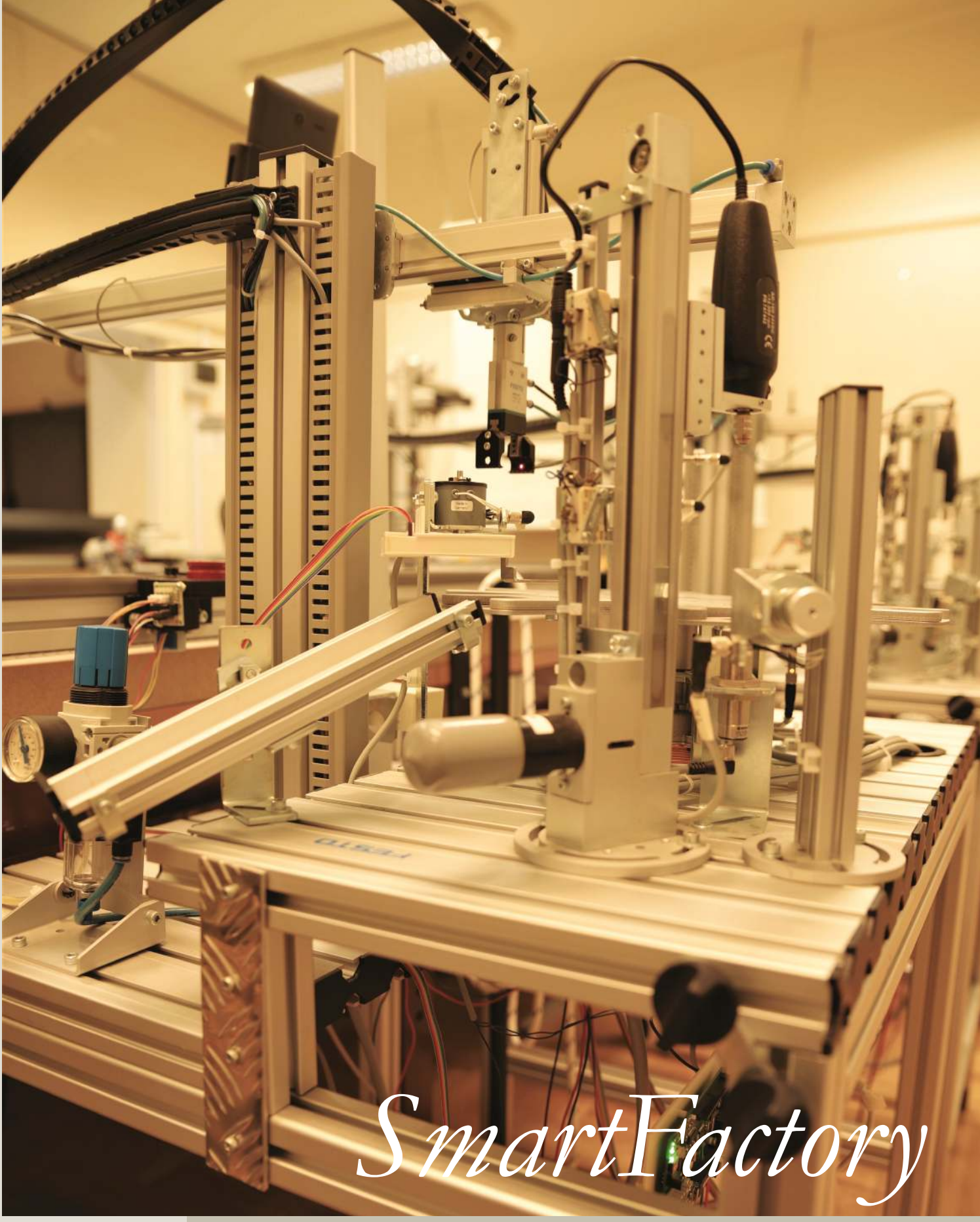
SZTAKI has established experimental cyber-physical manufacturing and logistics systems at its sites in Budapest and Győr, open for university education and industry alike. We are determined to build and showcase such innovative solutions which can meet the demands of local SMEs, too.

https://ipar40kutatas.hu/

EPIC EUROPEAN CENTRE OF EXCELLENCE

SZTAKI considers it an important task to expand the use and impact of its research results related to industrial digitalization in engineering, economy, and society. Both European and national R&D&I agencies support the innovative and educational activities of the Institute in the field of cyber- physical production systems. In particular, SZTAKI coordinates the operation of a European Centre of Excellence in production Control and Informatics (EPIC) which also involves the Budapest University of Technology and Economics, three major, manufacturing- focused centres of the German Fraunhofer Society, Fraunhofer Austria, as well as EPIC InnoLabs Ltd, a company co-established with Fraunhofer Society. The main agenda of the organization is to enrich Hungary's Industry 4.0 ecosystem with already established international practices, direct application of scientific results, and further development of education tools for Industry 4.0 subjects.

https://www.centre-epic.eu/

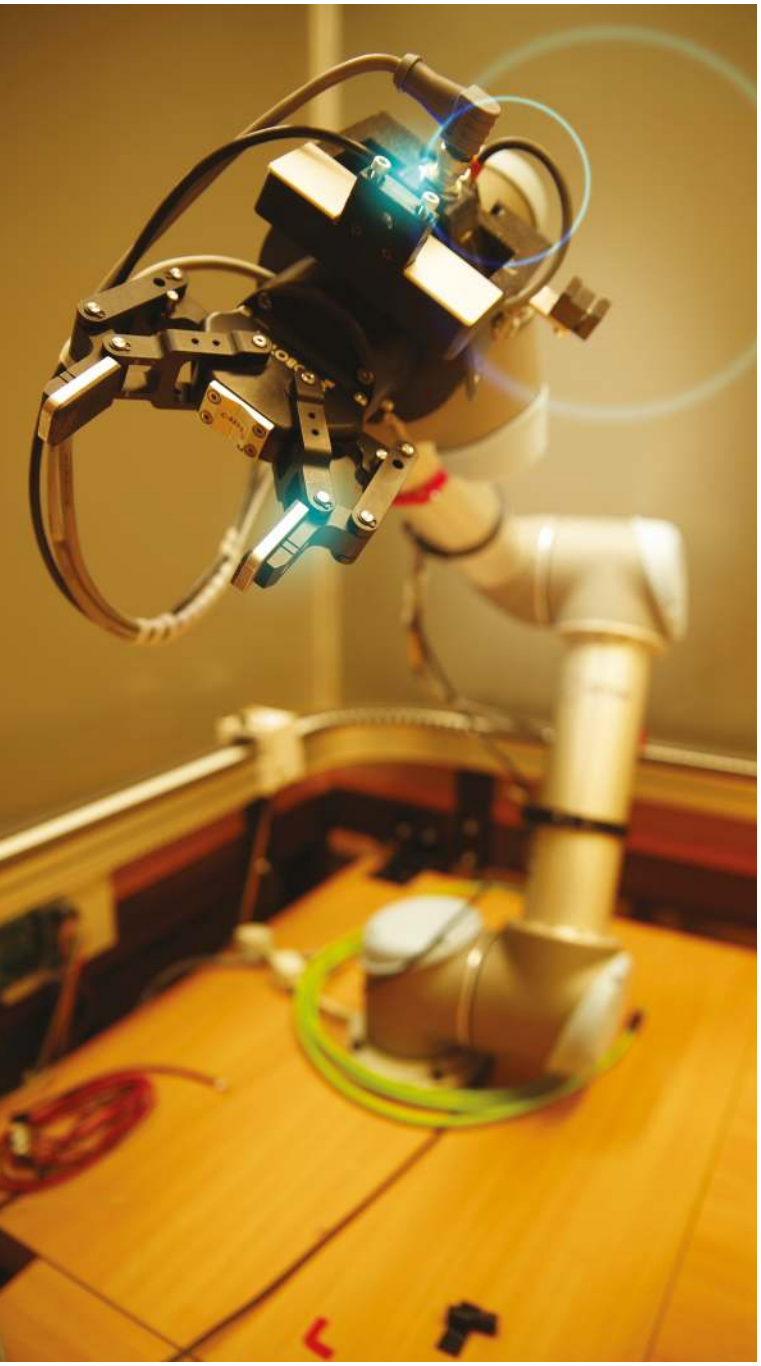


SmartFactory

SZTAKI hosts the so-called SmartFactory demonstration system for cyber-physical production, which among others includes mobile robots, workstations and a high-bay warehouse. See more in the chapter about **SmartFactory** on *page 76*.

ADVANCED ROBOTICS

Traditionally, industrial production is considered the main deployment area of robots, and robotics research at SZTAKI, too, focuses on this application domain: we analyse, plan and evaluate in production environments. Most importantly, we investigate methods and technologies of human–robot collaboration.



In the industrial production of the future, robots, too, have to meet new expectations: instead of automated machines that are mostly rigid, working in pre-defined environments, and sensing little of their surroundings, production will call for robots that can better fit into the common cooperative operation of a flexible production system, due to their advanced sensing capabilities and control.

Developing such robotised systems consists in more than merely programming robots and elaborating sensing and control methods — it also involves comprehensive planning of the production environment and its processes at the highest achievable level of detail. The latter is carried out by several collaborating expert teams, and has to deliver flawless results that pass validation.

The modelling and communication resources required for more flexible, and simultaneously more coordinated, operation are already available. Nevertheless, methods typically requiring more local as well as team intelligence are still subject to research.

Results that **SZTAKI** has achieved in these areas are being applied in factories **in Hungary and abroad as well**.

ANALYSIS, PLANNING AND EVALUATION

The processes, from designing a working environment to planning robot motion, span a complex chain of tasks which have to be solved by the coordinated collaboration of several human experts and computational resources. Addressing this challenge, a comprehensive analysis, planning and testing environment has been developed at SZTAKI, which gradually amends the digital models of production resources and workpieces with information related to their designed arrangement and planned motion.

Breaking down complex tasks into smaller subsets and combining several types of automated methods (sequential planning, geometric reasoning) with human intervention, the approach enables parallel alternatives to be tried, the current planning phase to be tested, and flexible re-planning actions to be taken if flaws are encountered. The virtual mapping of tasks and solutions relies on the same, constantly extended, model throughout the entire process. We are able to accurately capture the interrelation of system components, capabilities and states, thereby enabling the use of our models as Digital Twins (DTs). DTs can be kept up-to-date to follow the changes of a complex system. Moreover, with suitable control background, changes effected in the model can be transferred to physical reality as well.

All this assumes that machines and human participants in the work environment form an adequately reliable and accurate picture of each other's presence, state, and planned or intended actions. In the extremely complex domain of human–machine collaboration, SZTAKI has achieved much in the areas of modelling, planning, and customised human–machine communication.

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IDENTIFICATION OF BULK WORKPIECES

The flexibility of robotised production systems partly builds on their ability to sense and recognise the state of their environment and the production process. SZTAKI investigates compound systems which match camera images with pre-calculated virtual models, thereby identifying type and position of randomly located bulk workpieces, followed by autonomously planning optimal steps to assemble the workpieces, or place them as prescribed.

Similar methods are also suitable for identifying relevant geometrical features in unknown or partially documented environments, enabling the accurate matching of physical reality with spatial tasks (e.g., grinding, welding) associated to the geometrical features.

HUMAN–MACHINE COLLABORATION

Developing work environments which allow humans and machines to work closely together, and complement each other's strengths, is a major challenge of the future, but also an opportunity to profoundly shape the picture of industrial production. This allows the focus of human activity to shift towards areas where such capabilities as quick and intuitive recognition of exceptional situations, conscious problem solving, or responsible decision making are put to more fruitful use. Machines can facilitate this by more efficient execution of "mechanical" operations, bridging gaps in human attention or assessment due to typical human weaknesses or biases, and revealing perspectives which are vital but remain hidden to human perception.

AUTONOMOUS VEHICLE PLATFORM

& automotive test track

SZTAKI and the **University of Győr** are cooperating to develop an autonomous vehicle platform. Testing of this platform takes place at the **ZalaZONE automotive test track**. Read more in the chapter **Autonomous Vehicles** *(page 14.)*!

MACHINE PERCEPTION AND INTERACTION

Nowadays, the focus of research is on processing large amounts of data, mainly available online. Our goal is to recognise information coming from the machine-perceived world and to organise data from different sources, applying the latest results of machine learning, data mining, human perception and optimisation procedures.

RESEARCH AREAS

Earth observation with long duration, multispectral satellite image comparison and change detection

Target recognition and tracking in multi-camera systems

3D LIDAR point cloud analysis – scene and object recognition, position estimation

Object recognition and tracking in remote sensing

3D point cloud processing – object recognition near the resolution threshold

Environment mapping based on image and 3D point cloud comparison and actual position estimation

Development of deep learning methods for semantic image analysis

Computer-aided microscope technologies (digital holographic and phase contrast microscope)

Design and application of novel, specific image features (saliency models) in medical image analysis and remote sensing

Camera-based medical diagnostic technologies, non-contact detection of physiological signals

REMOTE SENSING, SATELLITE-BASED EARTH OBSERVATION

SZTAKI was mapping wetlands around the largest Hungarian lakes and developed algorithms for automated monitoring of small, hidden wetlands. As a result of the **OWETIS** project – funded by the **European Space Agency (ESA)** – in cooperation with the **Centre for Ecological Research** and with **Airbus DS Geo Hungary Ltd**, a database was built, including more than 200 wetlands around the three large Hungarian lakes (*Lake Balaton, Late Tisza and Lake Fertő*).

3D AND 4D GEOINFORMATICS

New generation Geographic Information Systems (GIS) store highly detailed 3D city maps as dense 3D point clouds, oriented photographs and semantic metadata. However, the high cost of scene scanning, low-cost evaluation of large amounts of data, and rapid data retrieval and update are still challenging. Our goal is to support the combined exploitation of instant vehicle perception and GIS information with a novel algorithmic toolkit which can help self-driving cars to obtain real-time information for decision making.

IMAGE BASED NETWORKED VISUAL SURVEILLANCE

Mathematical methods for multispectral camera image based detection were developed for the combined evaluation of images acquired by aerial cameras (such as drones) and ground-based camera systems. In cooperation with Montana Ltd and the Hungarian border patrol, camera images of different modalities and positions were processed, and a detection and tracking system was designed. SZTAKI developed the tracking and positioning modules and also worked on change detection and fusion-segmentation methods for aerial, high-resolution images acquired by drones.

CAMERA BASED MEDICAL DIAGNOSTICS SYSTEMS

Medical diagnostic research now aims both to define and to measure more and more physiological signals, and to simplify the measurement technology of currently measurable signals. With camera-based technologies, measurement is simplified as the patient's respiratory rate and heart rate can be read from the camera image. With this technology, the patient does not have to be tied to machines, their movement is not restricted, their comfort is improved. This is especially important for long-term bedridden patients, infants in incubators, and in the care of the elderly. At the same time, by analyzing the images, we can also detect other, hitherto unmeasured signs: movement pattern, activity, skin discoloration, tremors.

SZTAKI works with **Medicor** and **Semmelweis University** on a pulse-respiration monitor for use in incubators.

Premature infant in incubator with contactless respiration curve.

POINT CLOUD LABELLING

We created a hybrid system fusing deep learning and geometric approaches, which automatically labels and classifies the points of a 3D point cloud into different semantic classes. We also tested the system on data from the BKK Közút (Budapest Highways) mobile mapper and the Velodyne HDL-64E Lidar sensor. The segmentation method is already essential for the navigation of self-driving vehicles and it can also establish various approaches to annotation and HD map generation.

ENVIRONMENT MAPPING

In urban areas, the GPS signal is often shielded by surrounding buildings, so cannot be efficiently applied, and safe driving and flying also require the semantic recognition and understanding of the environment. Our goal is to design, develop and test algorithms that provide robust positioning in urban scenes based on Lidar data and camera images. This is achieved by integrating artificial intelligence, novel machine learning approaches and detailed 3D models.

COMPUTER OPTICAL DEVICES AND PROCEDURES

The newest generation of microscopes generates such perspectives and visuals that require one or multiple, variously positioned, precision optics to gather information. This information is later combined by computers. Digital holography is one such method, in which the hologram is recorded by a camera but the reconstruction is computed by a machine, adding 3D calculations of light intensity and phase to the picture. Implementing this procedure in the microscopic world, we get the **Digital Holographic Microscope**, which scopes an entire section of space, rather than the thin layer that is visible to conventional microscopes. Thus, a sample of hundreds of times larger volume can be evaluated with a single sample. The advantage of this can be seen especially in rare samples, where only a few but critical objects are found in large volumes. An example is drinking water, where health standards allow a certain amount of algae or other microscopic aquatic organisms per litre.

The equipment manufactured and patented by SZTAKI is used in several water treatment plants. We are experimenting with the application of the technology in medical diagnostics, environmental protection and algae cultivation.

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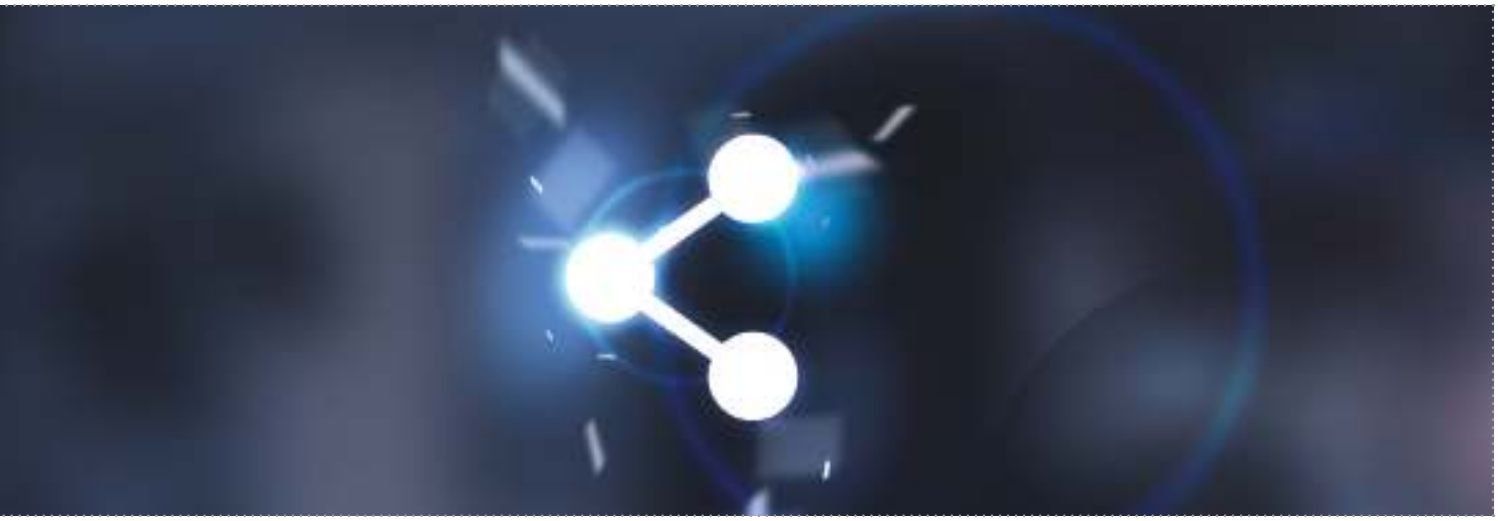
DISTRIBUTED SYSTEMS

Modern IT services are created through the establishment and cooperation of separate and scalable components that are based on virtual servers in the computing cloud. SZTAKI runs many online services – like SztakiSzótár (Sztaki dictionary) – helping users with, on occasion, as many as 8-10 servers that are working together in an effective and complex way.



Among the solutions that **DSD** offers to international companies and other organizations, many stand out, like the data service of **MTMT**: **Hungarian Scientific Bibliography**, which registers all Hungarian scientific publications and citations; the research data repository that is developed for the **ELKH Centre for Social Sciences Research Documentation Centre**; the SZTAKI full text publication repository; **lod.sztaki.hu** linked data services and the centralised query service of Hungarian scientific, full text repositories that has national significance.

SERVICE COMPOSITION, DISTRIBUTED APPLICATIONS

When harmonising several online services so they can run simultaneously, service discovery, planned and ad hoc coordination, and orchestration of these services are of vital importance and, to enable this, DSD implements solutions based on semantic web technologies. In the DASaaS (Digital Assistance System as a Service) project, DSD is developing an **Industry 4.0 solution** that provides assembly instructions for production line workers and also monitors task execution. Using cloud-based and modular technologies, the system can be integrated into existing MES (Manufacturing Execution System) systems, and implemented on local IT tools and public cloud services.

KNOWLEDGE GRAPHS, LINKED (OPEN) DATA

SZTAKI has been a pioneer in web technology development for over a quarter of a century, participating in numerous governmental, institutional and industrial projects. For DSD, one key area for research and development is the semantic web. Applying linked data technologies, our aim is to connect heterogeneous datasets that (possibly) have different schemas and to enable combined queries on the information that these datasets store. We have many years of practical experience in **linked data handling (semantic repositories)**, planning data schemas and complex ontologies, and in maintaining them as well. In the COURAGE EU-H2020 project we created a complete research-supporting infrastructure based on knowledge graphs.

GROUPWARE, SUPPORTING WORKFLOW AND DECISION-MAKING

Internet-based cooperation – structured or ad hoc - among the employees of any firm or institution is vital today. Our software solutions provide peer-to-peer, ad hoc network negotiation support: they enable awareness of events in the working environment and its current state, and manage streams of notes and data transmissions that occur on different levels. **DSD has developed flexible systems that have both mobile and web user interfaces to perform and support ad hoc, informal workflows**.

There is a special focus on supporting group decision making in an innovative way, either to organise a vote or to analyse the potential outcomes of a multiple-criteria group decision, based on decision parameters (sensitivity analysis).

DIGITAL LIBRARIES, ARCHIVES, SEMANTIC REPOSITORIES

DSD has many decades of international experience in the research, development and maintenance of digital libraries and archives: from handling metadata, through the problems of combined queries, to building knowledge bases and graphs that are on the rise nowadays (Eprints, Dspace, VIVO systems). Besides digital entity recognition, and managing linked entities, DSD deals with the practical problems of **long-time preservation of digital information, open science**, and mainly **scientific research data (open data)**. We regularly experience with the latest technologies, and the early, innovative application of them.

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ONLINE SERVICES

SZTAKI Szótár (Sztaki dictionary) is the most popular free dictionary service on the Hungarian web. KOPI Plagiarism Search Portal is the only public similarity search service that has been developed and run in Hungary.

Sztaki dictionary was launched in 1995, as one of the very first interactive web services in Hungary, as an English-Hungarian dictionary with 3,500 users per week. By 2006 it already had six dictionaries and over 90 thousand users per day (with 700,000 webpages viewed daily), making it a rival of the most popular daily papers' online editions and thematic portals.

Creating **SZTAKI Szótár** had been motivated by two aspects: on the one hand the early recognition of the social need for a free, online dictionary, so those who could not or would not pay for the services of professional dictionary publishers would be able to access the dictionary online.

On the other hand, Sztaki Szótár has provided us, the researcher-developer pioneers of Hungarian web technology, with a test environment for web technology experiments.

Today **SZTAKI Szótár** is a test environment for semantic web technologies, where a NoSQL database, together with adaptive dynamic web user interface technologies, create useful online services. Through collaborative editing the dictionary also serves as a test field for groupware technologies. In the past 25 years not only have more and more bilingual dictionaries been added to it, but Sztaki Szótár has also extended its functions. The online dictionary now includes nearly all functions (part of speech classification, pronunciaton, example sentences) that a printed bilingual dictionary has.

The main aim of the **KOPI plagiarism** search project is to help higher education teachers, professors, and also conference organizers to search original documents in case of copied content, and to protect digital libraries from illegal copying. **KOPI** also informs students about what plagiarism is and how to reference or cite a source (document) properly. **KOPI** is able to indicate to the user if the given document involves parts of other documents, which documents are involved and the ratio of the similarity.

KOPI can find similarities in foreign languages as well (translation plagiarism), even regarding internet sources. **KOPI** is a free service offered to individual users, however, it can provide plagiarism search services to institutions and companies as well.

WWW.SZOTAR.SZTAKI.HU

CLOUD COMPUTING SYSTEMS AND SERVICES

The ultimate goal of cloud computing is to provide cost-efficient, reliable, easily accessible and scalable services for the diverse requirements of industry, academia and civil services by handling their on-demand (temporary or periodical) peak workloads.

PRIVATE AND COMMUNITY CLOUD COMPUTING

Cloud Computing

At SZTAKI we developed private cloud based research infrastructure for facilitating the spread of precision agriculture which is unique in the region.

The **Agrodat cloud** builds on open source **Big Data and IoT components** to provide an analytics and decision support system with over 1000 deployed complex sensor pillars. It offers support for the cultivation of 5000 hectares for over 70 farmers.

Community clouds can be positioned between private and public clouds. **SZTAKI** and **Wigner Datacenter** founded and built the **MTA Cloud** in 2016 for the academic science community, leveraging a federated operational model by two data centers.

SERVICE ORCHESTRATION

Service Orchestration

Nowadays most organizations rely on server virtualisation and IT cloud services. Orchestration solutions allow deploying such services and platforms, and the automatised operation of the systems.

The main aim of our research focuses on cloud provider independence, automatic scalability, and cost-effectiveness, in major areas like artificial intelligence, **Internet of Things (IoT)**, **Big Data**, **Industry 4.0** and connected cars. We make our results available in the form of reference architectures that are exploitable by research communities as well as by industrial partners.

As part of our ongoing research activities, we are continuously improving our scaling mechanisms and troubleshooting methodologies with the assistance of machine learning methods. Additionally, we have been developing multi-level scaling solutions (including virtual machine and software container layers) as part of larger frameworks.

WORKFLOW SYSTEMS AND SCIENCE GATEWAYS

Workflow Systems

Science gateways provide user-friendly access for distributed application development and execution on clouds and other distributed and parallel computing infrastructures. Our research in this field is not specialized nor limited to any application specific area. Thus, our research and development results can be used in, and custom tailored to, the requirements of many different use cases.

Data processing raises several problems for which we develop the following major solutions:

- The usage of private or community clouds due to the sensitive nature of data, that are capable of hybrid operation as well, with the involvement of public clouds on demand.
- Reducing and optimising human resources costs with automatic orchestration and management tools for IT support and operations. Building on open source solutions as much as possible for economic reasons (reducing investment costs) and to comply with other security requirements.
- Complex, workflow based solutions for data processing, enabling intuitive ease of use by lowering the barrier for analysts, experts and data scientists.

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Our solutions

ELKH CLOUD

As a significant further development of the MTA Cloud, founded in 2016, the federated community cloud is accessible to the national research network and university research teams. The ELKH Cloud provides advanced infrastructure and platform services based on OpenStack as a result of cooperation between SZTAKI and Wigner Datacenter. We are planning to join the European Open Science Cloud (EOSC) initiative with this scientific infrastructure in the near future.

OCCOPUS

A cloud independent orchestration tool that allows the dynamic scaling of complex services. These services can be deployed on demand at most major public and private clouds. The tool is incorporated in the Flowbster workflow system, and into the MiCADO platform as well. As part of the latter it is able to perform automatic scaling at two levels aided by machine learning algorithms.

FLOWBSTER

Flowbster is a new cloud-oriented workflow system for creating effective data pipelines in clouds, even for large datasets. The workflow components can be deployed as needed in a destination cloud with the Occopus orchestration tool. Flowbster provides an intuitive user interface that hides the complexity of the lower layers. Thus, it allows the users to concentrate on the business logic of their data applications.

DATA AVENUE

A data transfer tool that makes different storage systems (sFTP, Amazon S3, GridFTP, etc.) available through a unified user interface. The latest development efforts for Data Avenue focus on cloud-based storage protocols and object storage systems, allowing the efficient transfer of large datasets between clouds. The service is highly-scalable so it can handle a large number of users concurrently and cost effectively.

PUBLICATIONS

& books

The researchers of SZTAKI often publish textbooks, reference books and book chapters. The books above are all works of our colleagues.

CYBERSECURITY

Once the pioneer of cyberspace in Hungary and nowadays a regional ICT R&D powerhouse, SZTAKI puts great emphasis on new, innovative solutions without forgetting the need for security. In addition to developing our own solutions in the domain of cybersecurity, we are strong advocates of security awareness in education, as well as all kinds of collaborative and in-house R&D and innovation processes, even when the primary focus is not on security itself.

AUTHENTICATION AND AUTHORIZATION INFRASTRUCTURES

Authentication and Authorization Infrastructures (AAI) serve as trust anchors in large, mass-usage ICT systems such as e-Governance infrastructure, credit card service providers, and mobile carriers. In federative infrastructures that enable collaboration between the elements or the entirety of such systems, it is especially important that the system is deployed and managed in such a way that personal data protection and information autonomy is implemented to the highest standards. These systems protect not only the users but also the service providers, both in terms of cybersecurity and the law.

The solutions developed by the SZTAKI Institute enable data exchange based on trusted authentication and personal consent between all parties involved.

NETWORK SECURITY CONTROL SYSTEMS, DISTRIBUTED NETWORK SENSORS

In the field of network security incident management, SZTAKI focuses on collecting information from large-scale critical infrastructure by mostly passive means, relying on its extensive sensor network, then on storing and analysing the data. **The incident response support solutions** we offer are developed in-house. They enable us to identify the threat and attacker profiles in the very early stages of data collection, thereby facilitating a timely response and minimising damage.

CYBER SECURITY SITUATION MANAGEMENT

The events and threats unfolding in cyberspace are often very opaque. It is not straightforward to establish the exact scope of a threat or affected parts of the infrastructure, which hinders the formation of the appropriate external and internal strategies.

The Incident Response Team of SZTAKI Institute can provide effective and accurate situation assessment, counsel on appropriate response actions, and appraisals of their efficacy based on its vast experience and the tools that it has developed in this domain.

SZTAKI's security team is comprised of internationally certified experts, possesses relevant real-situation experience, undergoes continuous training, and participates in Hungarian and international collaborations, in addition to its own in-house innovation.

SZTAKI Institute and its partners derive significant benefits from this interdisciplinary know-how in industrial, commercial, and government applications.

The social and business role of cyberspace often outweighs the importance of physical space.

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Our Solutions

HEXAA

Developed for an Open Call of the **GÉANT** Project and directly funded by the **European Commission**, HEXAA is an attribute authority service that plays a key role in the national EduID-HU federation, as well as several internal and external services of the SZTAKI Institute. The system offers attribute and role management, implementing a wide range of workflows by providing both a friendly UX and a comprehensive API.

http://hexaa.sztaki.hu/

HUNCERT

The **HunCERT** service, operated by SZTAKI since 2003, coordinates and supports Hungarian commercial internet providers and their users to prevent and manage network security incidents. Besides around-the-clock incident reporting service, we enhance the security of the Hungarian network infrastructure by providing security alerts, notes, and assessments, as well as organising workshops and communication exercises.

https://www.cert.hu/

PROBE

The PROBE distributed network security sensor system aims to improve the incident response capabilities of HunCERT. The volunteer organisations in the project host probes provided by us in various locations in the country, not unlike an extensive network of weather sensors. The data provides real-time insight into the threats and events of interest just as they unfold. This, in turn, enables an assessment of the overall state of Hungarian cyberspace, a deep analysis of events, and the timely planning and execution of counteractions, if necessary.

https://www.cert.hu/probe

LiDAR

Machine perception is an important area of our autonomous vehicle research: several SZTAKI projects focus on laser field detection. For more information, see chapters **Machine Perception and Interaction** *(page 28)* and **Autonomous Vehicles** *(page 14)*!

E-LEARNING, VIRTUAL REALITY

SZTAKI has become a key player in several segments of the domestic education and IT market during recent decades. This covers the development of innovative software products and services in a range of expert areas including eLearning and Virtual Reality platforms.

UBIQUITOUS LEARNING

Adequate support for people involved in ubiquitous learning requires the availability of various methods and development tools. A number of EU RTD projects defined recommendations and produced sample solutions to contribute to the design, preparation and application of complex education packages starting from the early 2000s. Based on our participation in these projects we have obtained notable experience in adapting such toolkits to meet domestic needs. This activity resulted in valuable training packages for several branches and target groups and were successfully presented in both domestic and international contests.

MULTIMEDIA CONTENT DEVELOPMENT

In order to comply with customer requirements in developing diverse presentation facilities, the application of bespoke methods is needed. We offer solutions to implement a variety of multimedia components (e. g. text, picture, figure, animation, simulation, voice, 3D panorama photos, interactive games, etc.) to be built into digital training materials. A modular Content Management and Presentation System has been created to satisfy manifold high level customer demands. It offers multiple levels of user access (e. g. to upload and/or check new content) on multiple platforms (PC, tablet, smartphone) and helps to manage and present multimedia components.

These results can be used in many application areas, including (among others) industry, tourism and, of course, education. Solutions already implemented cover multiple platforms and equally apply to electronic and ubiquitous learning, application development, multimedia delivery and research.

INDUSTRIAL VIRTUAL REALITY STANDARD

OpenXR

Virtual reality technologies extended by augmented and mixed reality technologies create a new era in information technology with the human centered computing revolution. These emerging technologies must reach a higher level of maturity to eliminate barriers such as market fragmentation.

An open and royalty-free industrial standard can solve these problems and open up the possibility of integrating these technologies even into already existing industrial software systems. SZTAKI was invited to join the world's largest IT industrial standardization consortium called **Khronos Group**.

Our colleagues are involved in the OpenXR workgroup to create the very first virtual reality industrial standard with the World's leading IT companies such as Google, NVidia, Microsoft, Intel, and Samsung.

SZTAKI created an open-source virtual reality software library called ApertusVR which is an official implementation of the OpenXR standard. Therefore ApertusVR can be integrated into existing industrial systems.

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Solutions

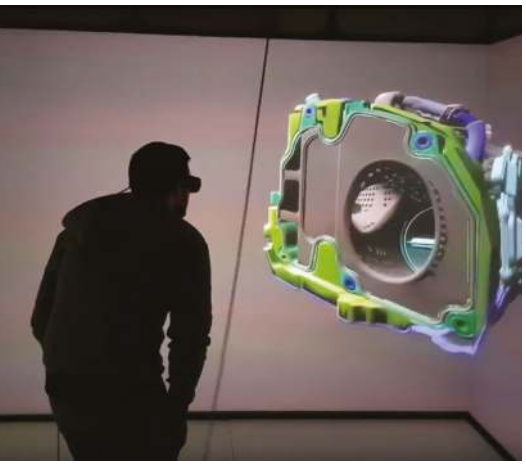
GUIDE@HAND

GUIDE@HAND is a multiplatform (smartphone, web) application family based on RTD work at SZTAKI of the early 2000s. The first member of the line was GUIDE@HAND Budapest, offering touristic services in three languages. This has been followed by many thematic applications for settlements, regions, companies, institutions, enterprises, organizations, etc. both in Hungary and abroad.

https://guideathand.com/

INTERACTIVE THEMATIC WALKS

The development of interactive, thematic, guided walks for multiple platforms (smartphone, web) was started in 2012. The latest walk named **"In the footsteps of the Pal street boys"** was created in 2019. It is available free of charge, in Hungarian and English, the app presents its users the locations of the world-famous novel by Ferenc Molnár, the life of Budapest in the middle of the 1900s and shots of the classic film based on the novel. The walk makes use of several multimedia items (text, picture gallery, collection of articles, narration, shots of the film).



APERTUSVR

SZTAKI's most successful open-source development, called **ApertusVR**, makes it possible to integrate virtual reality technologies even into industrial software systems.

ApertusVR has been utilized in various applications, in fields such as medical (The University of Texas at Austin), education (Tallinn University of Technology, Chalmers University of Technology, Politecnico Milano), and production (RoboDK).

http://apertusvr.org/

SZTAKI IN NUMBERS

More than **1,5 million users of our services**

~30 industrial projects every year

33 international and EU projects

38 years – the average age of our researchers

250 publications a year

More than **50 mentored students** a year

More than **20 PhD. students** a year

ARTIFICIAL INTELLIGENCE
National Laboratory

Artificial Intelligence National Laboratory

The **Artificial Intelligence National Laboratory (MILAB)** aims to strengthen Hungary's position in AI:

- Funding for flagship basic and applied research projects (publications, patents, emerging industrial relations, technology transfer).
- Networking, strengthening synergies between actors, representing competencies in industry and international projects.
- International relations, interconnected research ecosystem.
- Source multiplication, funding for risky or high societal utility research.
- Coordination with market and application needs, organization of demos and conferences.

The MILAB research plan follows the Hungarian National Artificial Intelligence Strategy (2020-2030) and implements its research components. Stakeholder needs and requirements from industry, society and government are considered in the cooperation of the MILAB Project Office and the Hungarian Artificial Intelligence Coalition Program Office. Our fields of research are:

- Industrial research: medical diagnostics, biometric applications, agri-food industry, transportation, manufacturing, processing industry, telecommunications.
- Research of artificial intelligence and the mathematical basics of machine learning.
- Developments of machine perception and language procession.
- Research of data processing technologies to protect personal data.

The 2020 established Artificial Intelligence National Laboratory is led by **SZTAKI**, and basic research topics are coordinated by Alfréd Rényi Institute of Mathematics. The laboratory has launched with 10 collaborative partners including universities and research institutes.

MŰEGYETEM 1782

Eötvös Loránd University

INSTITUTE OF EXPERIMENTAL MEDICINE

SPECIAL SERVICE FOR NATIONAL SECURITY

Alfréd Rényi Institute of Mathematics

AUTONOMOUS SYSTEMS
National Laboratory

National Laboratory for Autonomous Systems

The **National Laboratory for Autonomous Systems (ARNL)** aims to research, develop and coordinate innovative solutions for the mobility of road vehicles, aerial vehicles and robots, particularly their complex systems, formations and applications that necessitate either the autonomous, or the cooperative functioning of these mobile agents.

Its activity is directed towards mobility research and development, demonstrating functional and cooperative operation, facilitating knowledge transfer, preparating publicly funded and industrial projects, and to education. The research results and know-how thus generated not only help to increase the added value of the domestic automotive industry but, by communicating the results and promoting closer collaboration between industry and academia, it will also raise public confidence in autonomous vehicles.

We cooperate with several international and local industrial firms.

RELATIONSHIPS

INDUSTRIAL RELATIONS

Scientific excellence is not the only important factor at SZTAKI: the practical use of our scientific results as products or services is our strategic intent. Digital transformation, mobility, the industrial and service sectors are woven through every area of life, creating so many special requirements and new tasks that can be solved by the scientific and development potential one may find in SZTAKI.

László Monostori, director of SZTAKI, Erzsébet Knáb, member of the board of directors responsible for personnel and organisation of Audi Hungaria Zrt. And József Bokor, scientific director of SZTAKI.
Photo: Audi Hungaria

SZTAKI's connections to industry were completely reconstructed after having been scaled down during the nineties. Our institute has direct working relationships with several, world-leading industrial companies. We work together on common industrial solutions.

We have often formed successful international cooperation, mostly due to our completed research and development projects within European framework programmes.

Some of our partners

ARTIFICIAL INTELLIGENCE, MACHINE LEARNING

Ericsson Magyarország
Magyar Telekom
Robert Bosch
OTP Bank

OPTICAL SOLUTIONS, MACHINE VISION

3B Hungária
77 Elektronika
BHE Bonn
Gamma
Geonardo
Google
Intel
Interinn
Knot
Medicor
Microsoft
Nvidia
Samsung
Tateyama Kagaku Industry

TRANSPORT TECHNOLOGY, AVIATION AND TERRESTRIAL VEHICULAR PROJECTS

Airbus
Audi
Dassault Aviation
Knorr-Bremse
Ricoh
Robert Bosch
ZalaZONE

CONTROL TECHNOLOGY

MVM Paksi Atomerőmű
Paks II. atomerőmű
Thyssen

INDUSTRIAL DIGITISATION

Anton AQ
Aventics-Emerson
FSegura
Hitachi
Siemens

CYBERSECURITY TOOLS, CRISIS MANAGEMENT

Internet Szolgáltatók Tanácsa
Nemzeti Kibervédelmi Intézet

MULTIMEDIA DEVELOPMENTS

BFTK Budapest Fesztivál- és Turisztikai Központ
IFKA Iparfejlesztési Közhasznú Nonprofit Kft.
Szerencsejáték Zrt.

EPIC INNOLABS

Developing Together

EPIC InnoLabs Nonprofit Kft. is a project company co-owned by SZTAKI and the German Fraunhofer Society (Fraunhofer Gesellschaft). Supported by the knowledge base of our research institute, the team of experts has proved repeatedly through international cooperation that its research and development results are effective in industrial environments.

László Monostori, Director of SZTAKI, Reimund Neugebauer, President of the Fraunhofer research network in Germany, József Pálinkás, former director of NKFIH, and József Bokor, scientific director of SZTAKI at the opening of EPIC Innolabs.

How to prepare and live up to the opportunities offered by industrial digitisation? Currently, prime focus of EPIC InnoLabs is on industrial digitisation and production informatics, backed by multiple decades of experience.

EPIC InnoLabs mainly focuses on project-based engineering, IT, research and development, and educational tasks, at the request of mostly Hungarian medium and large industrial companies, mainly from the fields of car manufacturing, electronics, and logistics. Our developers – often in cooperation with SZTAKI researchers – have been involved with over **40** projects ordered by close to **30** different partners.

Excellence in Production Informatics and Control

EPIC InnoLabs considers that it is in prime position to fuse industrial and research knowledge bases. We hold our yearly **INDIGO – Industry Digitalisation Day** event for this very reason.

The motto of EPIC InnoLabs is: **"developing together"**. We offer many cooperation choices for our partners, in topics such as industrial problems, solving part tasks, introducing special informatics for production, and subcontractor partnerships for more complex projects.

All this is augmented by the multi-decade professional software development competencies of several institutes within the **Fraunhofer Society** that we can put to use in EPIC InnoLabs' and SZTAKI's development projects, as well as in customer cooperation. Our surveys show global demand expanding in these fields.

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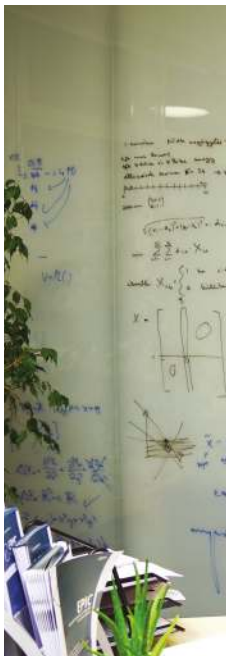
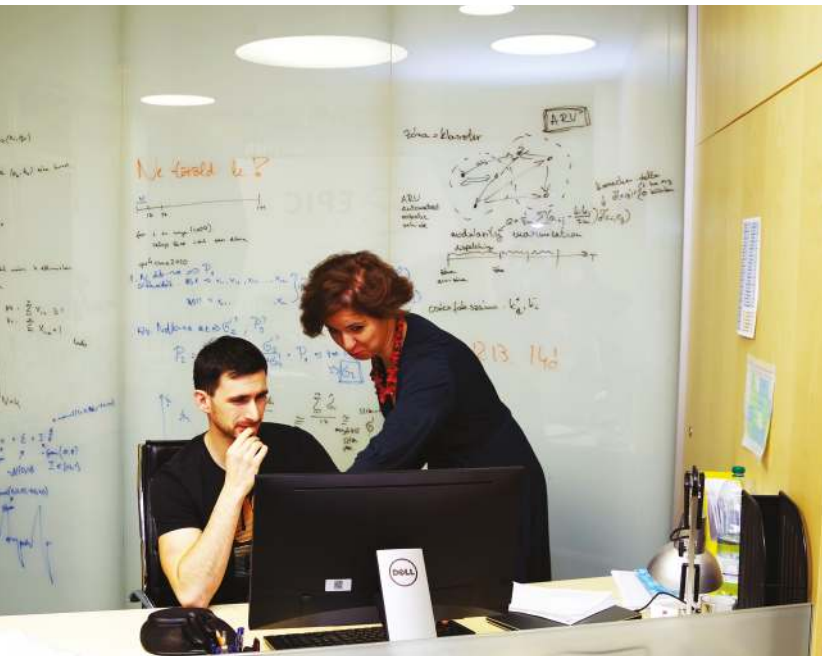
EPIC InnoLabs, as the **only company** of its type in Hungary, is offering industrially **proven model-based** solutions supported by **scientific background** for the following fields:



PLANT SIMULATION AND OPTIMIZATION OF PRODUCTION AND LOGISTIC SYSTEMS

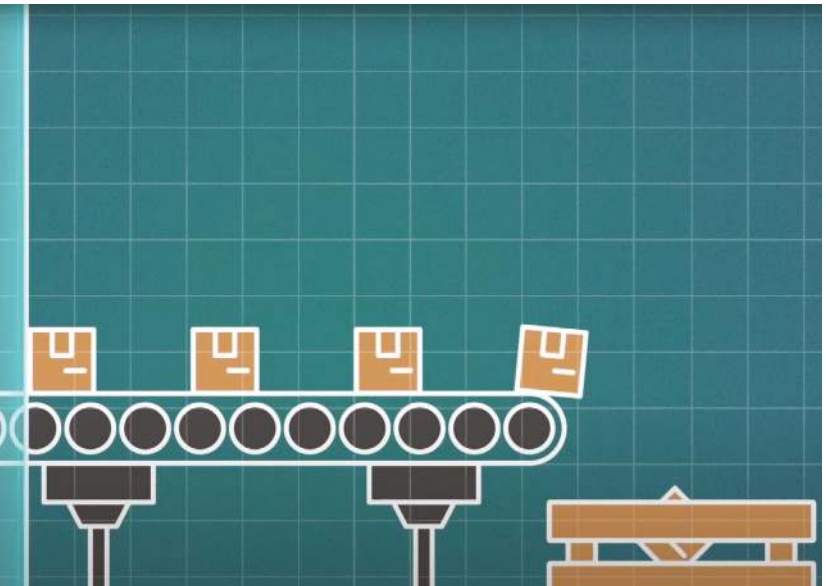
RESEARCH, PROTOTYPES, AND UNIQUE PROJECTS

INDUSTRIAL DATA ANALYTICS



BID DATA, ARTIFICIAL INTELLIGENCE, MACHINE LEARNING

DESIGNING SPECIAL ROBOTIC SYSTEMS



INDUSTRY 4.0 STRATEGY, EDUCATION AND INTRODUCTION

IPAR 4.0 NTP ASSOCIATION

The Industry 4.0 National Technology Platform

In May 2016, co-organised by the Ministry for National Economy and SZTAKI, the Industry 4.0 National Technology Platform was formed, in association with companies, research institutes and higher education institutions. The Industry 4.0 National Technology Platform Association has existed as a legal entity since December 2017.

Founding the Platform was urged by the recognition that production and logistics systems are entering a new, digitised era, resulting in fundamental restructuring. Such processes demand fast problem solving and never-before-seen levels of innovation by economic actors to build bridges between the physical and the digital worlds.

The main goal of the Platform is to enhance information exchange in key areas of Industry 4.0, and in parallel, strengthen the global competitiveness of the contributors to the field as well as of Hungary itself.

László Monostori, director of SZTAKI, is the president of the Association. The Association operates in Working Groups, involving SZTAKI employees. SZTAKI also provides the secretariat of the Association for daily operational purposes.

As one of its first tasks, the Association has been revealing Hungary's Industry 4.0 ecosystem, the technological and business maturity of Hungarian companies in an unprecedented way, providing an overview of the current directions of the macro-economic developments.

IPAR 4.0
NEMZETI TECHNOLÓGIAI PLATFORM

WWW.I40PLATFORM.HU


SZTAKI
Computer science and automation
since 0000 0111 1010 1100
RESEARCH
FROM THE BASIC TO THE APPLIED ONE
INNOVATION
FROM THE LABORATORY TO THE MARKET
CONSULTING
FROM THE SHOP FLOOR
TO THE ORGANISATION
www.sztaki.hu
Centre of Excellence

PUBLIC SERVICE

SZTAKI plays a leading role in several associations, is a member of innovative associations, and also provides services to the Hungarian government.

5G Coalition

Hungary is at the forefront of digital innovation: with the world's 3rd best 4G mobile network, it is in good shape to turn its position in mobile telecommunications into a competitive advantage with the launch of 5G. In 2017, the **Hungarian 5G Coalition** was formed with the involvement of SZTAKI, the government, the research sector, the infocommunications sector and the automotive industry. Its aim is to prepare for the development of a 5G test, to create a regulatory background, and to develop a Hungarian 5G strategy.

5G koalíció

Artificial Intelligence Coalition

The aim of the Artificial Intelligence Coalition, of which SZTAKI is a founder member, is to define the development directions and framework of AI in Hungary, and to provide a professional and cooperation forum for AI developers, market and state actors representing AI users, as well as academic, professional organizations and interstate institutions. The AI Coalition Data Industry Working Group is led by SZTAKI.

artificial intelligence coalition

EGI

Since 2021, SZTAKI is a member of the European EGI organization, which unites national e-infrastructures (www.egi.eu). EGI federates computing and data management services from more than 23 countries and makes them available to international research projects and industry. EGI membership will give SZTAKI the opportunity to integrate ELKH Cloud into the EGI federation of European cloud systems, and will also provide support to Hungarian researchers with EGI resources.

Network for Digitisation

Netzwerk Digital (Network for Digitisation) was established with the cooperation of SZTAKI and the German, Austrian and Swiss chambers of commerce operating in Hungary. Their multi-annual cooperation addresses the practical issues of digitisation from the perspective of economic actors. The founders, through the special programs DigiTalk, DigiWorkshop, DigiEvent, and DigiLearn, provide an opportunity to learn about the benefits of digitisation, to exchange professionals and to support digital training.

GovCERT

HunCERT, operated by SZTAKI, is in continuous cooperation with the GovCERT National Incident Management Center maintained by the National Institute of Cyber Defense, as a sectoral security organisation of Hungarian Internet service providers. In addition to the continuous sharing of information, the two organizations cooperate in organising professional workshops and exercises. Through the organisation, the research and development results of SZTAKI aimed for a more accurate assessment of cyber security to be utilised at the national level.

SCIENCE RELATIONS

At SZTAKI, we deal with targeted basic and applied research inspired by industrial challenges, and we are connected to domestic and international scientific life by a thousand threads. Our scientific results are also regularly published in the most important conferences and journals in their fields.

In the framework of the EU's "Horizon 2020 – Widening, Teaming" research excellence program, which is of great importance in engineering and business intelligence, the Centre of Excellence in Production Informatics and Control (EPIC) international research project was launched in 2017 under SZTAKI's leadership. Our partners are the German Fraunhofer Society, and the Faculty of Transportation Engineering and Vehicle Engineering of BME. In our international projects, research, and our scientific contributions to commercial projects (unmanned aerial vehicles, flexible-wing aircraft) we at SZTAKI deal with targeted basic and applied research inspired by industrial challenges to international scientific life. Our scientific results are also regularly published in the most important conferences and journals in their fields. We develop technology with the Department of Aeronautics of the University of Minnesota, the US Navy Research Office (ONR), and the German (DLR) and European Space Agency (ESA) .

We cooperate in R&D with several international economic players - for example: Volvo, Opel, and Audi. A joint international patent was also issued with Hitachi on the integration of production, capacity and installation planning.

International university and industry relations

We maintain a long-term professional relationship with several well-known foreign universities:

- Freie Universität Berlin
- KTH Stockholm
- University of Bordeaux
- University of Melbourne
- RWTH Aachen University
- University of Westminster
- Technische Universität Berlin
- Universität Bonn
- Université de Montpellier
- Technische Universiteit Eindhoven
- Université Paris-Sud
- Hebrew University of Jerusalem
- North Carolina State University
- University of Minnesota
- Karlsruhe Institute of Technology
- KU Leuven

The **Hungarian office of the World Wide Web Consortium (W3C)** is operated by SZTAKI.

We are members of the ERCIM research consortium, which brings together leading European institutes in our field, among partners such as INRIA, CWI and the Fraunhofer ICT Group. The Institute has participated in the ERCIM Fellowship programme, several times as host institution. Our senior staff hold positions in several other prominent international professional organizations (CIRP, IFAC, IMEK, IEEE, IARP).

International scientific relations

SZTAKI's researchers are editorial members in fifty-three international and domestic journals. For example: CIRP Journal of Manufacturing Science and Technology (CIRP-JMST), Elsevier; CIRP Annals, Elsevier; Computers in Industry, Elsevier.

We also strengthen our scientific relations by organizing international conferences, for example:

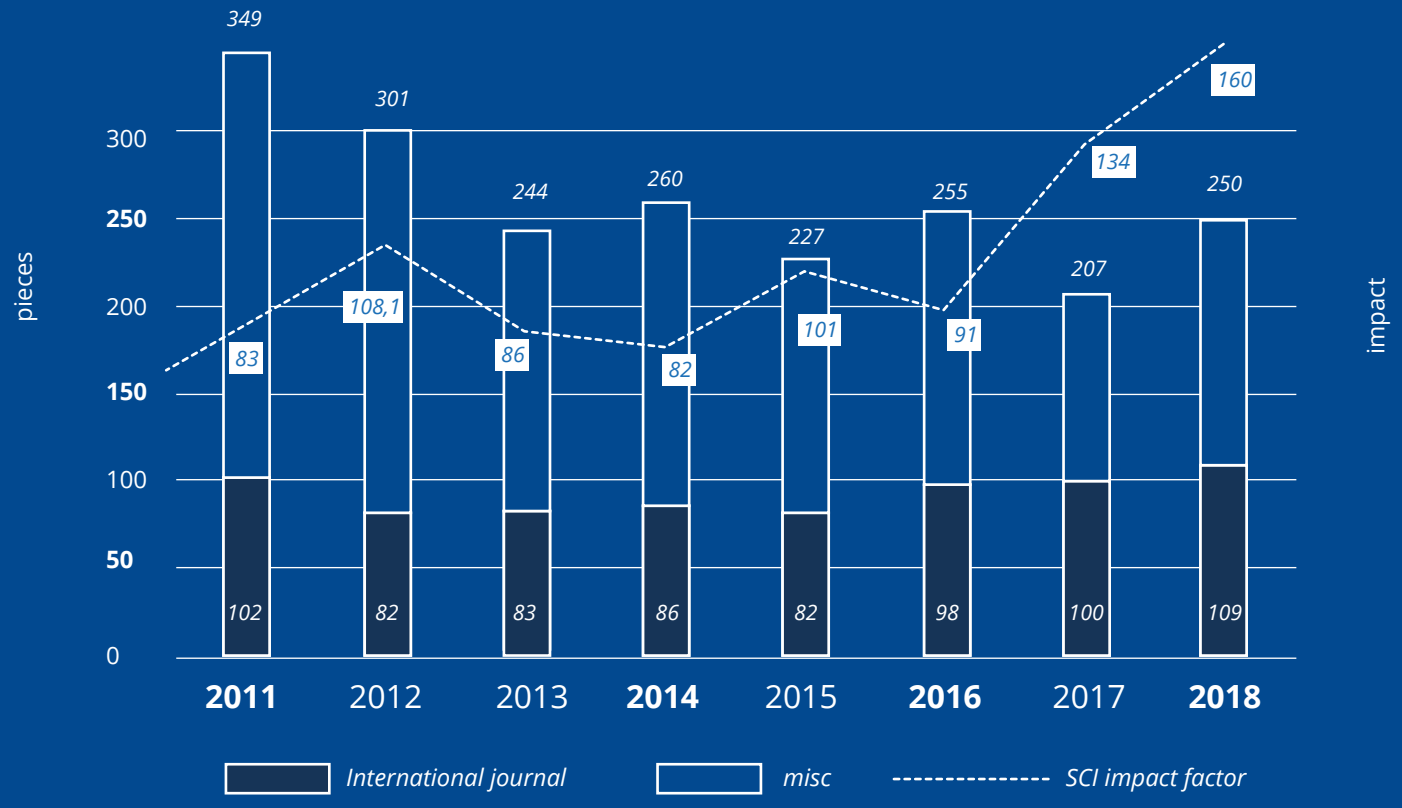
- **INDIGO Industrial Digitidation Day** (200+ attendees)
- **Central European Cooperation for Industry 4.0 Workshop**, proposed by the EU
- **The 20th European Conference on Mathematics for Industry** (ECMI 2018, 350+ attendees)
- **Hungarian Operations Research Conference**
- **The International Measurement Confederation, IMEKO, Technical Committee 10 on Testing, Diagnostics & Inspection**

SCIENTIFIC PUBLICATIONS

SZTAKI's mission is to create new results in the plan of wide-ranging domestic and international collaboration, based on strong - and typically targeted - basic research activities, and to support their application to sustainable development of the economy and society, while helping to preserve and to raise Hungarian scientific and technical culture to a higher level.

We have achieved our goals along the lines of the above mission and with the motto "Excellence in Science and Innovation". We won several new basic research projects and, between January 1st and August 31st, 2019, we published 181 publications, 59 of them in journals with an impact factor. In the last three years, we have written ten textbooks and 23 book chapters. We have published three new patents and renewed seven (several of which are international patents). In Horizon 2020, we won 27 projects, of which six are consortium leaders.

We publish in a large number of international journals, and the SCI impact factor of SZTAKI researchers is constantly rising.



OUR MOST IMPORTANT INTERNATIONAL AND DOMESTIC PROJECTS

Lung cancer diagnostic AI, based on chest CT scan: the aim of the project is to develop artificial intelligence methods based on chest CT scan for the diagnosis of lung cancer.

FliPASED (Flight Phase Adaptive Aero-Servo-Elastic Aircraft Design Methods): the project is researching the combinatory possibilities between aeroelasticity, behaviour adaptable to atmospheric turbulence, aircraft control methods, on-board instruments and certification aspects.

NEANIAS (Novel EOSC services for Emerging Atmosphere, Underwater and Space Challenges): the project aims to develop new European Open Science Cloud services for emerging atmospheric, underwater and space applications.

Ready2BIM (Planning of the renovation of residential buildings and adaptation into the BIM workflow): the project aims to develop innovative GIS services, to support cities' energy and reconstruction tasks.

Integration of speed and suspension control to increase automated driving comfort: working with the Institut Polytechnique de Grenoble and GIPSA, the project aims to integrate speed and suspension control to increase automated driving comfort.

Optimization in Sustainable Supply Chains: SZTAKI researchers develop models and procedures to facilitate the optimal operation of supply chains, considering unforeseen events, operational environmental impacts and energy use.

DigiPrime (Digital Platform for Circular Economy in Cross-sectional Sustainable Value Networks): the project aims to develop a new concept digital platform based on a circular economy that bridges the current information asymmetry between actors in the value chain.

AIDPATH (Artificial Intelligence-driven, Decentralized Production for Advanced Therapies in the Hospital): the project aims to support the next generation of personalised treatment in Europe's hospitals with artificial intelligence tools.

HRDA (Hungarian Research Data Alliance): HRDA aims to disseminate good practices in the management of research data in Hungary, under the umbrella of the RDA (Research Data Alliance).

EDUCATION

The involvement of SZTAKI in higher education is a crucial expansion of its research, and a tool for building the future. More than fifty of our colleagues hold classes in BSc., MSc. and post graduate schools, while also working as supervisors for PhD. students. Twenty PhD. students pursue their research under professional supervision in SZTAKI every year. Our staff provides 25 external and five internal founding members to Hungarian doctoral schools. We give seventy talented diploma planners and intern students per year the opportunity to gain research and development internships at SZTAKI.

ELTE

Eötvös Loránd University

ME

University of Miskolc

BGE

Budapest Business School

PE

University of Pannonia

BCE

Corvinus University of Budapest

NJE

John von Neumann University

The eLearning Department of SZTAKI also supports the educational needs and plans of external partners and organizations with services in methodology, system implementation and for developing educational material. We also sponsor and organise a Hungarian e-learning conference series, the eLearning Forum.

In addition, **we organise training programmes** for our industry partners where they can learn about and adopt the latest technology solutions.

SZTAKI places great emphasis on the **lifelong learning** of its employees: our colleagues can improve their **language skills** and pass on the latest research results from international scientific journals and conferences in **internal seminars**.

At the invitation of SZTAKI, **internationally renowned researchers** regularly give lectures on the latest developments within their fields.

PPKE

Pázmány Péter Catholic University

BME

Budapest University of Technology and Economics

PTE

University of Pécs

ÓE

Óbuda University

SZE

University of Győr

SZTAKI


Sim update:
- alternativ (routing)
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OUR SOCIAL RESPONSIBILITY

THE SZTAKI COMMUNITY

SZTAKI won "Lovable Workplace" award in 2019 and 2020.

We reward our colleagues' extraordinary achievements every year. We offer several sports options in our many sports departments. SZTAKI has its own gym and sauna, and it also offers work health sessions and therapeutic exercises.

EQUALITY OF OPPORTUNITY

Equal opportunities are important to us as we offer job opportunities for challenged employees. We focus on environmental protection. Our functioning is sustainable and energy efficient, according to our commitment to public responsibility.

TALENT DEVELOPMENT

As an internationally recognized research institute, we provide professional mentoring, development opportunities, a multicultural, modern work environment, and the opportunity to participate in foreign conferences for young people starting their careers. The most important values in our organizational culture are teamwork and cooperation.

A FAMILY FRIENDLY WORKPLACE

We organize family days, Santa Claus events, and summer IT camps for employees' children. We also offer a school starter support package.

We support flexible work for expectant mothers returning to work and their part-time employment on demand.

HEALTH PROTECTION AND COMMUNITY

Maintaining health and working safely is paramount to the well-being of employees and the performance of the organisation. Our goal is to create the best possible working conditions. We provide state-of-the-art, ergonomic tools for safe and efficient work, and we develop a professional IT, office and support infrastructure.

The public spaces of SZTAKI, the modern library and the corporate community programs (for example, our family days) also contribute to our employees' satisfaction and to the community experience. In our various sports departments, we offer many sports facilities and physiotherapy for those who work here, who can also use the gym and sauna.

PUBLIC RESPONSIBILITY

The researchers and staff of SZTAKI not only take part in events dedicated to the profession but we are also present at events promoting science, which are primarily aimed at interested members of the general public. We regularly take part in demonstrations at Hungary's largest science promotion event, which is part of an international series of events, the **Researchers' Night**. We are also to be seen at the **Science Festival**, the **Hungarian Science Festival**, the **Autumn Festival of Museums**, **World Tourism Day** and **Hungarian Poetry Day**. We regularly participate in **Digital Theme Week**. In 2019, we participated in the organization and holding of the **Eötvös 100 Memorial Year**. Our TV and radio appearances and newspaper articles about them present our results, and SZTAKI researchers often speak as experts in the handling of topics related to their research. Our laboratories are regularly visited by interested college students, and secondary and primary school pupils.

SPORTS DEPARTMENTS OF SZTAKI:

- rowing
- tennis
- squash
- sailing
- gym
- football

SZTAKI JOINED THE FIGHT AGAINST COVID-19

SZTAKI and Wigner Research Centre for Physics donated the capacity of their computing resources, integrated in the ELKH Cloud (formerly MTA Cloud), consisting of thousands of CPUs and terabytes of memory to fight the COVID-19 pandemic caused by the new coronavirus.

SUCCESSFUL MODELING OF THE SPREAD OF THE PANDEMIC AIDED BY THE CLOUD

SZTAKI and Wigner Research Centre for Physics, with the support of the Hungarian Academy of Sciences (MTA) and the Eötvös Lóránd Research Network (ELKH), donated the capacity of their computing cloud for fighting the pandemic caused by the new coronavirus. The ultimate goal of the cloud is fostering research, and the donated capacity includes thousands of CPUs and terabytes of memory.

SZTAKI connected its computing resources to the Folding@home international research project, where are already computational tasks running with the explicit aim to stop the spread of the pandemic. The first projects search for the answer for how the coronavirus binds to the so-called ACE2 receptor.

The **University of Pécs – Szentágothai Research Centre** with the help of SZTAKI was able to migrate the research-related tasks to the cloud within a day. Thus, they were able to execute the tasks fifty times faster than planned. Thanks to the accelerated execution the partial results were handed to the researchers within hours instead of the estimated more than one week time.

The researchers investigated the genomic data of the virus collected from 100 different places and at different times in over 500 million steps. This information helped to map the evolutionary tree of the virus and thus, uncover the spread of the virus in Hungary.

„The availability of our state-of-the-art cloud-based platform, the expertise of the virus researcher colleagues, our applied computer science related expertise, and the full cooperation were all required to achieve this result of social significance."

Róbert Lovas,
deputy director of SZTAKI

WE CONTRIBUTE TO THE FIGHT AGAINST

COVID-19

WITH THOUSANDS OF CPUS!

SZTAKI AND WIGNER RESEARCH CENTRE FOR PHYSICS DONATED THEIR COMPUTING RESOURCES TO THE FIGHT.

SZTAKI

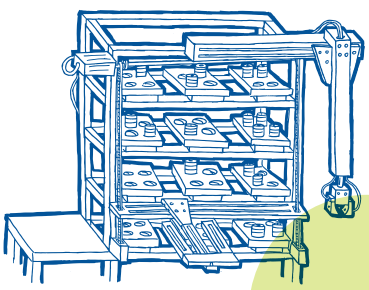
WIGNER

SMARTFACTORY

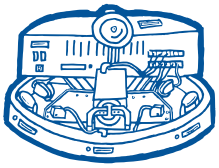
Demonstrator System for Cyber-Physical Production

Although much smaller than a real production facility in terms of size, SmartFactory can be classified as a Cyber-Physical Production System (CPPS) due to the complexity of the system itself and the processes running inside.

The laboratory displays the four core components of Cyber-Physical Systems (CPS), which are software, hardware, integration, and network, furthermore meets the requirements for the CPPS paradigm. EMI-SmartFactory can therefore be considered as a production and logistics demonstration system in terms of functionality and appearance.

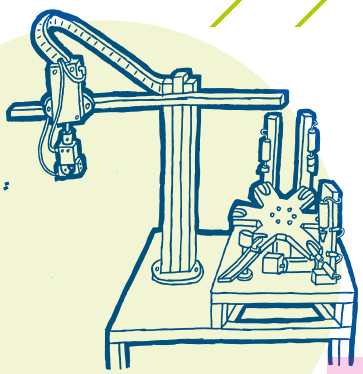


WAREHOUSE



MOBILE ROBOTS

When walking around the system, the **collaborative robot arm** is likely the first to catch one's eye. This device is also part of the system as a pick and place robot, but it is mostly the subject of other research projects. Behind the robot is a **scaled down shop-floor table** surrounded by a **conveyor belt**, where the **mobile robots** operate.

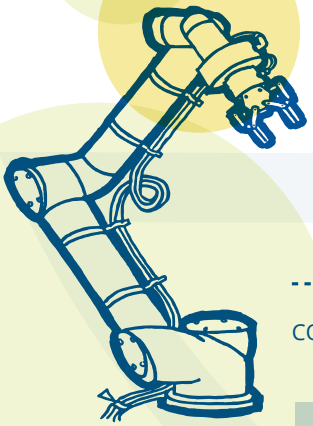


WORKSTATIONS

3 4

WORKPIECES

CONVEYOR SYSTEM



COLLABORATIVE ROBOT

The **small mobile robots** carry the **workpieces** between the **high-bay warehouse** and the four **workstations** in competition with one another and the **conveyor system**. The workstations perform the machining operations (stamping and drilling), while the warehouse stores the workpieces.

Learn more about Cyber-Physical Production Systems on page 20!

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