Institute for Computer Science and Control
Hungarian Academy of Sciences

H-1111 Budapest, Kende u. 13-17, 1518 Budapest, Pf. 63.
Tel: 279-6184, Fax: 466-7503,
http://www.sztaki.mta.hu/, e-mail: laszlo.monostori@sztaki.mta.hu

Annual Report on Scientific Activity at MTA SZTAKI

2014

Budapest
March 16, 2015

CONTENTS

I. Priorities and main tasks

II. Outstanding results in research, development and public relations

a) Research, development and innovation

b) Science and society

III. Domestic and international relations

IV. Summary of national and international grants won in the past year

V. List of major publications in the past year

I. Priorities and main tasks

The main focus of the institute is on *cyber-physical systems* (*CPS*), a framework that is capable of streamlining research activities and directing them into a broader international trend of R&D. Newer laboratories of the institute – such as the i4D Intelligent Space, System Control, SmartFactory and Cloud Computing laboratories – were created with this vision in mind, and have as a result significantly contributed to the emergence of new interactions between the theory and the practice of relevant applications.

Cyber-physical systems are computational structures that are strongly linked with the physical surroundings – including both physical entities and processes – and make intensive use of Internet-based services for data access and data processing. The application areas of CPS are already diverse and continue to rapidly evolve. The domains currently investigated at the institute include autonomous land and aerial vehicles, robot-assisted surgery, intelligent buildings, intelligent power grids, and intelligent manufacturing. Results are expected to contribute significantly to the development of "smart" cities, as well as "smart" systems for production, transportation, logistics and energy management, thus leading to higher living standards. As a reflection on this latter aspect, the term '*cyber-physical society'* has emerged to integrate not only physical and cybernetic spaces, but also the spheres of individual users, society and culture. According to the German Federal Ministry of Education and Research (BMBF), *cyber-physical production systems* (*CPPS*) can be expected to pave the way to a 4th Industrial Revolution, often referred to as Industrie 4.0.

Expectations towards cyber-physical systems are already significant, including among others robustness, self-organization, adaptive situational awareness, self-maintenance, transparency, predictability, efficiency, inter-operability, and support for global monitoring. While remarkable advances have been made in areas such as cooperative control, multi-agent systems, complex adaptive systems, emergent systems, sensor networks and data mining, such advances have not only reinforced but also extended expectations associated with the field, leading to a continued need for research and development.

II. Outstanding results in research, development and public relations

a) Research, development and innovation

In the following sub-sections, four key directions of basic research are introduced (specifically those of computational theory, systems and control theory, engineering and business intelligence, and machine perception / human-computer interaction). This is followed by a discussion on how results obtained contribute to those domains that are supported by the EU Horizon 2020 Framework Program, as well as the Hungarian programs of S3 Strategies for Smart Specialization and the New Széchenyi Plan. Separate sub-sections focus on application-oriented achievements in the areas of vehicle production / transportation, production informatics / logistics, energy / sustainable development, security / surveillance, and distributed computing / Future Internet.

<u>BASIC RESEARCH</u>

<u>Computer science</u>

Several interrelated research areas contribute to work on computer science carried out in the institute. In particular, results in theory of algorithms – dealing with parallelization and effective application of new hardware architectures – combined with results in data mining, information extraction, machine learning, database theory and large-scale graphs have led to important new synergies. Application areas include business intelligence, searching and sorting

of multimedia content, large-scale information processing problems in Web data mining and other areas, as well as extraction of patterns / anomalies from data. Work carried out in this area relies on extensive collaboration between engineers and mathematicians: research is primarily based on experimentation, and the sheer size of data sets involved requires a strong background in mathematically verifiable algorithms and probabilistic approaches.

Key results obtained in 2014 can be summarized as follows:

- A proof was given of Littlewood's 50 year old geometric conjecture, according to which a set of 7 cylinders with the same diameter and infinite length can be arranged so as to be in mutual contact. The proof is based on a homotopic approach combined with root verification algorithms
- A polynomial algorithm was developed for the optimization of *PageRank* values by iteratively turning edges on and off. It was proved that the optimization task can be efficiently reduced to a Markov decision problem. PageRank values are widely used to define the relative importance of nodes in directed graphs.
- Primarily with respect to the kinds of geometric graphs that are characteristic of parameter vectors used to specify multimedia databases: new foundations were laid down for the selection and ranking of parameters through the analysis of giant components.
- FPGA-based circuits were developed for faster performance in the simulation of non-Boolean operators, using high-speed simulations of non-transistor based, post-CMOS processors.
- On the subject of algorithm design and complexity: A book was published with Springer Verlag, entitled Internet Optical Infrastructure – Issues on Monitoring and Failure Resoration. It details results on the security of optical networks.
- Valuable new theoretical results were achieved on the polynomial time countability of small-sized graph pattern occurrences, and on the parametric complexity of the partial graph search problem.
- On the subject of recommendation systems, specifically regarding the analysis of changes in networks of social relationships and shared interests, both theoretical and practical (leading to highly ranked competition performance) results were achieved through the use of matrix factorization based models combined with new methodologies of online, time-sensitive learning.

Results in these areas have led to the winning of grant support through the ERC and the Momentum programs. Continued R&D activities based on these results are being carried out in cooperation with Hungarian Telekom, AEGON Hungary, Vodafone Hungary as well as a number of SMEs (Schibsted Media Group, Glia Kft, Petabyte Kft). AEGON Hungary uses results in its customer recognition and fraud detection technologies. Hungarian Telekom, Vodafone Hungary and AEGON Hungary are users of a Hungarian language search engine developed at the institute. These companies, together with the SMEs listed above, also provide important testbed environments for experimentation with the institute's R&D results in text mining.

Systems and control theory

In general, the implementation and deployment of automated control systems requires a solid mathematical background in systems and control theory. The institute places strong emphasis on both theory and practice with respect to this domain. Relevant theoretical research addresses, among others, the topics of systems modeling and identification, theory of adaptive and robust control, signal processing and filtering, distributed and networked control systems, as well as process control. Within these areas, both linear and nonlinear systems are considered

in both continuous and discrete time domains, and in both deterministic and stochastic contexts as necessitated by the particular application at hand.

Key results obtained in 2014 can be summarized as follows:

- Results were achieved on problems associated with robust control design based on Linear Parameter Varying (LPV) and quasi-Linear Parameter Varying (qLPV) models. Conventional convex LMI/LTI design approaches are in general not applicable to qLPV problems, or otherwise yield conservative solutions. Recent results obtained at the institute have highlighted a common geometric background behind robust control design approaches that provide a suitable theoretical foundation for both the design and analysis of controllers.
- Results were achieved in the synthesis and analysis of practical fault tolerant control systems, using the approaches of fault detection and structural reconfiguration. Methods were developed to guarantee the fulfillment of quality requirements using switching-based reconfiguration strategies and qLPV models. Results have been applied to a variety of complex control problems in vehicle dynamics.
- In the area of signal processing and system identification: a new non-parametric system identification method was developed based on hyperbolic wavelet constructions. The method was inspired by approaches that perform system identification using rational orthogonal basis functions, and is capable of interactively finding the poles of a system based on measurements in either time or frequency domain.
- A new convex hull and TP model manipulation based optimization method was developed to support LMI-based control theoretical approaches.

Relevant results have been primarily used in the industries of energy, transportation and vehicle production. The institute brought together its industrial partners (i.e. Airbus, Bosch, Knorr-Bremse) in a number of Hungarian and European R&D projects, allowing questions of practical applicability to be considered in all phases of research. Industrial level solutions were developed in fault tolerant on-board vehicle control systems, coordinated control of vehicle fleets, intelligent driverless vehicle control, sensor fusion methods, and integrated control methods for electronic steering and braking.

Engineering and business intelligence

Challenges associated with the design, operation and adaptive resilience of complex engineering and economic systems necessitate strong cooperation among a variety of fields including computational theory, operations research, manufacturing science, production engineering and knowledge-based approaches.

Key results obtained in 2014 can be summarized as follows:

- Investigations were carried out on scheduling tasks that depend not only on the availability of machines, but also on a set of materials that are transported to the production site on several occasions but at different times. Both positive and negative results were obtained on the approximative treatment of challenges relevant to such tasks.
- An analysis was given on a basic problem of disjunctive programming. The analysis has led to a generalized integer programming approach capable of further strengthening well-known disjunctive cuts.
- A new approach was proposed to support the discovery of sources of inconsistency in paired comparison matrices. In this context, it was shown that the eigenvector approach can lead to inefficient solutions at arbitrarily small levels of inconsistency.

- New production planning and resource allocation methods were developed for modular assembly systems in which the relationship between the hierarchical modeling levels of capacity planning and production planning are guaranteed through regression models.
- The inverse problem of single product multiperiod lot-sizing was defined and solved. The solution allows for the approximation of supplier cost parameters based on historical demand and supply data in asymmetric supply chains.
- A generic, integrated order and path planner, as well as an inverse kinematic approach was developed for the planning of cycle time optimized paths for laser welding robots. All of the solutions take into account various physical constraints including visibility, collisions, technological process parameters and workspace dimensions.
- A set of generic methods were developed in collaboration with the Hitachi Yokohama Research Laboratory, using which the characteristic components of complex, large-scale engineering objects and their topological relationships can be reconstructed based on point cloud surface data.
- A novel tool-path planning procedure was developed for robot-based incremental sheet forming. The procedure is built on the foundations of past results which are now patented under EU patent number EP2505279 B1.

The research detailed above was carried out in the framework of EU supported research projects. In some cases, the institute acted as consortium leader within these projects. The theoretical results obtained have served as a strong foundation for industrial applications (see later sections on Production informatics and logistics, as well as on Energy and sustainable development).

Machine perception and human-computer interaction

Detection and recognition in the heterogeneous world of sensor networks is an increasing challenge. Researchers at the institute have addressed a variety of relevant problems, including the fusion of the different sensors in space and time, the discovery and geometric processing / modeling of causal links between temporally and spatially separate measurements, the organization, storage, manipulation and modeling of collected measurement and categorization data, as well as the static and dynamic reconstruction, editing and animation of indoor and outdoor objects and color spaces. Key results obtained in 2014 can be summarized as follows:

- A set of Monte Carlo algorithms were developed for the automated categorization of traffic events in urban settings based on Lidar point cloud and radar data.
- An algorithm was developed for high-speed phase reconstruction, potentially through no more than a few iterations, based on the in-line hologram of an object. The algorithm makes use of data from an off-axis auxiliary hologram, i.e. from a lower-resolution reconstructed image of the object (the 0-order of the off-axis hologram can be interpreted as an in-line hologram). Phase reconstruction using earlier methods was problematic in the case of in-line holograms due to the fact that the diffractions of 0-order terms and twin image terms overlapped in the object reconstruction space, as a result of which segmentation was difficult to achieve.
- A set of 3D recognition and matching approaches linked with ad hoc sensor deployment were developed.
- Graph theoretic approaches were developed for multimedia data search in sensor networks.
- A procedure was developed for detecting changes in landscape surface geometry using aerial and space images based on search in image databases recorded years earlier. The procedure applies image segmentation fusion using a locally adaptive statistical model that is based on Markov field stochastic optimization.

- A solution was given to the problem of recognizing vehicles in series of 3D point cloud images. The developed framework receives a raw point cloud stream from the recording device and recognizes individual vehicles using detection and grouping procedures.
- An automated procedure was developed for image matching in networks of ad hoc mobile cameras. The procedure is capable of achieving fused mapping based only on partial location information and a comparison of images. Graph theory based extensions were also developed for the generation of contiguous space metrics based on local metric data acquired by arbitrarily positioned robot sensors.
- An optically correct chromatic model was developed to describe human visual perception. The model states that the optical resolution of a healthy eye is larger than the resolution of the retina, entailing that the retina sub-samples the image projected onto it. The model also predicts that this difference in resolution grows towards the periphery.
- An approach was developed for interactive modeling and object fusion based on point clouds in 3D space. The model can be applied to the simultaneous treatment of virtual and real spaces. The international patenting process of the approach is in its final phase ("Method and System for Generating a Three-Dimensional Model" PCT/HU2014/000017")

DEVELOPMENT AND INNOVATION

Vehicle and transportation systems

The structure of technological development in the fields of vehicle and transportation systems has been largely influenced by systems targeting road and aerial transportation. In line with global trends in vehicle and transportation systems research, one of the main focuses of in institute is on cooperative intelligent transportation systems (C-ITS). Hence, research is conducted on the theory of cooperative systems, integrated methods of large-scale vehicle and traffic control system design, modern network communication protocols, fault tolerant operation in on-board control systems, and driver assistance systems.

Key results obtained in 2014 can be summarized as follows:

- Demonstrations were given on theoretical results relevant to the subject of how road vehicles equipped with standard communication technologies can make use of cooperative communication techniques for enhanced safety and energy efficiency.
- In the area of cooperative autonomous vehicle control systems: a group of methods were developed for analysis of stability and control precision. The developed methods allow for the effective treatment of several classes of modeling uncertainty that are often present in practical applications, while also taking into account inherent properties of the underlying communication network.
- A set of distributed and hierarchical control strategies were developed for improved effectiveness in controlling hybrid and electronic road vehicles. Fault tolerant control and communication methods based on reconfiguration, as well as specialized vehicle topologies play a central role in the developed strategies.
- Design methods were developed for control tasks relevant to improved road stability, road safety and energy efficiency based on smart sensors as well as sensor fusion and communication networks. These solutions were obtained in collaboration with the Research Center of Vehicle Industry at Széchenyi István University, Győr.
- A camera-based safety enhancement system was developed for safe and dependable driving performance. The system was developed in collaboration with the Robert Bosch Knowledge Center.
- Advanced fault-tolerant control methods were developed to support high safety standards in civil aviation. The methods address a well-specified set of potential failures in

on-board sensor and actuator systems. In cases of failure, the state of the aircraft is guaranteed to remain within a specified domain, thus the burden placed on the pilot as well as a number of potential sources of danger are mitigated. This work was carried out in the framework of the RECONFIGURE FP7 project in cooperation with Airbus.
- A novel safety critical avionics architecture was developed for continued operation in the event of single component failures in unmanned autonomous vehicles (UAVs). This capability is essential for the future integration of UAVs into the common airspace.
- A vision based sense-and-avoid (SAA) collision avoidance detection system was developed to help mitigate risks of mid-air collision in aviation. The system uses information fusion from the state of the aircraft and information on the predicted path of intruder aircrafts. The system was developed with the goal of integration of UAVs into shared airspace in mind.
- The fault tolerant architecture and collision avoidance system described in the previous points was implemented for a small-scale, redundant and highly dependable avionic system that is unique among comparable systems. A set of experiments were carried out based on the implementation, which confirmed that the technology developed provides a solution to the safe spatial separation of autonomous aircrafts throughout the duration of their journey.
- Processing and analysis was performed on simulation and physical measurement data with the purpose of developing solutions for path estimation and probabilistic collision detection in research supported by the US Office of Naval Research (ONR).

Production informatics and logistics

Research, development and innovation in production informatics and logistics focuses on the design, modeling and operation of servicing and logistic systems, as well as on their optimization and monitoring so as to support adaptiveness to real-time conditions on shop floor, enterprise and network levels alike. In this area, the institute aims to closely follow current trends in cyber-physical production systems (i.e. *Industrie 4.0*) and to join international efforts in research, development and innovation targeting solutions used in large-scale global enterprises, as well as increasingly in small and medium-sized enterprises. A large part of the institute's activities in practically oriented R&D and industrial deployment are carried out in the framework of the *Fraunhofer-SZTAKI Project Center for Production Management and Informatics.* Key results obtained in 2014 can be summarized as follows:

- The production planning method developed for modular assembly systems was applied to the problem of resource capacity and production planning optimization in reconfigurable automotive industry production chains.
- Within the framework of a European R&D project: Methods developed at the institute supporting automated configuration and offline programming of laser welding robot systems were implemented in an integrated planning and simulation system. The implementations were verified in physical welding experiments modeled after real-world tasks in automotive industry.
- An implementation was given of a production planning system developed for Audi Motor Hungaria. The implementation has been deployed at the destination site, and its testing is currently under way.
- Within the framework of a domestic academic-industrial project: Systems were developed to support production technological and business processes in the areas of situation recognition, quality assurance and optimization based on modern artificial intelligence methods.
- In the area of cloud-based systems for production: A novel taxonomy was developed to describe possibilities for interconnection among virtual enterprises; an analysis of

standards for internal and external communications in enterprises; a new service model referred to as *Manufacturing as a Service* (MaaS).
- A set of novel methods were developed for data type definition and data stream processing in heterogeneous production networks. The developed methods support interoperability among different enterprises.
- A set of novel methods were developed for enhanced quality image fusion in multi-camera systems, as well as for the creation of complex virtual reality spaces with multiple layers. An international patent application has been submitted by the institute based on a system developed for the generation of unified 3D models. These methods and solutions were primarily developed for use in film industry.

Most of the above results were commissioned by the industrial partners of the institute, including world-class manufacturing companies such as Audi Hungaria Motors Ltd, GE Hungary, Knorr-Bremse Braking Systems Ltd, Bosch Rexroth Pneumatics Ltd., Hitachi, Gamesa, Jaguar-LandRover, and Palletways. The R&D cooperation between SZTAKI and HITACHI, which dates back to seven years, and which has already resulted in several joint patent applications is especially important. While this later cooperation was originally initiated in the area of semiconductor manufacturing, it has subsequently been extended to domains such as production for power systems industry and visual monitoring of power plant construction.

Energy and sustainable development

A fundamental requirement behind sustainable development is the capability of energy production, transfer, and transformation systems to adapt to changing demands and possibilities. Relevant R&D activities within the institute focus on the development and deployment of intelligent systems capable of minimizing energy costs associated with various public services including public lighting and education.

Key results obtained in 2014 can be summarized as follows:

- An aggregation mechanism was developed to support prediction of energy production and consumption in renewable energy systems. The mechanism uses statistical machine learning to combine multiple sources of stochastic (both linear and non-linear, partly parametric) time series model predictions.
- The institute participated in the development of E+grid – an energy-positive public lighting system – in a consortium led by GE Hungary. The institute was responsible for the development and implementation of the central control subsystem. A prototype of the complete cyber-physical system is in operation on the premises of MTA MFA in Csillebérc. Public demonstrations of the prototype were held on several occasions.
- In the area of control and monitoring of energy production systems: Continued strategic partnership which the *Paks Nuclear Power Plant*. The institute provided background expertise for the renewal of existing control systems, and for the preparation of continued projects. Validation and verification tasks were developed by the institute in relation to the planned reconstruction of the Regulation and Security System (SZBVR) and Reactor Power Control System (RTSZ). In specific cases, the institute was involved in the investigation and reparation of failures in instrumentation and control systems operating at the plant. With its strong background in systems control, the institute has joined the planning phase targeted at extending the power plant with new blocks. In this area, the institute formulated a set of guidelines for the development the required control systems.
- A platform service was developed to support energy efficiency and relevant development decisions, as well as relevant workflows in the maintenance of school buildings. A prototype implementation is currently used in 4 locations (Genoa, Lesa, Plovdiv, Lisbon).

Security and surveillance

Security and surveillance are crucial in a large variety of domains, including computer network security, quality assurance of potable water, and protection of buildings and natural resources. Key results obtained in 2014 can be summarized as follows:

- Continuation of activities in the Computer Emergency Response Team (CERT): Established in January, 2000 and partially financed by the Council of Hungarian Internet Providers, Hun-CERT supports and carries out tasks associated with network security. The institute maintains the http://www.cert.hu webpage as part of this activity. Additionally, the institute participated in the handling of about 600 network security incidents on Hungarian computer networks in 2014.
- An integrated 4D modeling system (i4D) was developed through the interconnection of a 4D studio and a Velodyne LIDAR device. The system provides a solution to the automated reconstruction and visualization of dynamic spatiotemporal scenes by combining two different data types, primarily with the goal of measuring and representing the visual world at different levels of detail. Innovative solutions are offered in various application areas, including 4D virtual city reconstruction, urban environment protection, 4D video surveillance and augmented/virtual applications.
- The WaterScope microbiological monitoring device was deployed at the Norwegian Institute for Water Research (NIVA). The device was designed for the automated recognition of algae in high resolution and color, and was deployed with the goal of analyzing ballast water on marine vessels so as to reduce risks of biological contamination in international commerce. The device developed in the institute is based on digital holographic microscope, and is capable of analyzing volumes of water that are orders of magnitude (200x) larger than the those handled by classical optical techniques.

Networks, networking systems and services, Future Internet

The Horizon 2020 (FP8) program emphasizes basic research in the fields of information and communication technologies, and therefore the Future Internet, including context-oriented knowledge bases related aspects of information transfer and collaborative work in ad hoc communities.

Key results obtained in 2014 can be summarized as follows:

- The GUIDE@HAND smartphone app was extended to enable a broader range of services as part of a larger app family. While the original app was developed primarily for touristic purposes, the current applications allow users to obtain up-to-date information not only on tourist attractions, but also on cultural and scientific events, as well as on local municipalities, musical performers and educational institutions. Specialized versions have been developed to provide information on the Cemetery of Házsongárd, the Hungarian paintings available at the Uffizi Museum, the Hungarian Science Festival, the northern coast of Lake Balaton, etc.
- The SZTAKI Cloud project was finalized, resulting in a fully functional, service-oriented infrastructure supporting project work in several institutes.
- A set of methods and tools were developed for the accreditation of IaaS cloud service providers in the framework of the CLAKK project. The tools have since been deployed as part of an integrated environment.
- Support for the the Desktop Grid (DG) technology was continued in the European Grid Initiative (EGI) community. The technology was originally developed in the framework of the IDGF-SP (International Desktop Grid Federation Support Project) FP7 project.
- Interim results were reported in the ChaosFIRE project. The project is carried out by the institute within the framework of the Fed4FIRE project. Tasks include the evaluation of

performance and usability issues in peer-to-peer mobile technologies serving as an alternative to service-oriented solutions focusing on the centralized collection and distribution of sensor information in urban environments.

b) Science and society

The PR activities of the institute can be characterized by extensive use of modern media outlets, transparency, openness to issues of society and a harmonization of research and marketing perspectives. The institute issued around 40 press releases and had around 130 media appearances in 2014. This has led to a further strengthening of media relations: a long-term cooperation agreement was reached with Duna Television. The central webpage of the institute is kept up-to-date by its public relations officer on issues related to the academic community, industry as well as to the broader public. The institute is present on social media (Facebook, LinkedIn) as well as on video sharing sites (YouTube, Videotorium) on a daily basis.

The most important innovations of the institute were presented at the Researchers' Night program with the participation of 40 host researchers of 7 divisions at 8 locations. The event was visited by a crowd of around 500. Within the 6-hour long evening, representations spanned a wide range of topics, including cultural heritage preservation, unmanned aerial vehicles, 3D technologies, digital holographic microscopy and laser scanning. The organization of the Hungarian Science Festival was supported to a large extent by the mobile application developed by the institute. For the 50th anniversary of its establishment, celebrated in 2014, the institute compiled written material and also organized the opening of an informatics museum which was visited by nearly 400 guests. In addition to the above, the Wikipedia profiles belonging to the institute were updated in 2013, and since that time, special attention has been dedicated to international communication via newsletters.

The following list provides a summary of the more prominent events held for the wider public:

- Events and destinations supported by the GUIDE@HAND mobile app family:
  - Touristic application (GUIDE@HAND):
    At home: Tata, Gyula, Duna-Gerecse, northern coast of Lake Balaton, Budapest Zoo,
    Abroad: Vienna, Cluj Napoca, Sonkajärvi (Finland),
  - Event recommendation (EVENT@HAND):
    At home: Hungarian Science Festival, Museum Night, Researchers' Night, Miskolc Opera Festival, Hungarian Dance Festival
    Abroad: Art on the Street exposition (Madrid), IEEE CogInfoCom conference in Italy, DIPP 2014 conference (Veliko Tarnovo).
- In the framework of the Global Excursion FP7 project, which ended in 2014, a set of virtual tours were developed in collaboration with a group of high school students. For example, a tour was created on the KOPI plagiarism detection service developed at the institute, as well as on the Desktop Grid systems. Through such virtual walks, direct dialogue is facilitated between researchers and students.
- A workshop was organized in order to share knowledge with MTA researchers on cloud systems and their practical applications.
- The development and maintenance of global research e-infrastructures (Desktop Grids) was continued, allowing for volunteers to share their computational resources for the purposes of scientific applications. An important actor in this area is the IDGF (International Desktop Grid Federation) society, which was initiated and is maintained in a large part by the institute.
- In the framework of a project focusing on the further development of MTMT (a publication database for Hungarian researchers), the institute is in charge of developing a national registry which fulfills all requirements of security and usability. The

requirements and functional specifications for the task are complete, and development of the registry is under way.

III. Domestic and international relations

Organization of international and domestic events

Members of the institute have played an active role in the leadership as well as in the daily activities (board meetings, organization of workshops and conferences) of the most significant international societies relevant to their research domain (including IEEE, CIRP, IFAC, IMEKO, IAPR). The institute is one of the main organizers of the eLearning Forum series, which provides a yearly overview on the state of the domestic eLearning market.

The institute provides home for the Hungarian office of the World Wide Web Consortium (W3C), which supports the standardization activities of the consortium and is also involved in the organization of local workshops and conferences. They played a key role in organizing the annual IEEE International conference on the new field of Cognitive Infocommunications (CogInfoCom), which hosted 114 presentations in Italy. Several presentations at the conference were given through the VirCA (Virtual Collaboration Arena) platform developed at the institute. A set of geographically distributed measurement experiments were also conducted using the system.

International relations

The institute has a strong background in research and development for commercial aviation and vehicle industry. Based on these values the institute has established collaboration with a wide range of domestic and international partners. In avionics, collaboration is significant with the Department of Aerospace Engineering and Mechanics at the University of Minnesota, the US Office of Naval Research (ONR), the Laboratoire de l'Intégration du Matériau au Systeme at the University of Bordeaux, as well as the German Aerospace Center (DLR) and the European Space Agency (ESA).

The Fraunhofer-SZTAKI Project Center for Production Management and Informatics was established in 2010 and has had continued success ever since. Partly through the influence of the Project Center, several important industrial partnerships have been developed. One of the more important results was the development of a production planning system for Audio Motor Hungaria capable of generating 26-52 week plans for motor assembly lines.

Among the key results of the institute in 2014 was the development, in collaboration with the University of Minnesota, of a set of methods for error diagnostics and reconfigurable control of unmanned aerial vehicles (UAVs). In the framework of the Reconfigure FP7 project, an on-board control system was developed by the institute together with Airbus which guarantees that the pilot can continue to control an aircraft even in cases when several sensors or actuators fail. Together with the Robert Bosch Knowledge Center, the institute developed a camera-based safety enhancement system for safe and dependable driving performance.

Together with the researchers of the Yokohama Research Laboratory (YRL) at Hitachi, the institute developed a system capable of keeping up-to-date models of complex industrial machinery through large amounts of data collected using laser range finder technology. As a member of a GE Hungary led consortium, the institute took part in E+grid – an energy-positive public lighting system. A prototype of the complete cyber-physical system is in operation on the premises of MTA MFA in Csillebérc, and its software is hosted on the institute's cloud infrastructure.

R&D relations with enterprises

The institute continued to maintain valuable R&D cooperation with important large-scale enterprises, including Audio Motor Hungaria (development of production planning system, simulation of internal logistics), GE Hungary (intelligent public lighting system, smart city), Jaguar LandRover and Comau (robotics for laser welding), Knorr-Bremse Braking Systems (production system configuration), Aventics Hungary (previously Bosch Rexroth; development of production scheduling system).

In the area of energetics, the institute is in collaboration with MVM Paks Nuclear Power Plant Inc. on the subject of systems control tasks relevant to safe long-term operation, and with MVM Paks II Nuclear Power Plant Developer Inc. and MVM ERBE ENERGETIKA Engineering Office Inc. on the subject systems control tasks relevant to long-term sustainability of capacity.

Collaboration has also continued in 2014 with the Yokohama Research Laboratory of Hitachi, leading to joint publications and international patents as in the past years.

Most of the institute's activities pertaining to applied R&D and industrial deployment were carried out in the framework of the Fraunhofer-SZTAKI Project Center for Production Management and Informatics.

The Institute, with its *„Centre of Excellence in Production Informatics and Control (EPIC)"* application submitted with two faculties of the Budapest University of Technology and Economics (BME), i.e., Faculty of Mechanical Engineering and Faculty of Transportation Engineering and Vehicle Engineering; with three outstanding institutes of the Fraunhofer Society (FhG) in the field of production (IPA-Stuttgart, IPK-Berlin, IPT-Aachen), under the coordination of the National Innovation Office (NIH, from January 2015: NKFIH), won the support of the European Commission.

In this way, the *Centre of Excellence* title of the institute given by the EU in 2001 has been confirmed again.

The scientific objective of the project is *design, control and management of robust, cooperative systems in the cyber-physical world,* taking those trends into account which may lead to the *4th industrial revolution* (*Industrie 4.0*). The applied research / innovation objective of the proposal is to transfer the results achieved by SZTAKI and BME in the industry with the support of FhG, which is rightly recognised as the world's most successful network of institutes in the field of applied research. This technology transfer will be mainly accomplished through further strengthening the *Fraunhofer-SZTAKI Project Centre on Production Management and Informatics* (PMI, www.fraunhofer.hu), and is bound to be evolved into *Fraunhofer Hungary* in the course of the Teaming project.

National relations, participation in higher education

A multilateral partnership was formed among the institute and leading companies and universities in Hungary with interests in vehicle industrial R&D. The partnership focuses on the practical application and industrial deployment of theoretical results obtained in academia. The institute played an active role in the initiation of the Robert Bosch Knowledge Center (RBKC), as well as the Research Center of Vehicle Industry at Széchenyi István University, Győr (RCVI), both of which have led to new projects in 2014 (focusing on hybrid and electric vehicles at RCVI, and on R&D activities related to sensor development and image processing at RBKC).

The institute continues to view teaching activities in graduate and post-graduate education as an important and indispensable part of building the future. Hence, many researchers at the institute also fulfill teaching duties at various Hungarian institutions of higher-level education,

including BME, ELTE, Corvinus, Pannon University, PTE, ME, PPKE, and CEU. The institute is committed to strengthening its existing partnerships as well as to initiating new ones.

On average, around 20 PhD students conduct research at the institute under the supervision of leading researchers. Around 30 researchers at the institute also serve as founding members in various doctoral schools.

IV. Summary of national and international grants won in the past year

EGI-Engage Engaging the international scientific community and industry/SMEs to implement the Open Science Commons in EGI
(Péter Kacsuk, EU H2020, 87 375 €, 2015-2018)
Joint enhancement of large-scale grid and cloud infrastructures for European research.

WaterScope A new microbiological measurement setup and its use in green industry
(Ákos Zarándy, NFFKÜ, 35 272 eFt, 2014-2016)
Development of a new water quality verification system based on digital holographic microscopy, using which holograms are created of objects in liquid samples, and later analyzed. The approach is capable of analyzing volumes of water that are orders of magnitude (200x) larger than those handled by classical techniques.

JRC models Development of a solver for energy economic models for Europe
(Csaba Mészáros, EU H2020, 153 000 €, 2015-2016)
Efficient solutions for optimization tasks relevant to economic models of the JRC, involving large-scale linear and second-order cone constraints.

OTKA Paired comparison based preference modeling and ranking
(Sándor Bozóki, OTKA, 22 934 *eFt, 2014-2018)*
Solutions to special problems associated with the paired comparison methodology used in preference modeling, and use of those solutions to develop an on-line decision support system.

OTKA Scheduling problems with various resource constraints
(Tamás Kis, OTKA, 8 871 eFt, 2014-2018)
Research focuses partially on resource-enhanced machine scheduling problems, and partially on combined vehicle and driver scheduling problems.

OTKA Basic research supporting the creation of cyber-physical production systems
(*László Monostori, OTKA, 69 741eFt, 2014-2018*)
Basic research tasks contributing to the future development of cyber-physical production systems (CPPS)

ENTICE dEcentralized repositories for traNsparent and efficienT vIrtual maChine opErations (*Gábor Kecskeméti*, *EU H2020, 428 375 €, 2015-2018)*
A new system image store for distributed virtual machines is developed in support of increased efficiency in infrastructure clouds. The project aims to enable demand-driven scalability of virtual computing infrastructures at unprecedented levels of responsiveness.

SYMBIO-TIC Symbiotic Human-Robot Collaborative Assembly: Technologies, Innovations and Competitiveness
(*József Váncza, H2020, 611 250 €, 2015-2018)*

New innovative methods for perception, action planning and automated robot programming are developed to support enhanced human-robot interaction in industrial settings, primarily in areas of maintenance and packaging.

MAPIS Multichannel passive ISAR imaging for military applications
(*Tamás Szirányi*, EDA, 110.000 €, *2014-2017)*

A new method is developed for ISAR (Inverse Synthetic Aperture Radar) based passive radar systems, primarily for digital TV bands. Freely configurable passive radar networks enable passive target object detection and adaptive recognition.

V. List of major publications in the past year

Books

1. Németh Balázs: Application of LPV methods for integrated vehicle control systems. Saarbrücken: LAP Lambert Academic Publishing, (2014) 141 (ISBN:978-3-659-50679-6) *SZTAKI, Egyéb URL*
2. Szederkényi G: Computational analysis of nonnegative polynomial systems. Saarbrücken: Scholar's Press, (2014) 169 (ISBN:978-3639660135) *Kiadónál*

Journal publications

3. Baranyi P: The generalized TP model transformation for T-S Fuzzy model manipulation and generalized stability verification. IEEE Transactions on Fuzzy Systems, 22:(4) 934-948. (2014) IF:6.306 *DOI, SZTAKI, WoS, Scopus*
4. Benedek Cs, Martorella M: Moving target analysis in ISAR image sequences with a multiframe marked point process model. IEEE Transactions on Geoscience and Remote Sensing, 52:(4) 2234-2246. (2014) IF:2.933 *SZTAKI, DOI*
5. Csáji B, Jungers RM, Blondel VD: PageRank optimization by edge selection. Discrete Applied Mathematics, 169: 73-87. (2014) IF:0.677 *REAL, SZTAKI, DOI*
6. Decker T, Høyer P, Ivanyos G, Santha M: Polynomial time quantum algorithms for certain bivariate hidden polynomial problems. Quantum Information & Computation, 14:(9-10) 790-806. (2014) IF:1.625 *SZTAKI, arXiv,WoS, Scopus*
7. Erdélyi M, Benczúr A, Daróczy B, Garzó A, Kiss T, Siklósi D: The Classification Power of Web Features. Internet Mathematics, 10:(3-4) 421-457. (2014), *SZTAKI, DOI*
8. Erdős G, Nakano T, Váncza J: Adapting CAD models of complex engineering objects to measured point cloud data, CIRP Annals-Manufacturing Technology, 63:(1) 157-160. (2014) IF:2.541 *SZTAKI, DOI, WoS*
9. Ergu D, Kou G, Fülöp J, Shi Y: Further discussions on induced bias matrix mdel for the pair-wise comparison matrix. Journal of Optimization Theory And Applications**,** 161: 980-993. (2014) IF:1.406 *SZTAKI, DOI, WoS, Scopus*
10. Fazekas Z, Gáspár P, Bíró Zs, Kovács R: Driver behaviour, truck motion and dangerous road locations – Unfolding from emergency braking data. Transportation Research Part E-Logistics and Transportation Review, 65: 3-15. (2014) IF: 2.193 *SZTAKI*
11. Györgyi P, Kis T: Approximation schemes for single machine scheduling with non-renewable resource constraints. Journal of Scheduling, 17:(2) 135-144. (2014)IF: 1.186 *SZTAKI, DOI, WoS*
12. Gyulai D, Kádár B, Kovács A, Monostori L: Capacity management for assembly systems with dedicated and reconfigurable resources. CIRP Annals-Manufacturing Technology, 63:(1) 457-460. (2014) IF:2.541 *SZTAKI, DOI, WoS, Scopus*
13. Hangos KM, Szederkényi G: A model structure-driven hierarchical decentralized stabilizing control structure for process networks. Journal of Process

Control, 24:(9) 1358-1370. (2014) IF: 2.179 *SZTAKI*, *DOI*, *WoS*, *Scopus*

14. Kecskeméti G, Terstyánszky G, Kacsuk P, Németh Zs: Towards efficient virtual appliance delivery with minimal manageable virtual appliances. IEEE Transactions on Services Computing**,** 7:(2) 279-292. (2014) IF:1.985 *SZTAKI*, *DOI*
15. Kiss M Zs, Nagy B J, Lakatos P, Göröcs Z, Tőkés Sz, Wittner B, Orzó L: Special multicolor illumination and numerical tilt correction in volumetric digital holographic microscopy. Optics Express, 22:(7) 7559-7573. (2014) IF:3.525 *DOI*, *SZTAKI*, *WoS*, *Scopus*
16. Marx D, Razgon I: Fixed-parameter tractability of multicut parameterized by the size of the cutset. SIAM J. on Computing, 43:(2) 355-388. (2014) IF:0.762 *SZTAKI*, *DOI*, *WoS*
17. Marx D, Wollan P: Immersions in highly edge connected graphs. SIAM Journal on Discrete Mathematics, 28:(1) 503-520. (2014) IF: 0.578 *SZTAKI*, *DOI*, *WoS*
18. Mészáros T, Rónyai L: Shattering-extremal set systems of VC dimension at most 2. Electronic Journal of Combinatorics, 21:(4) #P4.30. (2014) IF:0.568 *SZTAKI*, *Teljes doku*
19. Molnar J, Chetverikov D: Quadratic transformation for planar mapping of implicit surfaces. Journal of Mathematical Imaging and Vision, 48:(1) 176-184. (2014), IF:2.330 *SZTAKI*, *DOI*, *WoS*, *Scopus*
20. Nemes Cs, Barcza G, Nagy Z, Legeza Ö, Szolgay P: The density matrix renormalization group algorithm on kilo-processor architectures: Implementation and trade-offs. Computer Physics Communications, 185:(6) 1570-1581. (2014) IF:2.407 *SZTAKI*, *arXiv*, *DOI*, *WoS*, *Scopus*
21. Rödönyi G, Gáspár P, Bokor J, Palkovics L: Experimental verification of robustness in a semi-autonomous heavy vehicle platoon. Control Engineering Practice, 28:(1) 13-25. (2014) IF:1.912 *SZTAKI*, *DOI*, *WoS*, *Scopus*
22. Szirányi T, Shadaydeh M: Segmentation of remote sensing images using similarity-measure-based fusion-MRF model. IEEE Geoscience and Remote Sensing Letters, 11:(9) 1544-1548. (2014) IF:1.809 *REAL*, *SZTAKI*, *DOI*, *WoS*, *Scopus*
23. Terstyanszky G, Kukla T, Kiss T, Kacsuk P, Balasko A, Farkas Z: Enabling scientific workflow sharing through coarse-grained interoperability. Future Generation Computer Systems-the International Journal of Grid Comput**,** 37: 46-59. (2014) IF:2.639 *SZTAKI*, *DOI*, *WoS*, *Scopus*
24. Tettamanti T, Luspay T, Kulcsar B, Peni T, Varga I: Robust control for urban road traffic networks. IEEE Transactions on Intelligent Transportation Systems, 15:(1) 385-398. (2014) IF:2.472 *SZTAKI*, *DOI*, *WoS*, *Scopus*
25. Vanek B, Edelmayer A, Szabó Z, Bokor J: Bridging the gap between theory and practice in LPV fault detection for flight control actuators. Control Engineering Practice, 31: 171-182. (2014) IF:1.912 *SZTAKI*,*DOI*, *WoS*, *Scopus*
26. Visegrádi Á, Kovács J, Kacsuk P: Efficient extension of gLite VOs with BOINC based desktop grids. Future Generation Computer Systems-the International Journal of Grid Comput, 32: 13-23. (2014) IF:2.639 *SZTAKI*, *DOI*, *WoS*, *Scopus*