Institute for Computer Science and Control
Hungarian Academy of Sciences
H-1111 Budapest, Kende u. 13-17, 1518 Budapest, Pf. 63.
Tel: 279-6159, Fax: 466-7503,
http://www.sztaki.hu/, e-mail: monostori.laszlo@sztaki.mta.hu

Annual Report 2015
on the Scientific Activity
at MTA SZTAKI

Budapest, 11 March, 2016

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 the major domestic and international grants won in 2015

V. List of the most significant scientific publications of 2015

I. Priorities and main tasks

The main direction of the institute's activity is research in *cyber-physical systems* (*CPS*) that creates the framework of, and brings the activities pursued here, into the current mainstream of international research. Its laboratories (such as the i4D intelligent space, the system control, the smartfactory, the cloud computing and the cooperative cyber-physical research laboratories) were created in line with this end and as a result, new interactions between theory and practical engineering work are being born here.

CPS are computational structures that are strongly linked with the surrounding physical world and the physical processes therein while making an 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: they include inter alia autonomous land and aerial vehicles, robot-assisted surgery, smart buildings, smart power grids, smart manufacturing and implanted smart medical tools, and this listing could be continued onwards. CPS may contribute to creating a higher level of quality of life. As a reflection on this latter aspect, the term '*cyber-physical society'* has emerged as a reference to the integration of not only the physical and cybernetic spaces, but also the human, societal and cultural spheres, too. 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.

As a result of the new sensor and human-machine interface technologies, a special computational and sensor based environment focusing on the human being is arising where the adaptation of the human actors to the tools is being replaced by the automated adaptation of the tools to human activity.

Expectations towards the cyber-physical systems are already enormous and are growing speedily, simultaneously with the appearance of the new technologies, such as robustness, self-organisation, adaptive situational awareness, self-maintenance, transparency, predictability, efficiency, inter-operability, and support for global monitoring, to mention only the most important fields. Indeed, while notable advances have been made in areas such as cooperative control, multi-agent systems, complex adaptive systems, emergent systems, sensor networks, data mining and so on, they have reinforced the expectations of further progress, thus strengthening the demand for continuous research and development.

II. Outstanding results in research, development and public relations

a) Research, development and innovation

In the following, the institute's four key directions in basic research are introduced (computer science, systems and control theory, engineering and business intelligence, and machine perception and interaction). Five sub-sections summarise how the results attained in basic research contributed to the domains primarily supported by the EU Horizon 2020 Framework Program, and are also aligned to the goal setting of the Hungarian Smart Specialisation Strategy (S^3) and the Széchenyi 2020 Plan. The application-oriented achievements are discussed in the areas of vehicle and transportation systems, production informatics and logistics, energy and sustainable development, security and surveillance, distributed computing and Future Internet.

<u>BASIC RESEARCH</u>

<u>Computer Science</u>

The chief objective here is to provide foundations for business intelligence, search and

organization of multimedia contents, data mining of the Web and, more generally, identifying, defining and solving extremely large scale information processing tasks in other science areas, in particular, recognizing, mining, and exploring patterns and regularities hidden in large volumes of data. A characteristic feature of their approach is a strong collaboration of engineers and mathematicians. Their research leverages the synergies of several interrelated fields, including the theory of algorithms and databases with emphasis on new parallel hardware architectures, data mining, information retrieval, machine learning, and large (extremal) graphs. Their main results achieved in 2015:

- In the area of *parameterized algorithms*, one of the main directions of the research is the so-called square root phenomenon for planar graphs, i.e. the widely observed phenomenon that for many combinatorial algorithmic problems the optimal algorithm is exponential in the square root of the parameter. By substantially generalising and extending their earlier results in the literature, they have established that the phenomenon holds for many algorithmic problems such as the location planning of service centres.
- The way the algorithmic complexity of the *subgraph search problem* depends on the various subgraphs allowed were explored systematically. A dichotomy theorem was set up and proven providing a precise characterization of the cases tractable in (randomized) polynomial time, and the NP-hard cases as well. With a similar systematic approach they studied the possible kernelization of subgraph search and the closely related subgraph packing problems.
- The Chevalley-Warning theorem provides an important sufficient condition for the solvability of systems of polynomial equations over finite fields. A polynomial time algorithmic relaxation was developed for the case when the number of variables is sufficiently large, but polynomial in the number of equations at hand. It can be applied to the solution of relaxed additive problems of zero sum type, and to the design of new quantum algorithms.
- In the area of symbolic computation, a fundamental algorithmic problem is to find a common invariant subspace to a given set of matrices. On the path towards a solution, there is a difficult, building block type problem, i.e. the *explicit isomorphism problem*: here is given an associative algebra, which is known to be isomorphic to a full matrix algebra; the objective is to find constructively one such isomorphism. Here, building on a series of their earlier results, they made progress in the case when the ground field is a field of functions over a Galois field. Potential applications include algorithms for factoring in the ring of skew polynomials.
- *Combinatorial group testing* is a widely used basic method in the practice of fault detection. The essential in the method is that one simultaneously tests a larger subset of elements at once, and the result is positive if there exists a faulty item in the subset. They managed to extend the method by Eppstein-Goodrich-Hirschberg to the case when the test yields only the parity of the number of the faulty elements of the subset tested.
- In *Operations research and decision sciences* pairwise comparison matrices were studied in optimization type tasks which occur in multi-criteria decision making contexts. For a given inconsistency index and level of acceptance, the minimal number of matrix elements was determined whose modification is necessary to bring the index below the acceptance level. Based on Newton's method an optimization algorithm was given to solve the eigenvalue minimization problem for incomplete pairwise comparison matrices.
- A new FPGA based architecture was developed to *speed up DNA and protein sequence alignment algorithms*. This takes data locality into consideration, and is well scalable even up to several hundred processing units, while data dependence can be eliminated.

The developments provide high speed by exploiting the pipeline architecture of the units.

The research activities above were supported partly by high prestige grants: an ERC Starting Grant and an MTA Lendület ("Momentum") Grant. Their main industrial partners in the R&D activities based on the basic research above are: Ericsson Hungary, OTP Bank, and Bosch.

Systems and control theory

Research in this field addresses various subjects of systems modelling and identification, theory of adaptive and robust control, signal processing and filtering, control of distributed and networked systems, as well as selected topics of process control. Linear and nonlinear systems in both continuous and discrete time domains and, also in deterministic and stochastic contexts are considered, as necessitated by particular applications. The most important results of the basic research activities achieved in 2015 can be summarised as follows:

- New results related to the control theory of nonlinear systems 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 LPV and qLPV problems, or otherwise yield very conservative solutions. Therefore, traditional methods – based on the separation theory and IQC (Integral Quadratic Constraints) techniques – for the solutions of linear robust control problems were put under revision. The results obtained highlighted a common geometric background behind the well-known robust control design approaches that provide a suitable theoretical foundation to the design and analysis of controllers. The geometric aspects of the Klein approach were successfully applied for the analysis of robust control problems. The representation of points in Klein geometry, for instance, can be corresponded to the stabilizable systems, while the Mobius transformations are of a close similarity to the movements defining the geometry. It was shown that the transformations of certain hyperbolic spaces provide a common background to the treatment of robust control problems by explaining the relations of various well known approaches. These new observations lead to the solutions of various, earlier not solvable problems.
- New methods have been elaborated for the synthesis and analysis of practical fault tolerant control systems, using the approaches of fault detection and null space-based structural reconfiguration. Methods were developed that guarantee the fulfilment of the quality requirements using switching-based reconfiguration strategies and qLPV models. By means of the new geometric achievements (see above), new methods could be synthesized for sensor reconfiguration algorithms that preserve stability during reconfiguration actions. The results were applied to a variety of complex control problems in ground and aerial vehicle dynamics.
- Significant research efforts were made with respect to the efficient modelling of flexible engineering objects such as e.g. aircraft wings by means of the application of systematic mathematical model reduction processes. New results were obtained for the reduction of many hundred-dimension LPV models using Youla parametrization.
- 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 finding iteratively the poles of a system based on measurements in either time or frequency domain.

The results obtained have been primarily used in the energy, transportation and vehicle industries. The institute has brought various industrial (e.g. Airbus, Bosch, Knorr-Bremse)

and academic partners together in a number of Hungarian and European R&D projects, creating direct utilization of the theoretic achievements in the practice. Industrialized or near-industry solutions were developed for the fault tolerant design of on-board vehicle control systems, the coordinated control of vehicle fleets, the intelligent driverless vehicle control, the sensor fusion methods, and the integrated control methods for electronic steering and braking.

Engineering and business intelligence

The challenges associated with the design, planning, and control of cyber-physical production systems, as well as the adaptation of their operation to the ever changing conditions call for collaborative research in a number of fields including computer science, operations research, manufacturing science, production engineering and artificial intelligence. The key results in the basic research attained in 2015 are summarised as follows:

- The evolution of cyber-physical production systems has been analysed in a historical perspective, as the parallel but interrelated and converging development processes of the information and communication, as well as manufacturing and engineering sciences. New research challenges and opportunities have been identified from this stance.
- The non-asymptotic, distribution-free SPS (Sign-Perturbed Sums) method was generalized to the identification of closed-loop dynamic, stochastic systems. This extension is of high practical importance as feedbacks are essential parts of many industrial, biological, economic and social systems and greatly affect the data collection.
- An algorithm was developed, based on the aforementioned SPS method, but of lower computational complexity, to build exact confidence regions around the instrumental variable estimate, even if the inputs of the system are correlated with the noises.
- The single machine scheduling problems were extended with non-renewable resources (such as raw material or energy). New approximation algorithms were developed, along with providing non-approximability results for some variants of the problem. The approximation algorithms are partly based on the strong connection to the so-called knapsack problem; the exploration of the relation between the two problem classes was also part of the research.
- A new exact method for the integrated vehicle and crew scheduling problem has been developed. The novel method is based on a novel LP formulation, which is used in a branch-and-price algorithm. Although there are some heuristic methods in the literature, this is the first solution method to provide exact optimum for this problem.
- In a game theoretic setting, assuming an asymmetric information structure, a mechanism was developed for providing efficiently the aggregated demand forecast in a one-vendor multi-buyer distribution chain even if the buyers generate their short term, however uncertain forecasting. The mechanism can be implemented in a distributed way, and it is applicable for improving efficiency both in supply and energy networks.
- An algorithm was developed that constructs complex integrated models comprising artificial neural network, support vector machines or neuro-fuzzy components. It is driven instead of heuristics by the more general and more efficient information theory measures.
- An integrated experimental design and technological parameter optimization algorithm was developed that goes beyond the classical, linear (Taguchi based) experimental design and optimization techniques and enables the specification of the technological parameters in a non-linear, multi-dimensional parameter space even if some dependencies are unknown. The methodology was verified in non-conventional machining.

Most of the research detailed above has been carried out in the framework of national (OTKA, Bolyai) and EU supported research projects. The theoretical results provided a strong

foundation for subsequent industrial applications (see later sections of this report on Production informatics and logistics, as well as on Energy and sustainable development).

Machine perception and interaction

3D reconstruction and visualization: Significant results were achieved in handling large multi-source point clouds produced by laser scanning devices (LIDARs) and mobile sensing platforms:

- *Processing large point clouds:* A novel solution was developed enabling real-time visualization of large point clouds (consisting of points in the range of billions). Such enormous point clouds cannot generally be expected to fit into regular workstation memory. However, continuous, high-speed and real-time visualization is enabled by creating a special storage structure and by accessing at a time regions of data only with local relevance and with different levels of detail.
- *Image based reconstruction and visualization:* A novel numerical algorithm was created based on bundle adjustment, which can produce spatial reconstructions of image patches. The approach refines the spatial localization of image patches and the extrinsic parameters of the cameras along with extracted surface normals, exploiting the calculated affine transformation between the image patches. This approach produces more accurate and more visually pleasing reconstructions than the simpler feature-point based methods.

With the combination of the holographic and fluorescent microscope technologies an efficient method was developed for inspecting rear transparent volumetric samples. In the spatially and temporally registered floating liquid biological samples, the high resolution images of the objects are generated by the holographic microscope, while their fluorescent markers are identified by the fluorescent microscope. The method can be applied for the identification of the toxic cyanobacteria contamination in the drinking water. This is extremely important, because not all the cyanobacteria species are toxic.

As a result of deep analysis of the special readout and sensing properties of some CMOS imagers, a novel intra-frame method was developed which can derive the speed of the bright objects from a single sharp frame by applying a quick algorithm. The double exposed frame contains image components with different gains and exposure times. From the images captured, one can read both the speed and the license plate number of a moving car.

DEVELOPMENT AND INNOVATION

Vehicle and transportation systems

In line with the global trends, the main focus of the activities was on cooperative intelligent transportation systems (C-ITS), the theory of cooperative systems, integrated approaches of large-scale vehicle and traffic control system design, modern network communication protocols, fault tolerant operation in on-board control systems, and driver's assistance systems.

- *Cooperative vehicle systems:* For the cooperative autonomous vehicle control, fully in line with the world trends, a group of methods was developed for analysis of stability and control precision. They allow for the effective treatment of several classes of modelling uncertainty that are often present in practical applications, while also taking inherent properties of the underlying communication network into account.
- *Hybrid control:* 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. For integrated vehicle control design problems, the convex LTI design methods was extended to qLPV robust control design problems. There were novel solutions developed for the stability analysis of cooperative autonomous drive problems, based on the use of Lyapunov-Krasovski functionals and IQC approaches. The camera sensor based driver's assistance system for the detection of road signs and the duly acquisition of various environmental parameters for the support of safe and dependable driving performance was made with close collaboration with the Robert Bosch Knowledge Centre. The solution for the control of partially automated vehicle platforms was invented together with Knorr-Bremse Ltd., which, beyond the control performance issues, takes the operational effectiveness of the platoons into consideration.

- Methods developed for *the analysis of cooperative systems* provided new approaches to the analysis of both the stability of formation control in vehicle systems and the accuracy of control as well. The methods can treat numerous classes of uncertainties originated in modelling and communication.
- *Adaptive actuators*: In the research of electro-mechanic actuators, which are widely used in the aviation industry, a new, light-weight electro-mechanical actuator device was developed that can be used in small unmanned robotic flying vehicles, such as drones. In the FP7 program ACTUATION2015, novel control algorithms and actuator models have been developed for civil aircraft applications in collaboration with UTC Aerospace.
- *Advanced fault-tolerant control methods* were developed to maintain the 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 safety 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 control architecture for avionics applications* was developed for continued operation in the event of a single component failure in unmanned autonomous vehicles (UAVs). This capability is essential for the future integration of UAVs into the common airspace. A camera 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. It was developed with the goal of integration of UAVs into the shared airspace in mind. The fault tolerant architecture and the vision-based collision avoidance were implemented for a small-scale, redundant avionic system that is unique among comparable systems in that the GPU based image processing unit together with navigation instruments are capable of the timely detection of situations potentially leading to collision. A set of experiments have been carried out based on the implementation, which confirmed that the technology provides a viable solution to the safe spatial separation of autonomous aircrafts throughout the duration of their journey. Processing and analysis were performed on simulation and physical measurement data with the purpose of developing solutions for path estimation and collision probability calculation, in a research supported by the US Office of Naval Research (ONR).
- *Flexible aircraft wing fluttering research* was conducted in the FLEXOP H2020 European framework project. A number of models of different abstraction levels were

developed for the representation of both the resonance issues (i.e. fluttering) occurring in flexible wings and the dynamic behavioural patterns of the entire aircraft structures during high speed courses.

Production informatics and logistics

Research, development and innovation in production informatics and logistics focus on the design, modelling and operation of service and logistic systems. Of special concern is the optimization as well as adaptability to real-time conditions on the shop floor, enterprise and network levels alike. In this field, the institute aims at closely following current trends in cyber-physical production systems. Key results obtained in 2015 are as follows:

- A novel production planning method defined specifically for *modular assembly systems* was applied for integrated production and capacity planning of robotized automotive assembly cells. The implemented discrete-event simulation component of the system enables the evaluation of plans in a realistic, dynamic environment considering also stochastic parameters and random events (e.g., disruptions).
- *Novel statistical learning methods* were developed that predict key system performance indicators by applying the results of proactive simulation runs as training datasets. The new methods and training algorithms have been validated and evaluated in a stochastic flow-shop environment, predicting the lead time of production orders.
- A new data representation scheme was developed on the basis of the SISO Core Manufacturing Simulation Data (SISO CMSD) standard that supports efficient *discrete-event oriented simulation analysis*. The scheme was applied in a number of industrial case studies.
- *The production planning system* developed for Audi Hungaria Motor Ltd. was tested on six production lines, followed by some modifications and fine-tuning to meet the user demands.
- *A production scheduler and decision support system* with advanced graphical user interface was developed for, and deployed at, a manufacturer that produces high-tech components both in small and large batches.
- A system formerly developed in a European R&D framework project for automatic configuring and off-line programming of *robotic remote laser welding cells* was applied in a first-time-right manner for setting up a cell and making a series of physical tests for the automotive industry.
- *A pilot cyber-physical production system* was established with various kinds of integrated and most advanced sensors and actuators. This environment enables to investigate problems of production, logistics and robotics, including decentralized control and human-robot collaboration, both in the physical and the corresponding virtual worlds.
- In cooperation with the *Hitachi Manufacturing Technology Research Centre* novel methods were elaborated for recognizing the relevant components of complex engineering objects along with reconstructing their topological relations departing solely from the scanned, pixel-based two dimensional technical drawings of the objects.

Most of the activities pertaining to applied production informatics and logistics were carried out in, and by the Fraunhofer-SZTAKI Project Centre for Production Management and Informatics established in 2010. Beyond performing contract-based research for small and medium-sized enterprises, main results were commissioned by world-class manufacturing companies such as Hitachi, Audi Motor Hungaria, GE Hungary, Jaguar LandRover, Opel, Volvo, Festo, BPW, Knorr-Bremse Fékrendszerek Kft, Aventics Hungary, Denso.

Energy and sustainable development

A fundamental precondition of sustainable development is the capability to adapt the energy production, transfer and transformation systems to the changing demands and available facilities. In the area of control and surveillance of these systems, one of the key preliminaries is the increased data processing, storage and transmittance capacity of the applied IT devices opening new opportunities also to enhance automation and efficiency, however, also generating new problems to face. In this context the following topics were addressed with special focus:

- Continued partnership with the *Paks Nuclear Power Plant* is part of the strategic collaboration program of the institute which provided background expertise for the refurbishment of existing control systems, and for the preparation and technical establishment of future projects aiming at the lifetime extension of equipment. Targeting the continuous improvement of the reactor protection systems, the reactor power control (rod control) system of the primary circuit and the regulation and nuclear security system are distinct application areas where contributions have been made. With its strong background in systems control, the institute has joined the planning phase aiming at the extension of the power plant with new blocks. The institute continued to support the International Atomic Energy Agency in the pursuit of creating a new nuclear safety standard by the submission of the report "Dependability Assessment of Software for Safety Instrumentation and Control Systems at NPPs".
- *The E+grid intelligent energy-positive public lighting system* whose controller is running in the computational cloud of SZTAKI was fine-tuned and maintained. The continuous incoming data stream provided opportunity for elaborating further stochastic model fitting methods for forecasting both the demand and supply of energy.
- *Energy management*: a special mathematical solution package for an efficient energy management platform was developed with the sponsorship of the EC Joint Research Centre (JRC).

Security and surveillance

- *Earth observation and remote sensing:* The DUSIREF project is a joint project of the institute and the Airbus Defense & Space Hungary, sponsored by the European Space Agency (ESA). The main objective of the project phase completed in 2015 was high level urban scene recognition and change interpretation based on heterogeneous Remote Sensing (RS) data sources (mainly optical and TerraSAR satellite images and LIDAR data). Novel environmental analysis and reconstruction methods were developed relying on the 4 dimensional (3 spatial and 1 temporal) data representation: classification of urban objects, change detection, multi-level hierarchical analysis of object populations, estimative reconstruction of 3D building structures with textured polygonal models.
- *Ad-hoc mobile camera networks:* Based on the results of the PROACTIVE FP7 project, a multispectral sensor fusion and shape localization method was developed, which does not require the extraction of a flat ground plane. Further application areas include mapping, localization and tracking of partially covered objects in indoor spaces (e.g. bank branch offices). A novel pattern recognition algorithm augmented in conjunction with "deep learning" theory produced improved recognition rates. The optimized algorithm can achieve a speed of up to 100 FPS and can also be used in poor visibility environments.
- *Automatic recognition of traffic signs:* Developed for Budapest Közút Zrt, this application can produce a geographical database of different objects found along the roads based on MLS (Mobile Laser Scanner) LIDAR point clouds and associated image data. The produced solution was integrated into the partner's geo database system.

Networks, networking systems and services, Future Internet

- *Organizing workflows based on Occopus:* A new workflow concept called infrastructure-aware workflows was developed. The nodes of such new types of workflows can define not only computing and data processing tasks but also virtual infrastructures required by such kind of nodes. This new concept can lead to a breakthrough in the long-term sustainability of complex workflow based applications.
- *Agricultural data management:* An exceptionally large scale research infrastructure, unique in the region, to facilitate the promotion of precision agriculture was developed and implemented. With the adaption of an analytical, prediction, and decision support framework to the field of agriculture, the new cloud computing and big data based platform enables the creation of a continuously growing knowledge centre of ever widening scope. The system supports the reliable and efficient collection of structured time series, picture and other data, gathered by a large number of complex sensor pillars deployed on the fields of arable farming and also coming from other sources, as well as the efficient exploitation of the information contained therein.
- *Industrial Data Science:* In collaboration with the Budapest research laboratory of Ericsson, a joint research work was carried out in the area of predicting mobile session losses. This was based on the analysis of time series data for several radio parameters. The method extends the dynamic programming based time warping method to handle multiple time series. It employs the natural distance metrics provided by the Fisher information matrix over the time series. In 2015, in addition to the earlier joint applied research projects with Ericsson and AEGON, two more industrial data science projects have been started. For OTP Bank, based on machine learning techniques, new prediction methods for non-payment problems related to credit cards are provided. For Bosch, forecasts on the basis of time series for the physical parameters of the production line are generated to help avoiding production losses.
- *Recommender systems*: The institute's team finished on the fifth place at the RecSyS Challenge 2015 competition, a worldwide contest of more than 500 teams in the area of predicting the behaviour of on-line users. Based on this and past successes, the institute was asked to organise the professional program of the 2016 competition, whose main focus is intended to be predictions related to career/job advertisements on the Xing business network.
- *Human-machine interface*: A glove for gesture-recognition has been developed, that - via a sensor network - is able to recognise the spatial orientation of fingers and the dynamics of individual finger movements (hand gestures). With the help of the glove, human-robot communication can take place in industrial environment, while collaboration in shared workplaces and real human-robot cooperation, too, become feasible. The prototype has been demonstrated on the international arena, too.

b) Science and society

MTMT (The Repository of Hungarian Scientific Publications): the software system for the new digital archive of the National scientific publications' repository is being developed by the institute. The archive, being of nationwide authority, raises special security and usage requirements.

The institute's PR activities can be characterised by the extensive use of the advanced media outlets, transparency, intensive social participation activity as well as a harmonisation of the research and marketing perspectives in its work. In 2015 the institute managed even to surpass the results of external communications of 2014 by its around 50 press releases and approx. 200 media appearances. In parallel to the online media, the institute has been strengthening its relations to the television and radio broadcasting institutions, too. Besides the news channels

of the partners, dozens of its scientific achievements have appeared on the major professional portals and in the papers. Additionally, its experts have regularly given interviews for the major media as well. The institute is present on the social media (Facebook, LinkedIn) with a content kept up-to-date on a daily basis and has also a high number of visitors on the video sharing sites (YouTube, Videotorium).

Their most outstanding innovations were presented at the event "Festival of the Hungarian Science", at numerous other occasions for publicising science including the Researchers' Night program. At the latter event 5 departments, with 25 researchers presented visually at 6 locations in 7 different programmes their achievements to 250 attendants. The presentations spanned a wide range of topics, including cultural heritage preservation, unmanned aerial vehicles, smart factories, 3D technologies, digital holographic microscopy and laser scanning.

A draft communication campaign has been elaborated with the aim of repositioning the institute for the public, focusing on efficiency and uniformity of appearance but covering the aspects of organisational development and communication policy, too. The institute's logo and the whole set of the off-line and on-line visual identity elements have been renewed; a new webpage is being developed in conjunction with the related procedures manual.

A few examples of the results and events of 2015 communicated to the greater public:

- The large scale commercialisation of the new generation mobile application set GUIDE@HAND. Due to the development work of the recent period, the institute offers today more than 50 mobile applications that can be downloaded mostly free of charge from the online webstores, in the areas of cultural heritage preservation, tourism and the cultural and scientific events. The applications demonstrating the Hungarian Society of Hydrology, the Esztergom Castle Museum, the Hungarian folk carnival "Busó" or the Collection of Bulgarian Iconography may be mentioned as samples.
- The MOL Bubi (the municipal bike-sharing rental network) data analysis competition was organised jointly by the Budapest Transport Centre (BKK) and the Big Data - "Momentum" Research Group of MTA SZTAKI in the frame of the European Mobility Week. The participants were current and former students in mathematics, physics, economics, informatics and other specialists. 60 teams registered altogether and for the 3 analysis tasks a total of 30 solution bids were submitted.
- Attendance both as exhibitor and presenter at *Science Agora*, Tokyo where the results of the research project "Laser Welding with Robots" were demonstrated. This exhibition is an annual event dedicated to science education, with around 10.000 visitors each year.
- At the exhibition *Akari Park* in Tokyo (approx. 100.000 visitors) organised in the spirit of the International Year of Light, the *E-grid+* intelligent energy-positive system was presented which was developed in cooperation with GE Hungary.
- The special issue of the 6th IEEE International CogInfoCom conference was edited by the institute that was published in the periodical *Journal on Multimodal User Interfaces* under the title: *Special Issue*: *multimodal biases in CogInfoCom networks.*

III. Domestic and international relations

Organising international and outstanding domestic events

Members of the institute played an active role in the leadership as well as in the daily activities (board meetings, organising workshops and conferences) of the most significant international societies relevant to their research domain (including IEEE, CIRP, IFAC, IMEKO, IAPR).

The institute provides home for the Hungarian office of the World Wide Web Consortium (W3C), which takes part in the activity of the working groups, supports the dissemination of

standards in Hungary and also, directly contributes to web developments.

In cooperation with the German-Hungarian Chamber of Commerce and Industry as well as with several Fraunhofer partner institutes an international workshop was organised for the representatives of the Hungarian industry about the challenges and opportunities offered by Industrie 4.0.

International relations

The institute's successful participation in the EU research programmes continued in 2015: within the 7th Framework Program the institute participated in 44 grant winning projects, in 8 cases it had even the role of the consortium leader. In the Horizon 2020 program, up to now 9 winning projects may be reported with consortium leadership in 2 of them.

The institute has a strong project background in research and development for commercial aviation and vehicle industry. With respect to the research in avionics, the relationships 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 Système at the University of Bordeaux, as well as the German Aerospace Centre (DLR) and the European Space Agency (ESA) should be mentioned.

The collaboration with the *Manufacturing Technology Research Center, Hitachi Ltd.* dating back to many years, was pursued this year too, producing joint publications, filing of 2 international patent applications and the launch of a Hitachi-Fraunhofer-SZTAKI joint research project.

R&D relations with enterprises

On 25th June, 2015 a document was signed in Budapest to confirm MTA's contribution to the outstanding research in the vehicle industry being performed in Győr and to support by its presence the technical and nature science research activities in the region. The Centre of Excellence in Vehicle Technology Research (J3K) was formed at the Széchenyi István University of Győr in cooperation with MTA SZTAKI and the University of Győr. Its operation is secured by the joint support of MTA, Audi Hungaria, the university and the City of Győr. In addition to this, the institute has created in 2015 a new research site in Győr to deepen the existing cooperation with the industrial companies in the city and its environment.

In the area of energetics, the institute is working in collaboration with MVM Paks Nuclear Power Plant Inc. in the area of the systems control tasks relevant for the long term safe operation of the plant, and also with MVM Paks II Nuclear Power Plant Developer Inc. and MVM ERBE ENERGETIKA Engineering Office Inc. in the area of the later systems control tasks to ensure the long term sustainability of production capacity.

Most of the institute's activities pertaining to applied R&D in production informatics and logistics as well as to the industrial deployment thereof were carried out in the framework of the Fraunhofer-SZTAKI Project Centre for Production Management and Informatics.

In 2015 the institute continued to maintain valuable R&D collaboration with such important large national and multinational enterprises like Audio Motor Hungaria (development of production planning system, simulation of internal logistics), GE Hungary (intelligent public lighting system, smart city), Jaguar Land Rover and Comau (robotics for laser welding), Opel (visual recognition), Volvo (human-robot symbiosis in the assembly), Knorr-Bremse Braking Systems (production system configuration), Aventics Hungary, Festo and Denso (digital production).

The institute and the Fraunhofer Gesellschaft, Germany have been pursuing in a joint project

– including the Faculty of Mechanical Engineering and the Faculty of Transportation and Vehicle Engineering of BME, too – significant science organisational activity in the frame of a EU Teaming Call, launched in 2015 whose main goal is to reinforce the institutional grounds of the long term European scientific cooperation. The future vision is to establish an internationally acknowledged Centre of Excellence in the cyber-physical systems on the basis of, and by upgrading the current *Fraunhofer-SZTAKI PMI Project Centre.*

Also, one of the local domestic competence centres for the Tecnomatrix product family of the SIEMENS PLM software is operated by the institute.

National relations, participation in higher education

The institute continues to view teaching activities in graduate and post-graduate education as an important ingredient of its research work and also as an indispensable part of building the future. Hence, many researchers at the institute also fulfil teaching mandates at various Hungarian institutions of higher-level education, including BME, ELTE, Corvinus, Pannon University, PTE, ME, PPKE, and CEU. On average, around 20 PhD students conduct research work at the institute under the tutorship of senior researchers. Around 25 researchers at the institute act as external and 5 as founding members in various doctorate schools.

IV. Summary of the most relevant national and international grants won in 2015

FLEXOP Flutter Free FLight Envelope eXpansion for ecOnomical Performance improvement
(Bálint Vanek, EU H2020, 894750 €, 2015-2018)

The consortium, which is coordinated by the institute, consists of partners from the industry such as Airbus, the German Aerospace Center, some academic institutions (Bristol, München, Delft, Aachen), as well as major technology suppliers operating in the aircraft industry (FACC, INASCO). The flexible properties of aircraft wings are studied and active control methods are aimed to be developed for keeping undesirable resonance effects under control.

EPIC Centre of Excellence in Production Informatics and Control
(László Monostori, EU H2020, 138750 €, 2015-2016)

The project is aimed at elaborating the business plan of an Industry 4.0 Centre of Excellence within the European Teaming initiative. Partners in this work are the National Research, Development and Innovation Office, two faculties of BME, the Fraunhofer Gesellschaft and Fraunhofer Austria.

Streamline Improving Competitiveness of European Enterprises through Streamlined Analysis of Data at Rest and Data in Motion
(András Benczúr, EU H2020, 250063 €, 2016-2019)

In this project appropriate data stream-oriented analytic tools are built that reduce the complexity, cost, and burden associated with jointly supporting analytics for both “data at rest” and “data in motion".

EXCELL Actions for Excellence in Smart Cyber-Physical Systems applications through exploitation of Big Data in the context of Production Control and Logistics
(Angyalka Ilie Zudor, EU H2020, 317875 €, 2016-2019)

The project is aimed at facilitating the cooperation of four European research centres in the field of cyber-physical production and logistics systems, with special regard to big data applications.

COURAGE Understanding the Cultural Heritage of Dissent in the Former Socialist Countries

(László Kovács, EU H2020, 198100 €, 2016-2019)

The project creates an international archive for the resistance movements of the former communist countries. The institute is developing the information infrastructure to serve as the basis of the whole project.

SEPPAC Safety and Economic Platform for Partially Automated Commercial Vehicles
(Péter Gáspár, VKSZ, 310260 eFt, 2015-2017)

The collaborative project, involving the joint activity of MTA SZTAKI, Knorr-Bremse and MABI-BUS Kft. aims to develop new control methods for automated vehicle platforms.

SCOPIA Development of Endoscopic Diagnosis based Software Supported Clinical Tools
(Ákos Zarándy / Tamás Szirányi, VKSZ, 73382 eFt, 2015-2018)

The goal of the project is the development of hyperspectral imaging tools and methods in medical diagnoses. SZTAKI is addressing the design of the hyperspectral endoscopic lighting and imaging systems, and the evaluation of the produced narrow bandwidth video flows.

OTKA Physically inspired control and diagnosis of nonlinear dynamic systems
(Katalin Hangos, OTKA, 32232 eFt, 2015-2019)

The objective of research is to invent new cyber-physical methods to facilitate the dynamic analysis, design of control and diagnostics in advanced nonlinear systems.

VISION Validation of Integrated safety-enhanced intelligent flight control
(Bálint Vanek, EU H2020 (EU-Japan), 250063 €, 2016-2018)

The project aims at the improvement the safety measures of avionic systems by using smart technologies with the support of traditional flight control systems. The image processing techniques, the advanced control and navigation methods complemented with forecasting information may contribute to the enhanced safety of aerial vehicles.

V. List of the most significant scientific publications of 2015

Books

1. Baranyi P, Csapó Á, Sallai Gy:
   Cognitive Infocommunications (CogInfoCom).
   Springer, 219 (2015) http://real.mtak.hu/33478/
2. Cygan M, Fomin F V, Kowalik L, Lokshtanov D, Marx D, Pilipczuk M, Pilipczuk M, Saurabh S:
   Parameterized Algorithms.
   Springer, 613 (2015)
3. Keviczky L, Bányász Cs:
   Two-degree-of-freedom control systems: The Youla parameterization approach.
   Elsevier Academic Press, 514 (2015)
4. Tapolcai J, Pin-Han Ho, Babarczi P, Rónyai L:
   Neighborhood Failure Localization in All-Optical Networks via Monitoring Trails.
   IEEE-ACM TRANSACTIONS ON NETWORKING, 23 (6): 1719-1728. (2015)
   http://eprints.sztaki.hu/8561/

Publications in professional periodicals

5. Becsi T, Aradi S, Gáspár P:
   Educational Frameworks for Vehicle Mechatronics.
   IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, 16 (6): 3534-3542. 9 (2015)
   http://eprints.sztaki.hu/8502/

6. Bozóki S, Lee T-L, Rónyai L:
Seven mutually touching infinite cylinders.
COMPUTATIONAL GEOMETRY-THEORY AND APPLICATIONS, 48 (2): 87-93. (2015) http://eprints.sztaki.hu/8156/
7. Börcs A, Benedek Cs:
Extraction of Vehicle Groups in Airborne Lidar Point Clouds with Two-Level Point Processes.
IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, 53 (3): 1475-1489. (2015)
http://eprints.sztaki.hu/7835/
8. Csáji B Cs, Campi M, Weyer E:
Sign-perturbed sums: A new system identification approach for constructing exact non-asymptotic confidence regions in linear regression models.
IEEE TRANSACTIONS ON SIGNAL PROCESSING, 63 (1): 169-181. (2015) http://eprints.sztaki.hu/8416/
9. Csikós A, Varga I, Hangos K M:
Modeling of the dispersion of motorway traffic emission for control purposes.
TRANSPORTATION RESEARCH PART C-EMERGING TECHNOLOGIES, 58 (Part C): 598-616. (2015)
http://real.mtak.hu/33476/
10. Erdős G, Nakano T, Horváth G, Nonaka Y, Váncza J:
Recognition of complex engineering objects from large-scale point clouds.
CIRP ANNALS-MANUFACTURING TECHNOLOGY, 64 (1): 165-168. (2015) http://real.mtak.hu/30243/
11. Farkas K, Fehér G, Benczúr A, Sidló Cs:
Crowdsensing Based Public Transport Information Service in Smart Cities.
IEEE COMMUNICATIONS MAGAZINE, 53 (8): 158-165. 8 (2015) http://real.mtak.hu/26081/
12. Galambos P, Csapó Á, Zentay P, Fülöp IM, Haidegger T, Baranyi P, Rudas IJ:
Design, programming and orchestration of heterogeneous manufacturing systems through VR-powered remote collaboration.
ROBOTICS AND COMPUTER-INTEGRATED MANUFACTURING, 33: 68-77. (2015) http://eprints.sztaki.hu/8164/
13. Györgyi P, Kis T:
Approximability of scheduling problems with resource consuming jobs.
ANNALS OF OPERATIONS RESEARCH, 235: 319-336. (2015) http://eprints.sztaki.hu/8421/
14. Ilie-Zudor E, Ekárt A, Kemény Zs, Buckingham C D, Welch P G, Monostori L:
Advanced predictive-analysis-based decision support for collaborative logistics networks.
SUPPLY CHAIN MANAGEMENT-AN INTERNATIONAL JOURNAL, 20 (4): 369-388. (2015)
http://eprints.sztaki.hu/8401/
15. Kovács J, Marosi AC, Visegrádi Á, Farkas Z, Kacsuk P, Lovas R:
Boosting gLite with cloud augmented volunteer computing.
FUTURE GENERATION COMPUTER SYSTEMS-THE INTERNATIONAL JOURNAL OF GRID COMPUT, 43-44: 12-23. (2015)
http://eprints.sztaki.hu/8107/
16. Lipták G, Szederkényi G, Hangos KM:
Computing zero deficiency realizations of kinetic systems.
SYSTEMS & CONTROL LETTERS, 81: 24-30. (2015) http://real.mtak.hu/33477/
17. Manno-Kovacs A, Sziranyi T:
Orientation-selective building detection in aerial images.
ISPRS JOURNAL OF PHOTOGRAMMETRY AND REMOTE SENSING, 108: 94-112. (2015)
http://eprints.sztaki.hu/8580/
18. Marx D, Végh LA:
Fixed-parameter algorithms for minimum-cost edge-connectivity augmentation.
ACM TRANSACTIONS ON ALGORITHMS, 11 (4): Paper a27. 24 (2015) http://real.mtak.hu/31198/
19. Monostori L, Valckenaers P, Dolgui A, Panetto H, Brdys M, Csáji B Cs:
Cooperative control in production and logistics.

ANNUAL REVIEWS IN CONTROL, 39: 12-29. (2015) http://real.mtak.hu/24088/
20. Németh B, Varga B, Gáspár P:
Hierarchical design of an electro-hydraulic actuator based on robust LPV methods.
INTERNATIONAL JOURNAL OF CONTROL, 88 (8): 1429-1440. (2015) http://real.mtak.hu/27956/
21. Orzó L:
High speed phase retrieval of in-line holograms by the assistance of corresponding off-axis holograms.
OPTICS EXPRESS, 23 (13): 16638-16649. (2015) http://real.mtak.hu/24840/
22. Péni T, Vanek B, Szabó Z, Bokor J:
Supervisory fault tolerant control of the GTM UAV using LPV methods.
INTERNATIONAL JOURNAL OF APPLIED MATHEMATICS AND COMPUTER SCIENCE, 25 (1): 117-131. (2015)
http://real.mtak.hu/24116/
23. Tapolcai J, Pin-Han Ho, Babarczi P, Rónyai L:
Neighborhood Failure Localization in All-Optical Networks via Monitoring Trails.
IEEE-ACM TRANSACTIONS ON NETWORKING, 23 (6): 1719-1728. (2015) http://eprints.sztaki.hu/8561/