CZECH INSTITUTE
OF INFORMATICS
ROBOTICS AND
CYBERNETICS
CTU IN PRAGUE

ANNUAL REPORT 2019 AND OUTLOOK 2020

FOREWORD OF THE DIRECTOR AND THE SCIENTIFIC DIRECTOR

Our institute started its full operation after the new CIIRC CTU building was opened two years ago in May 2017. It makes me feel proud that the year 2019 was the second in a row where we managed to operate with a positive economical result.
In 2019, we achieved a profit of about 0.8 mil. euros in a situation where just 4.5% out of our 13.8 mil. euro turnover was made up by government support. All the remaining income was achieved in competition with European or national research projects or through co-operation with industry. It's hard to find better proof that the existence of CIIRC CTU makes great sense, and that idea of creating an (inter) national hub for robotics, smart manufacturing, smart cities, assistive technologies and other informatic fields was the right decision.
Our modern and, in Czech academic terms, innovative "Director – Scientific Director" management structure is fully functional and it allows each of us to concentrate on our part of the job – general management and operations or research.
It's my personal pleasure to be the Director of self-motivated, smart CIIRC employees jointly supporting our common goal. There's certainly still a lot of work ahead to create a thriving, modern, flexible and international environment, but we can already see that the Czech Institute of Informatics, Robotics and Cybernetics makes a difference in the field of Czech research.

Mgr. Ondřej Velek, Ph.D.
Director, CIIRC CTU

The first stage of building the Czech Institute of Informatics, Robotics and Cybernetics and its establishment on the Czech and European academic and industrial scene was completed in 2019. In 2013–2019 we managed to create an institution that is a leading European centre for artificial intelligence, a mover in the Czech ecosystem for AI and a respected centre for technology transfer. You can verify all these claims on the following pages of this annual report, where we describe our activities, projects, scientific results and cooperation with other institutions.
I am glad that, as the Scientific Director of the CIIRC CTU, I can lead the institute into the future and further develop its excellence. At this moment, we have secured sustainable financing for at least the next six years and we are building a European RICAIP Centre that has the potential to shift the limits of our current understanding of automated industrial production towards flexible, distributed production. We can connect experimental Testbeds for Industry 4.0 – in Prague, Brno and Saarbruecken – today, and additional ones outside the European space will soon be added to them. We will soon connect whole factories and realise the concept of decentralised production. In 2019, together with another 42 European partners, we submitted an application to the Eternitis project that would connect leading European laboratories into a European Network of Excellence for AI and Intelligent Robotics. There are currently successful transfer centres here – the National Centre for Industry 4.0 and the Centre of the City of the Future; we are realising European and national research projects. Thanks to this we are a leading activity integrator in the Czech Republic.
The world is constantly changing and science is playing a key role in this, as well as for the society of the future. We want to be and we are part of these wider social changes, so not only international, but also interdisciplinary co-operation is important to us.
I would like to thank my colleagues that made a significant contribution to the institute's excellent reputation, I would like to thank all supporters on the state administration side, international organisations and the European Commission, partner companies and laboratories, as well as co-operating research organisations and universities. Only thanks to all of you we are able to realise our vision – to create a leading scientific institution of a modern type in the Czech Republic.

Prof. Vladimír Mařík
Scientific Director, CIIRC CTU

HIGHLIGHTS 2019

2019 was a very successful year for the Czech Institute of Informatics, Robotics and Cybernetics. It has gained its financial stability, its teams have grown and it has broadened its international cooperation with excellent research institutions and laboratories, as we believe that the only way towards scientific excellence and growth is achievable only through intensive international cooperation with the best institutions.

After more than two years of intensive preparations, **RICAIP** (Research and Innovation Centre on Advanced Industrial Production) was launched in September 2019. In the next more than six years, the RICAIP partners will have access to funding of up to EUR 50 million (CZK 1.2 billion). Thanks to this support, the European Centre of Excellence for Advanced Industrial Production, the largest in the field of artificial intelligence (AI) and industrial robotics, will be created. It is based on a strategic cooperation between the Czech Republic and Germany. Partners of the project are its main coordinator CIIRC CTU, CEITEC BUT, and on the German side, the German Research Centre for Artificial Intelligence (DFKI) and the Centre for Mechatronics and Automatization Systems (ZeMA), both located in Saarbruecken. RICAIP has the potential to change the paradigm of industrial production as we know it.

Artificial Intelligence and Industry 4.0 have become very prominent themes at CIIRC CTU over the past few years and CIIRC CTU joined several world and European initiatives such as **CLAIRE** and **ELLIS**. Both the widely recognized initiatives established their Czech branches at CIIRC CTU in March 2019 and December respectively, as they rely upon names of excellent researchers such as Josef Šivic, Josef Urban, Robert Babuška or Tomáš Pajdla. The **AI Czechia** platform was established in 2019 and Scientific Director Prof. Vladimir Mařík was among the initiators. It served the Ministry of Industry and Trade as an advisory body in preparing the Czech Republic's National Artificial Intelligence Strategy and also it provided the data for the interactive map of subjects involved in AI in the Czech Republic. Moreover, CIIRC CTU has been a **Digital Innovation Hub for Artificial Intelligence** since 2018, the only one in the Czech Republic cooperating with 29 others across Europe in order to make a difference in transfer of knowledge to SMEs in Europe and boosting digitalization. In 2019, CIIRC CTU coordinated the submission of the EU H2020 project proposal **ETERNITIS** connecting more than 60 partners into a new **European Network of Excellence for AI and Intelligent Robotics**.

With this in mind, we are very happy that the Scientific Council of CTU awarded **professor Wolfgang Wahlster**, one of the most prominent figures of German contemporary artificial intelligence, scientific god-father of Industry 4.0 and long-standing partner and supporter of CIIRC CTU and Czech science, honorary degree doctor honoris causa. The ceremonial assembly took place in January 2020, as the proposal was approved in December 2019.

During 2019 we welcomed several significant guests who visited our premises and laboratories and discussed CIIRC's current issues and visions and cooperation with CIIRC management. To mention just a few, **Manfred Weber**, Chairman of the EPP Group in the European Parliament; **Judith Gerlach**, Bavarian State Minister for Digital Affairs; **Ryosei Tanaka**, State Minister from the Cabinet Office of Japanese Government, and **Kaoru Shimazaki**, Japanese Ambassador to the Czech Republic, representatives of the US government agency **National Science Foundation** or **Bernhard Maier**, CEO of Škoda Auto.

CIIRC also hosted and organized several conferences and events. **The European Conference on Mobile Robots ECMR** took place in September and welcomed more than 100 of the top researchers from Europe, the Americas and Asia. The international **Conference on Organising Urban Resilience** jointly organized by CIIRC CTU and EFEED took place in October and grasped an emerging research topic which naturally integrates achievements in different scientific areas and helps to prepare cities for handling risks connected with unexpected events, like earthquakes, flooding, blackouts or pollution crises. Earlier that year, in April, the 1st annual international conference **Future City Made by IoT** was organized by Centre of the City of the Future.

A very important part of CIIRC's mission is educating the public, engaging the local community into institute's life or cooperation with local NGOs. In 2019, CIIRC CTU took part and opened the institute to the public during the **Night of the Scientists** on September 27th, which attracted a record number of more than 1 000 visitors at CIIRC itself and more that 6 000 at CTU. A week earlier, the institute joined the country-wide event **Different City Experience** and opened not only its core facility **Testbed for Industry 4.0** but also its robotic bar and café. Children of all ages especially enjoy their encounters with technology with enormous zest. Highschool and university groups, SMEs and the general public could visit Testbed for Industry 4.0 and partner stands during the **Open House Day** organised by **the National Centre for Industry 4.0**, which takes place at least twice a year and also offers an educative conference programme.

Finally, we cannot forget to mention our distinguished guest lecturers. Just to mention a few, Prof. Ruzena Bajcsy, University of California, Berkeley, a distinguished roboticist and Czechoslovak expatriate gave a lecture on *Scientific methods in the backdrop of Data Science and Machine Learning*. Prof. Geoff Suttcliffe, Department of Computer Science, University of Miami lectured on *Automated Theorem Proving and the TPTP World – Infrastructure for Automated Reasoning* and Prof. Jacob Biamonte, Skolkovo Institute of Science and Technology in Moscow, gave a speech on *Grand Challenges of Modern Quantum Computer Programming*.

ABOUT CIIRC CTU

The Czech Institute of Informatics, Robotics and Cybernetics is a modern scientific and research institute of the Czech Technical University in Prague, which brings together excellent research teams, young talents and unique know-how in order to push technological boundaries and to build on the best of the Czech tradition in technical education. CIIRC CTU's research work focuses on four key areas: manufacturing, energy, smart cities and a healthy society, both in basic and applied research.
The Institute currently has nearly **300 employees** working in **8 research departments** complemented by specialised academic transfer **Centres** and **Testbed for Industry 4.0**. CIIRC CTU aims to concentrate on excellent research in the fields of robotics, intelligent systems, computer vision and machine learning, automatic verification, energy transport, including smart homes and smart cities, biomedicine and assistive technologies.
CIIRC CTU creates a unique ecosystem of academic-industrial cooperation in which it uses diversified forms of project financing from national, European and private sources.
The aim of the institute is also to help integrate the research and education of superior doctoral students in the field of informatics, robotics and cybernetics on the national level.

Currently, CIIRC CTU is training 80 students in doctoral programs in cooperation with CTU faculties and other universities. Students already find a range of research opportunities within CIIRC during their bachelor's or master's degree programs in many projects and departments, such as the Industrial Informatics or Testbed for Industry 4.0.

Mission

By creating fusions of research disciplines, CIIRC CTU turns ideas into breakthrough technologies for industry, energetics, the health-care system and society. It serves as a broadly open cooperation platform enabling collaboration, exchanges and knowledge transfers on both the national and the international level.
The mission of CIIRC CTU is to carry out research, promote quality doctoral and master courses, attract students to research, create a scientific research infrastructure and a creative open academic environment that makes a space for mutually beneficial cooperation among sections of the Czech Technical University, but also among other universities in the Czech Republic or abroad, the Czech Academy of Sciences, state authorities, industrial enterprises and other partners.

History

CIIRC CTU was established by the Academic Senate of the Czech Technical University in Prague on April 22nd, 2013, whereby it came into effect on July 1st, 2013. The main task in the first phase of the development of CIIRC CTU was to prepare a high-quality project in the area of the Research and Development for Innovation to revitalize the existing premises in the building that housed the Technical canteen and to provide adequate physical facilities for the work of CIIRC.
The new building was opened on May 2nd, 2017 on the Dejvice Campus and with its opening a new, fully operational era of CIIRC CTU could commence.

„CIIRC CTU is a key workplace that we can be proud of. It does an amazing job and not just in the development of the RP-95 protective mask. It is one of the few institutions that carries, and I dare say even in terms of the whole of science, the flag of Czech research. Its scientists receive one award after another, one project after another, they are very successful in the field of artificial intelligence."

Karel Havlíček, Deputy Prime Minister,
Minister of Industry and Trade, Minister of Transport
on CIIRC CTU during the press konference on June 17, 2020

AWARDS AND HONOURS 2019

CIIRC CTU researchers received several awards including:

- Z. Li, J. Sedlar, J. Carpentier, I. Laptev, N. Mansard, J. Sivic. Estimating 3D Motion and Forces of Person-Object Interactions from Monocular Video. IEEE Conference on Computer Vision and Pattern Recognition (CVPR) (2019) Best paper finalist.
- T. Duff, K. Kohn, A. Leykin, T. Pajdla. PLMP – Point-Line Minimal Problems in Complete Multi-View Visibility. ICCV 2019. November 2019. The Best Student Paper Award.
- Hugo Cisneros, Josef Šivic and Tomáš Mikolov. Evolving Structures in Complex Systems. IEEE Computational Intelligence (SSCI) 2019. Best Student Paper.
- Marek Vlk, Antonín Novák and Zdeněk Hanzálek. Makespan Minimization with Sequence-dependent Non-overlapping Setups. ICORES 2019. Best Student Paper Award.
- Jiří Vlasák, Michal Sojka and Zdeněk Hanzálek. Accelerated RRT* and Its Evaluation on Autonomous Parking. VEHITS 2019. Best Industrial Paper Award.
- Bernhard Wally, Jiří Vyskočil, Petr Novák, Christian Huemer, Radek Šindelář, Petr Kadera, Alexandra Mazak, Manuel Wimmer. Flexible Production Systems: Automated Generation of Operations Plans Based on ISA-95 and PDDL. 2019 IEEE 15th International Conference on Automation Science and Engineering (CASE). Best Application Paper Award Finalist, published at IEEE Robotics and Automation Letters.
- Vladimír Mařík. Manager of the Year. Czech Management Association.
- Vladimír Kučera. Albín Bráf Medal 2019.
- Team Alquist AI. AI Awards. Project of the Year. Organized by Economia.
- F1/10 Team, Industrial Informatics Department: F1/10 Autonomous Racing Competition: Columbia university, NY. 3rd place.
- System Satallax, Automatic Reasoning and Formal Methods group. World Championship for Automated Theorem Proving. 1st place in category High Order Theorems.
- ERC CZ grant for Mikoláš Janota: POSTMAN – Powering SMT Solvers by Machine Learning.

Point-Line Minimal Problems in Complete Multi-View Visibility. ICCV 2019

International Advisory Board

Chairman: **Prof. Wolfgang Wahlster**, Chief Executive Advisor of the German Research Center for AI (DFKI GmbH), Saarbrücken, Germany

Members:

Prof. Dr. Michael Berthold, FB Informatik & Informationswissenschaft, Universität Konstanz

Prof. Dr. Ivan Bratko, Faculty of Computer and Information Science University of Ljubljana

Dr. Dimitar Filev, Executive Technical Leader, Ford Research & Innovation Center, Dearborn, Michigan, USA

Prof. Herman Geuverse, Institute for Computing and Information Science, Radboud University Nijmegen

Mr. Kenwood H. Hall, Vice-President, Advanced Technology Rockwell Automation

Prof. Steffen Leonhardt, Chair for Medical Information Technology, Helmholtz Institute for Biomedical Engineering, RWTH Aachen, Germany

Prof. Duncan McFarlane, Institute for Manufacturing, University of Cambridge, Great Britain

Prof. Aart Middeldorp, Institute of Computer Science, University of Innsbruck, Austria

Prof. Masaki Nakagawa, Tokyo University of Agriculture and Technology, Tokyo, Japan

Prof. Dr. Reimund Neugebauer, President, Fraunhofer-Gesellschaft, Headquarters, München, Germany

Mr. Ram Ramakrishnan, EVP & Chief Technology Officer, Eaton Corporation, USA

Dr. Petr Skobelev, Director, Smart Solutions Company, Samara, Russia

Prof. Dr. A Min Tjoa, Director, Institute of Software Technology and Interactive Systems, Vienna University of Technology, Wien, Austria

Assembly

Doc. Ing. Tomáš Pajdla Ph.D., chairman
Prof. Dr. Ing. Robert Babuška
Prof. Ing. Václav Hlaváč, CSc.
Prof. Ing. Vladimír Kučera, DrSc., dr.h.c.
Prof. Ing. Mirko Navara, DrSc.
Prof. Dr. Ing. Zdeněk Hanzálek
Doc. Ing. Lenka Lhotská, CSc.
Dr. Ing. Josef Šivic
Mgr. Josef Urban, Ph.D.
Prof. Ing. Michael Valášek, DrSc.
Prof. Ing. Tomáš Vyhlídal, Ph.D.

Department of Cyber-physical Systems	Head **Prof. Dr. Ing. Zdeněk Hanzálek**
Department of Intelligent Systems	Head **Prof. Ing. Vladimír Mařík, DrSc., dr.h.c.**
Department of Industrial Informatics	Head **Prof. Dr. Ing. Zdeněk Hanzálek**
Department of Robotics and Machine Perception	Head **Prof. Ing. Václav Hlaváč, CSc.**
Department of Industrial Production and Automation	Head **Prof. Ing. Michael Valášek, DrSc.**
Department of Cognitive Systems and Neurosciences	Head **Doc. Ing. Lenka Lhotská, CSc.**
Department of Biomedical Engineering and Assistive Technologies	Head **Prof. RNDr. Olga Štěpánková, CSc.**
Department of Research Management of Platforms	Head **Prof. Ing. Vladimír Kučera, DrSc., dr.h.c.**

Director
Mgr. Ondřej Velek, Ph.D.

Vice-Director
Prof. Ing. Vladimír Kučera, DrSc., dr.h.c.
Prof. Ing. Václav Hlaváč, CSc.

Scientific Director
Prof. Ing. Vladimír Mařík, DrSc., dr.h.c.

Treasurer
Ing. Lenka Vysloužilová, Ph.D.

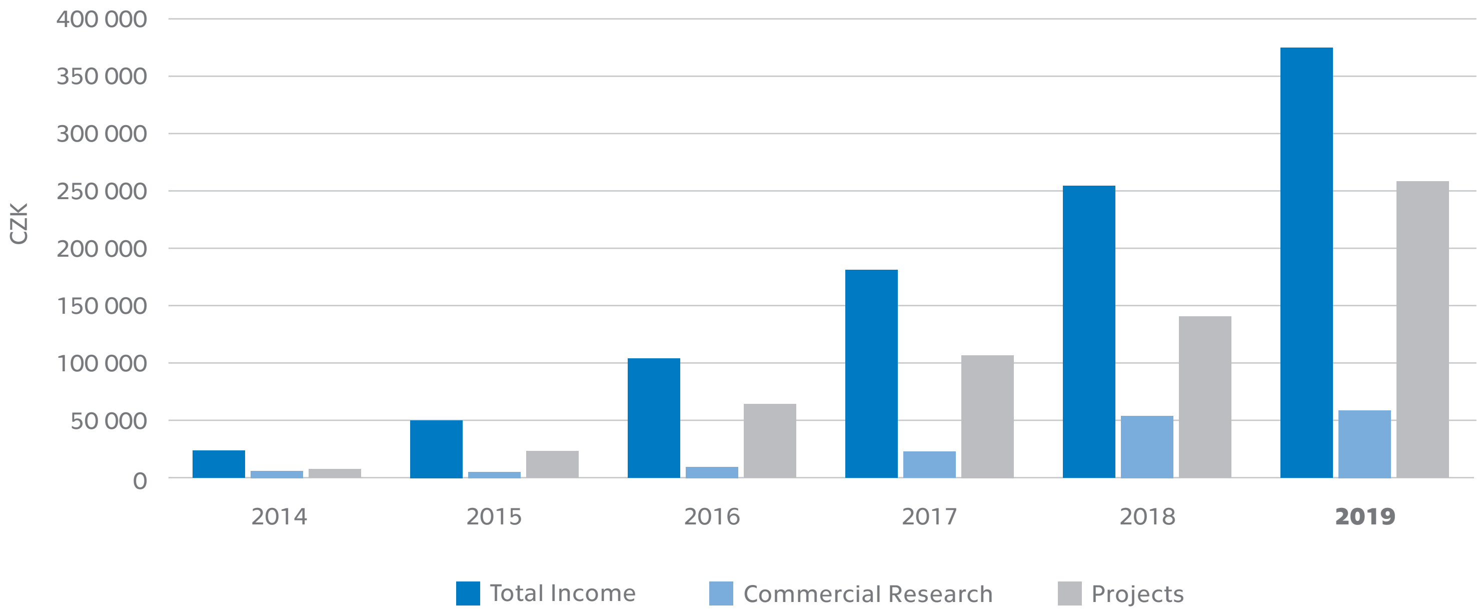
RICAIP autonomous centre
Head **Tilman Becker, Dr. rer. nat.**

National Centre for Industry 4.0
Head **Ing. Jaroslav Lískovec**

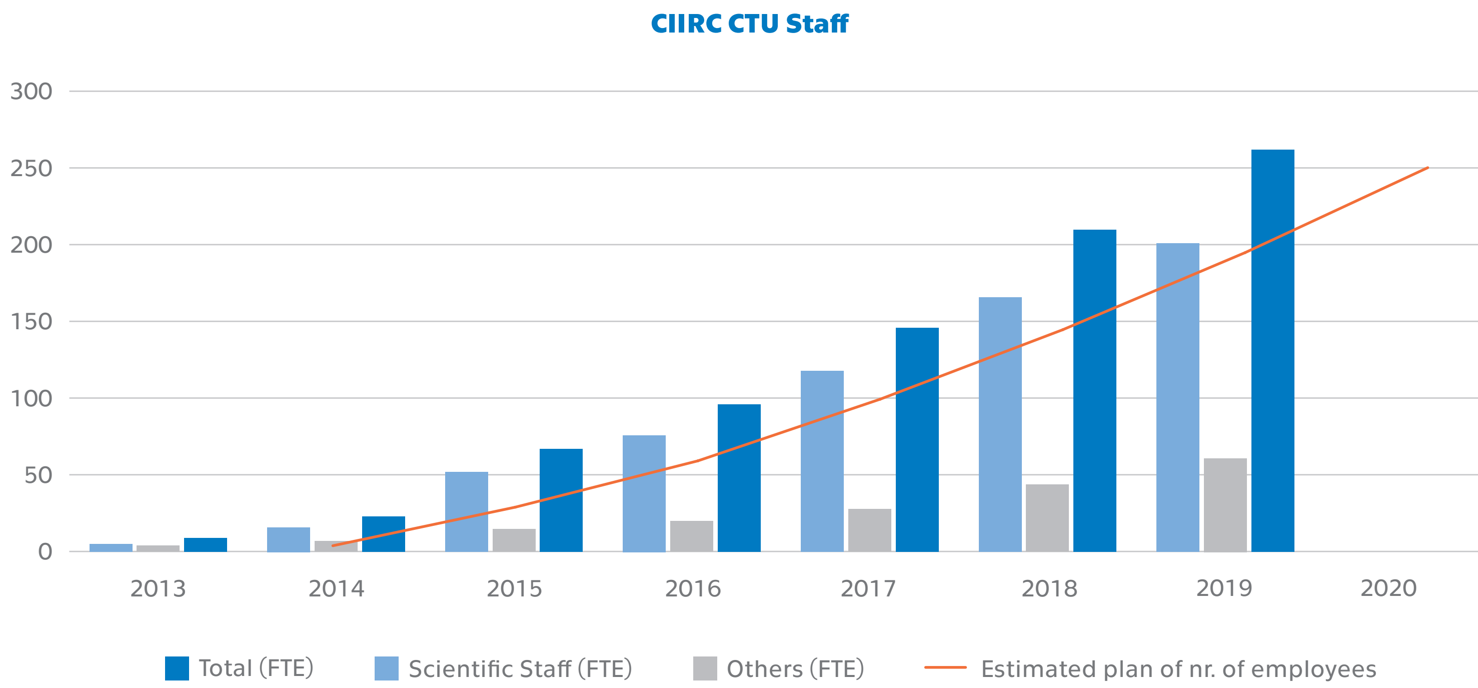
Center of the City of the Future
Head **Ing. arch. Michal Postránecký**

Testbed
Head **Ing. Pavel Burget, Ph.D.**

CIIRC CTU Income (in thousands CZK)



The total income of CIIRC CTU is substantially growing, especially in the past two years with the total income over 370 million Czech crowns in 2019. The budget is balanced on the income and the expense side. The largest portion of CIIRC CTU income arises from competitive projects, both national and European, such as TA CR, GA CR, H2020 or other EC projects. Income from commercial research means mainly contractual cooperation with industry.



CIIRC CTU staff is organically growing in accordance with the planned estimate. Already in 2018 the number of employees grew over the critical limit of 150 employees and it reached 262 people, (197 FTE) at the end of 2019.

SELECTED RESULTS

Department of Robotics and Machine Perception (RMP)

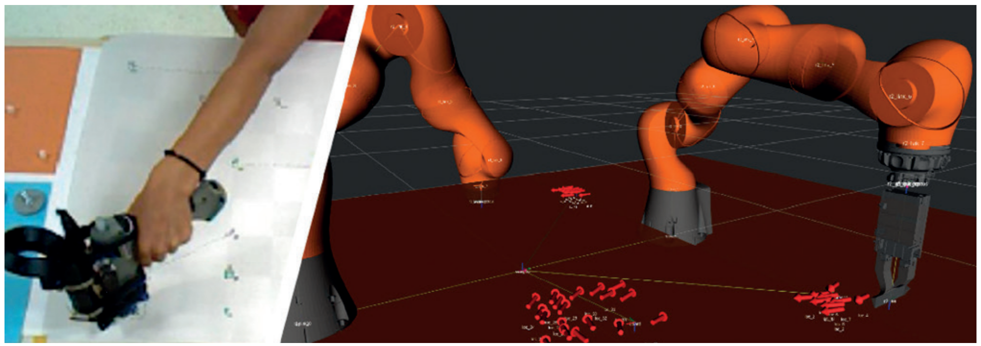
Robotic Perception (ROP)

Specifying Dual-Arm Robot Planning Problems through Natural Language and Demonstration

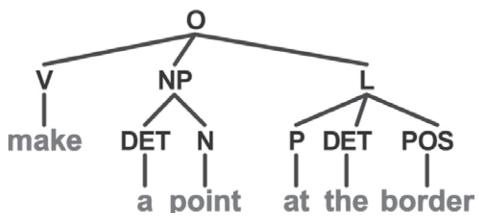
Multi-modal robot programming with natural language and demonstration is a promising technique for efficient teaching of manipulation tasks in industrial environments. In particular, with modern dual-arm robots designed to take over tasks quickly at typical industrial workbenches, the direct teaching of task sequences hardly utilizes the robots' capabilities. Therefore we propose a two-staged approach that combines natural language instructions and demonstration with simultaneous task allocation and motion scheduling based on constraint programming. Instead of providing a task description and demonstrations that are replayed to a large extent, the user describes tasks to be scheduled with all relevant constraints and demonstrates relevant locations relative to workpieces and other objects. With explicitly stated constraints on the partial ordering of tasks, the solver allocates the tasks to the robot arms and schedules them in time while avoiding self-collisions and reducing the makespan in our experiment by 33%. The linguistic concepts of naming and grouping enable systematic reuse of sub-task ensembles. The proposed approach is evaluated with four variants of a gluing use-case from furniture assembly in user studies with ten participants. In these user studies, we have observed a speed-up for the task definition of more than six times compared to a textual specification of the planning problems using the Python-based planner API.

Publication: BEHRENS, J. K. et al. Specifying Dual-Arm Robot Planning Problems Through Natural Language and Demonstration. IEEE Robotics and Automation Letters. 2019, 4(3), 2622–2629. ISSN 2377-3766.

Contact: Jan Kristof Behrens, MSc. (Jan.Kristof.Behrens@cvut.cz)



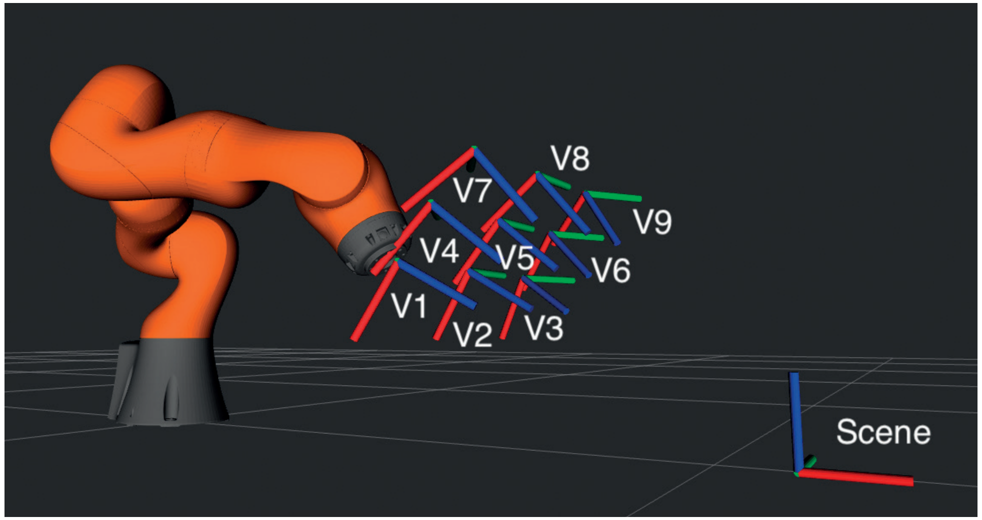
Gluing bolts into a board.
Left: The instructor demonstration. Right: The simulator executes the planned trajectory



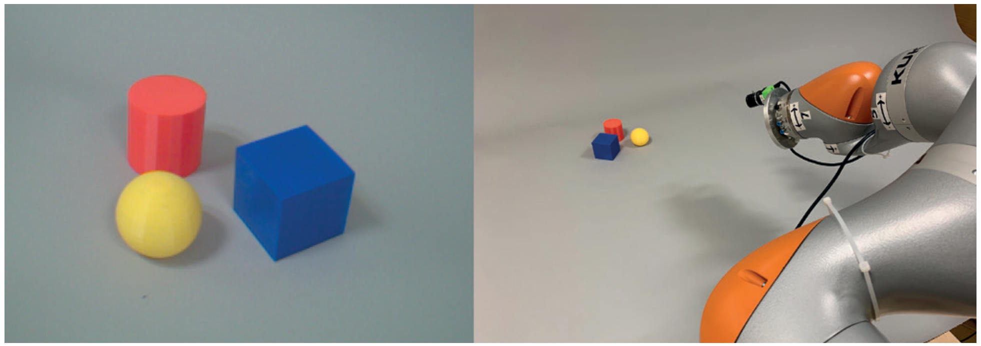
A sentence describing a simple task – gluing a point in a given location

Exploring logical consistency and viewport sensitivity in compositional VQA models

The most recent architectures for Visual Question Answering (VQA), such as TbD or DDRprog, have already outperformed human-level accuracy in benchmark datasets (e.g. CLEVR). We have administered the advanced analysis of their performance based on novel metrics called consistency (sum of all object feature instances in the scene e.g. shapes equals the total number of the objects in the scene) and revealed just 56% consistency for the most accurate architecture (TbD). In respect to this finding, we have proposed a new method of the VQA training which reaches 98% consistency. Furthermore, testing of the VQA model in real world brings out a problem with precise mimicking of the camera position from the original dataset. Therefore we have created a virtual environment along with its real-world counterpart with variable camera positions to test the accuracy and consistency from different viewports. Based on these errors, we were able to estimate the optimal position of the camera. The proposed method thus allows us to find the optimal camera viewport in the real environment without knowing the geometry and the exact position of the camera in the synthetic training environment.



Search for the best viewport based on minimizing testing error



Collecting the data from a real robot for the Visual Question Answering task

Publication: ŠEJNOVÁ, G. et al. Exploring logical consistency and viewport sensitivity in compositional VQA models. In: 2019 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). IROS 2019: the IEEE/RSJ International Conference on Intelligent Robots and Systems, Macau, 2019-11-04/2019-11-08. Piscataway, NJ: IEEE, 2019. p. 2108–2113. ISSN 2153-0866. ISBN 978-1-7281-4004-9

Contact: Mgr. Gabriela Šejnová (Gabriela.Sejnova@cvut.cz)

Project IMPACT – Intelligent Machine Perception

Estimating 3D Motion and Forces of Person-Object Interactions from Monocular Video

This work introduces a new approach to an automatic reconstruction of 3D motion and actuation forces of a person interacting with an object from a single RGB video. The objective is to enable robots to learn how to manipulate tools by watching instructional videos that are available at for example YouTube. The approach was developed in collaboration with researchers from INRIA in Paris and LAAS-CNRS in Toulouse. **This work was shortlisted among the best paper finalists at the Conference on Computer Vision and Pattern Recognition 2019 (CVPR 2019)**. CVPR is the premier annual computer vision event and represents one of the top three conferences in the field of computer vision (together with ICCV and ECCV) and is listed among the top 10 most cited journals and conferences over all areas of science by Google Scholar. A total of 1294 papers have been accepted in 2019 from a record-high 5160 submissions (25% acceptance rate). The best paper finalists were selected by the program committee as the top 45 papers (1%) from all submissions.

Publication: Z. Li, J. Sedlar, J. Carpentier, I. Laptev, N. Mansard, J. Sivic. Estimating 3D Motion and Forces of Person-Object Interactions from Monocular Video. IEEE Conference on Computer Vision and Pattern Recognition (CVPR) (2019) Best paper finalist.

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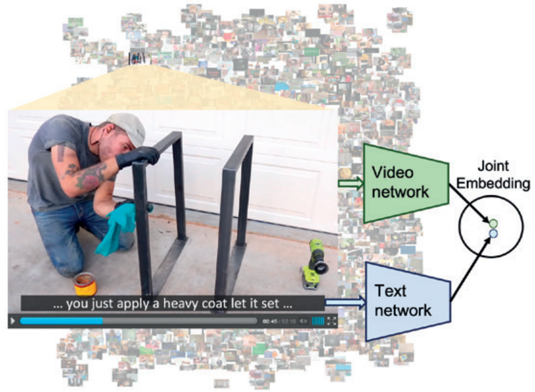
HowTo100M: Learning a Text-Video Embedding by Watching Hundred Million Narrated Video Clips

In this work, we propose to learn text-video embeddings from video data with readily available natural language annotations in the form of automatically transcribed narrations. The contributions of this work are three-fold. First, we introduce HowTo100M: a large-scale dataset of 136 million video clips sourced from 1.22M narrated instructional web videos depicting humans performing and describing over 23k different visual tasks. Our data collection procedure is fast, scalable and does not require any additional manual annotation. Second, we demonstrate that a text-video embedding trained on this data leads to state-of-the-art results for text-to-video retrieval and action localization on instructional video datasets such as YouCook2 or CrossTask. Finally, we show that this embedding transfers well to other domains: fine-tuning on generic Youtube videos (MSR-VTT dataset) and movies (LSMDC dataset) outperforms models trained on these datasets alone.
This work (Miech et al., ICCV 2019) is among the first works demonstrating that large-scale weakly-supervised learning of video representations can outperform fully supervised methods. It has also practical implications as it overcomes the need for large-scale annotated video datasets, which are expensive and time-consuming to annotate. This is an important step towards machines that



learn automatically from readily available but noisy meta-data without the need for explicit supervision, which is often expensive and hard to obtain.
The ICCV conference (IEEE/CVF International Conference on Computer Vision) is a premier international computer vision conference and one of the top three conferences in the field (together with CVPR and ECCV). It is listed among the top 75 most cited journals and conferences over all areas of science by Google Scholar. A total of 1075 papers have been accepted this year from 4303 submissions (25% acceptance rate).

Publication: A. Miech, D. Zhukov, J. B. Alayrac, M. Tapaswi, I. Laptev, J. Sivic – Howto100M: Learning a Text-video Embedding by Watching Hundred Million Narrated Video Clips, IEEE International Conference on Computer Vision (ICCV) (2019)

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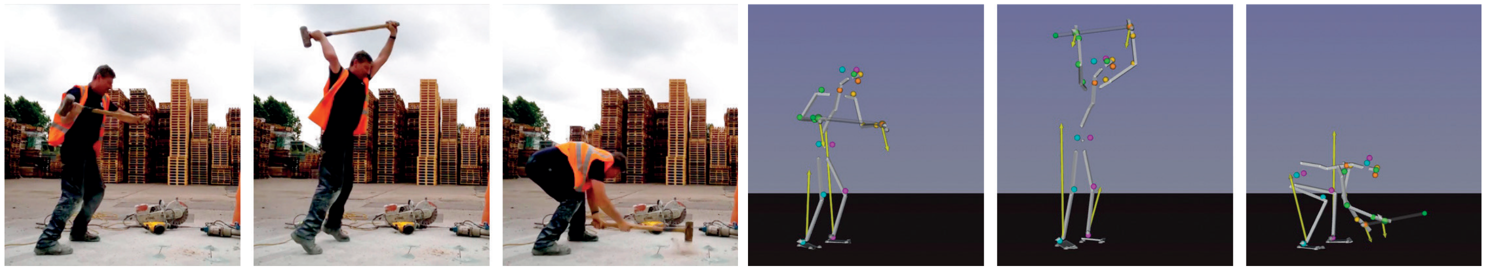
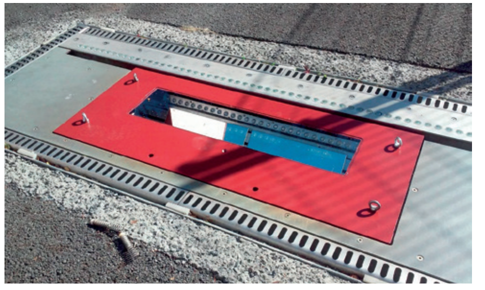


Input and output of the method...

Intelligent and Mobile Robotics (IMR)

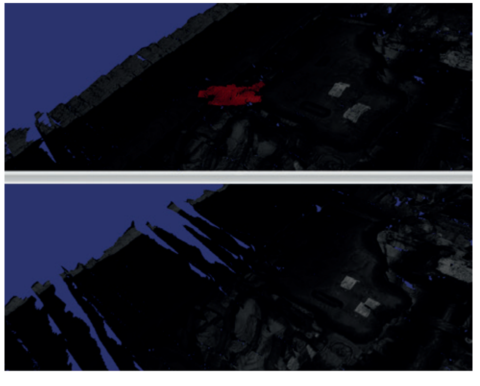
Dynamic 3D reconstruction of moving surfaces – Multi-camera vehicles' undercarriage security scanner

The project is funded by the Ministry of Interior of the Czech Republic under the project no. VI2VS/461.
Performed in cooperation with: VOP CZ
Recovery of RGBD images of moving objects, in particular their visible surfaces, represents a significant contribution towards security scanning of vehicle undercarriage. In this connection, off-the-shelf solutions either deliver only 2D (RGB) images lacking enough in-depth information or allow only low resolution and insufficient data due to sensing constraints. Neither approach provides sufficient resolution for the detection and recognition of objects of interest (mainly via comparison of to-date and preceding images/scans).



Construction of the Kerberos system and its placement into a drive lane (an experimental prototype)

Reconstructed undercarriage of the inspected vehicle



Pair of stereo images of the reconstructed vehicle undercarriage

The Kassandra project addresses research and development of methods and tools, in particular, advanced image processing algorithms that enable reconstruction of the coloured 3D mesh model of the undercarriage for the safety scanners. The designed system combines colour images from two cameras to cover the whole width of the car undercarriage. Each camera looks through a system of two mirrors to prolong optical distance without the need for a physically large installation. The mirrors split the image from one camera into two images from a virtual stereo pair. It decreases the number of cameras and the complexity of the installation at the same time.

These particular methods are designed so they can also handle rapid vehicle motion over the scanner frame. The solution can reliably reconstruct the 3D model despite the fact that in the typical undercarriages there are mainly uniform and evenly coloured surfaces. Due to the rapid movement of the vehicle, there is a need for intense artificial lighting. It makes the situation worse as it is tough to get the illumination even and constant with variable distance from the source.
During each operation, several pairs of images are captured in a sequence. A visual odometry is used to compute their relative position. Each pair of images serves to reconstruct a section of a 3D model of the undercarriage. The disparity map is obtained by correlation-based block-matching algorithm. The partial 3D model pieces are transformed into the global model frame of reference. By design, there is a significant overlap of the partial models. The final model is composed by trimming the overlapping sections and triangulating the space between resultant edges. The Kassandra system then compares the resulting 3D coloured model with the model gathered during the previous scanning identified by the registration plate of the car. Subsequently, it highlights any significant change in the shape or colour of the undercarriage for the operator to make a decision.
The significant properties of the targeted approach include its ability to handle moving vehicles at speed up to 20kmh and being able to attain a spatial resolution of the reconstructed 3D model about 1mm.

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An integrated approach to goal selection in mobile robot exploration

Project: Robotics for Industry 4.0 (R4I)
In collaboration with: Brno University of Technology and LTR Ltd.

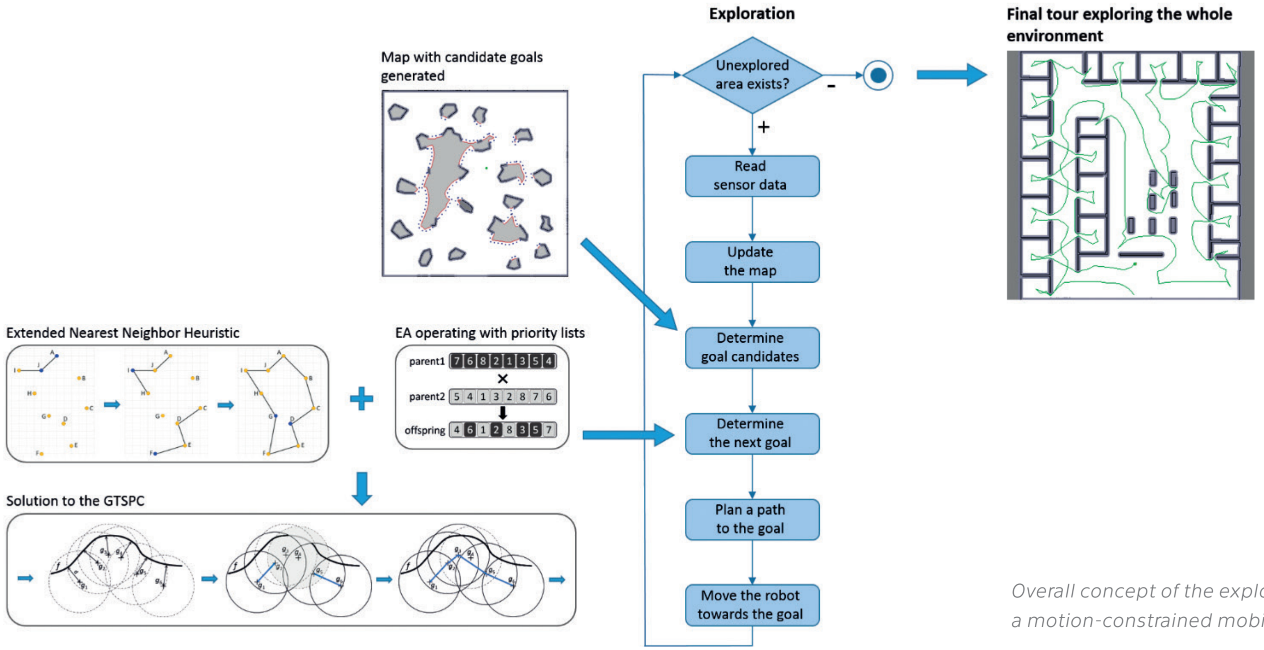
A fully localized autonomous mobile robot is assumed equipped with a ranging sensor with a fixed limited range (e.g., a laser range-finder) and 360° field of view operating in an unknown flat environment. Exploration is defined as the process in which the robot is navigated with the aim to build a complete map of the surrounding space to collect the information about this space. The map is built incrementally as sensor measurements are gathered, and it serves as a model of the environment for further exploration steps. Besides, the usage of resources (e.g., the exploration time, the length of the trajectory) is optimized.

The exploration strategy determines the next robot goal in each exploration iteration (one exploration step) with respect to the actual robot position, the current knowledge of the environment, and a selected optimization criterion.

A realization of the exploration strategy is the key part of the exploration process as it influences the exploration quality significantly – an inappropriate determination of the next goal to be visited may lead to revisiting of already explored places, which increases the time needed to finish the exploration. Therefore, the design of an efficient strategy that determines goals aiming to perform exploration with minimal effort plays an important role.

We have formulated the exploration strategy as the d-Watchman Route Problem consisting of two coupled tasks – candidate goals generation and find an optimal path through a subset of goals. The latter has been defined as a constrained variant of the Generalized Traveling Salesman Problem and solved using an evolutionary algorithm. An evolutionary algorithm that uses an indirect representation and the nearest neighbour based constructive procedure was proposed to solve this problem. Individuals evolved in this evolutionary algorithm do not directly code the solutions to the problem. Instead, they represent sequences of instructions to construct a feasible solution. The problems with efficiently generating feasible solutions typically arising when applying traditional evolutionary algorithms to constrained optimization problems are eliminated this way.

Experimental results show that the proposed approach allows a higher flexibility in planning the next robot actions and outperforms state-of-the-art methods in environments with a low density of obstacles by up to 12.5%, while it is slightly worse in office-like environments by 4.5% at maximum. The framework has also been deployed on a real robot to demonstrate the applicability of the proposed solution with real hardware.



Overall concept of the exploration task using a motion-constrained mobile robot

Publication: M. KULICH, J. KUBALÍK and L. PŘEUČIL. An Integrated Approach to Goal Selection in Mobile Robot Exploration. Sensors. 2019, 19(6), ISSN 1424-8220.

Contact: Dr. Libor Přeučil (libor.preucil@cvut.cz), Dr. Miroslav Kulich (miroslav.kulich@cvut.cz)

Visual Place Recognition and Neural Networks Applied to Mobile Robotics

Visual Place Recognition (VPR) is an important task in robot navigation systems such as SLAM. The technology has strong application field in autonomous mobile/logistic systems, autonomous cars and other unmanned vehicles on the ground (UGV) and in the air (UAV). By identifying places that have been previously visited by a robot, VPR helps to correct global errors that may occur during the construction of the environment map. A VPR system is proposed that it relies on robust image representations provided by descriptors from a standard, pre-trained, Convolutional Neural Network (CNN). The methodology resembles information retrieval pipelines in that it consists of two phases or stages. In order to recognize the place associated with a given image, (1) a number of candidates is selected from a database of previously visited places and (2) the candidate images are compared with the current query image in a more sophisticated geometrical fashion resulting in the identification of the best match.
Testing this approach against a number of commonly used datasets, recognition accuracy is shown to surpass the state of the art in VPR by a large margin. Especially notorious is the excellent performance achieved on some very challenging datasets, characterized by large changes in illumination, camera viewpoint or those cause by considering different seasons of the year.

Apart from the standard use in SLAM, the robustness of the proposed methodology allows for very promising applications. For instance, a simple tech-and-repeat navigation system based on the output of the place recognition pipeline has been developed. When compared with accurate ground truth, indoors maximum navigation error was in the order of centimetres, high enough to navigate comfortably in human-oriented spaces, through doors, corridors, etc. In addition, preliminary tests outdoors were also very successful.

Publication: Luis G. Camara, Carl Gäbert, Libor Přeučil (ICRA 2020). Highly Robust Visual Place Recognition

Contact: Dr. Libor Přeučil (libor.preucil@cvut.cz), Dr. Luis Gomez Camara (luis.gomez.camara@cvut.cz)

Examples of the same place look under different conditions

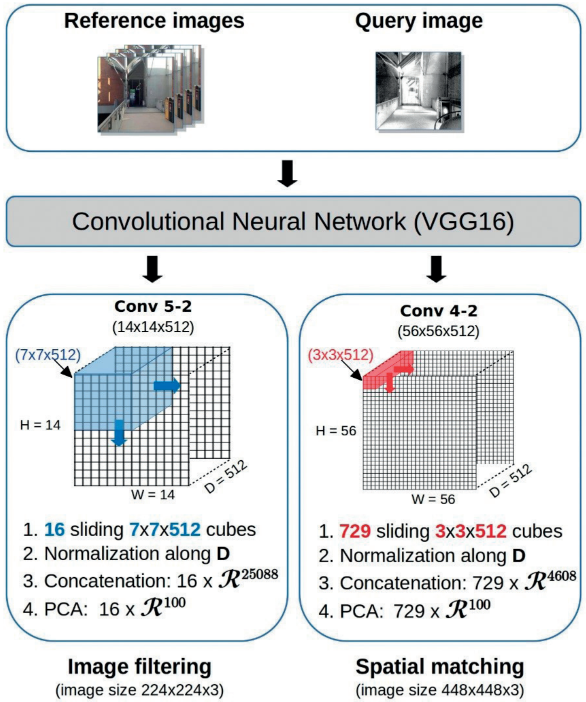


Image encoding scheme of images into CNN descriptors for stages 1 (left) and 2 (right) of the place recognition system

Multi-purpose robotic platform for nuclear waste manipulation

Project: Research and project concept of an underground multi-robot for storage of disposal casks, and realization of a prototype of a multifunctional robotic platform.
Project funded by: Ministry of Trade and Industry of the Czech Republic within program TRIO
Performed in cooperation with: HOPAX s.r.o., FITE a.s.
Robotic automation appears in a wide area of industrial processes and applications. It has high requirements for robustness in practical applications as well as for the efficiency of the solution. The focus of this project was the development of a novel and highly efficient robotic technology, with a vision of a new concept of a fully autonomous underground multi-robot for complex manipulation with disposal casks with spent nuclear fuel in deep geological repositories.

The newly designed robotic unit is equipped with a complex dual effector suitable for grasping disposal casks with spent fuel rods as well as bentonite pedestals on which the disposal casks are stowed. The design also allows the robotic unit to fill the storage tunnel with bentonite backfill after the disposal casks are stored. The solution brings improvement in various aspects of the manipulation process. Since it is based on direct manipulation with objects, it reduces undesired mechanical contact during the manipulation process, highly reducing the risk of damaging the disposal casks. The newly developed in-wheel motor unit removes the dependency on designated rail structures or unnecessary modifications to the storage area. This allows the use of a robotic unit in circular horizontal boreholes originally designed for the storage of the disposal containers, making it highly efficient in its use and reducing the necessary amount of the excavated material.


Robotic prototype for simulation of mobility in a circular tunnel


Test-bench of a dual-effector for nuclear waste manipulation, with a disposal cask on the left and bentonite pedestal on the right

The function of the dual robotic manipulation module was demonstrated via prototypes in real test simulators. The robotic units are equipped with a system of controlled drives, transmission mechanisms, sensors, and a control system providing guidance and a comprehensive trajectory for the robot. These modules will become the basic building blocks of an underground multi-robot equipped with a complex dual effector. The solution is critical for respecting the deposition process in long horizontal borehole storage areas wherein nuclear waste is serially stored. Taking full advantage of a single robotic platform, storing disposal casks simultaneously with bentonite blocks, the proposed method and novel robotic technology have extremely high technological utility and economic value in long-term applications.

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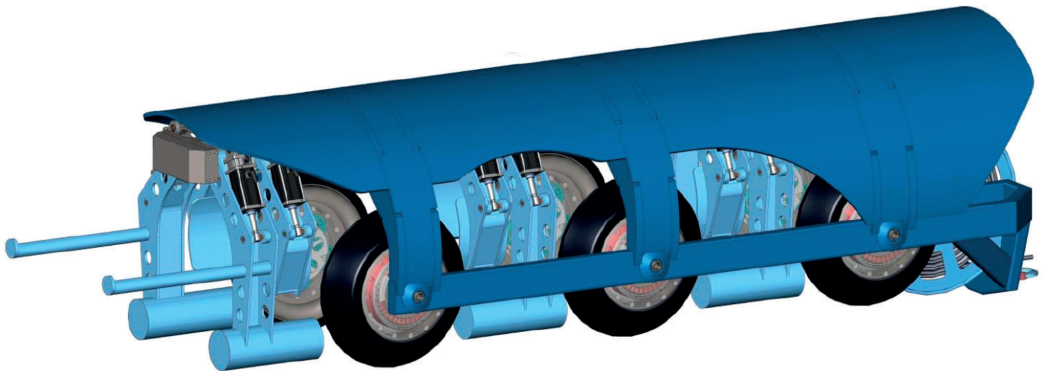
A conceptual design of the robot for nuclear waste manipulation

Safe human-robot interaction in logistics applications for highly flexible warehouses (SafeLog)

Funding scheme: H2020 – RIA Project
Performed in collaboration with: The Karlsruhe Institute of Technology (D), Fraunhofer Institute IML (D), SwissLog A.G. (D), The University of Zagreb (HR), The Institute of Electrical Engineering KONCAR Inc. (HR)

Especially in logistics, the concept of full automation is not desirable or even feasible. Thus the vision of "Warehouse Co-workers" becomes more and more important to advance automation as assistant system to a human worker. But this idea is completely contrary to the concept of sealed off automated areas. As a consequence, there is a dire need for new ways of realizing safety for cooperated warehouses, such as a mobile safety guard around the human itself in contrast to the classical way – around the machine. This kind of technology would help to enable:

- New kind of flexible human-robot cooperation at warehouse logistics systems at reduced costs
- Improved safety and working conditions for the staff involved in the warehouses
- Improved reliability of the system by improving service- and maintainability of automated warehouse logistics systems during operation.

The overall objective of ***SafeLog*** is the conception and implementation of a large-scale flexible warehouse system which enables a safe and efficient collaboration of human and robots in the same area and at the same time. To reach this goal, the following objectives were identified:

- **Safety concept:** Design of a holistic safety concept, which allows the collaboration of humans for a flexible warehouse system.
- **Safety vest:** Hard- and software design for a new kind of safety vest to be worn by the workers, which allows safe walking in a warehouse equipped with autonomous mobile robots.
- **Planning and scheduling:** Development of planning and scheduling algorithms for a heterogeneous fleet manager, which allows the ad hoc reactive planning and scheduling for human and robot work forces in a flexible warehouse system.
- **Assisting technologies:** based interaction strategies to support workers in a robotised warehouse system with information about their current task and environment.

The SafeLog project proposes to develop a complete new integrated safety concept, which will fundamentally change the usage of mobile robots in an environment where humans and robots work closely together. The concept consists of three levels of safety with the following responsibilities:

- Safety Level A: Safety level A draws a virtual circle around the human operator acting as a simulated electromagnetic pulse (EMP). No movements of mobile robots are allowed within this circle. Even if the human is moving around, all mobile robots will stop in a safe distance to the human. This level will ensure the intrinsic safety of the overall system.
- Safety Level B: In safety level B several options are available. First the human operator will be informed about approaching robots. In Safety Level B such approaching robots do not yet impose a threat. If a robot is equipped with corresponding safety infrastructure, its speed can be reduced, to avoid potential upcoming dangerous situations. Promising candidates for such an approach are Automated Guided Vehicles (AGV). The speed of the AGV is limited until the distance allows safe use of the full speed.
- Safety Level C: The Fleet Management System (FMS) plans the paths of humans and mobile robots, so that close encounters between those entities are generally avoided. If a human deviates from a pre-planned path, the routes for the mobile robots are automatically re-planned.

With the precise localization of all human workers in the warehouse, FMS plans trajectories for heterogeneous human-robot system taking into account all kinds of robot abilities (carrier single bins, pallet transporter, forklift, measurement/maintenance vehicle) and human specialized tasks (picker, reloader, system architect, maintenance personnel, programmer). FMS takes into account the dynamic changes caused by human interaction with the system, with respect to orders based on availability and priority. Therefore, a multi-objective multi-constrained large-scale planner with additional error handling subsystem (monitoring, diagnosis and maintenance) and lifecycle system-management subsystem (reorganization, flexibility, and setup) has been developed within SafeLog.

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Sharing the workspace between humans and robots, the safety-concept

Autonomous navigation for industrial robotic transporter – Project CreoBot

Funding scheme: Technological Agency of the Czech Republic project, program GAMMA
Performed in cooperation with: HOPAX s.r.o. and ROBOTSYSTEM, s.r.o.

Modern autonomous industrial mobile platforms cease to need of expensive and fixed infrastructure built exclusively for mobile systems navigation purposes. Instead, these tend to depend more on their own on-board sensors and intelligent data processing, which leads to full independence on the environment infrastructure, excellent flexibility of the solution to environmental variations and uncertainty and therefore to a massive reduction of transportation and logistics systems operation costs.
The CreoBot project aims at development of an autonomous mobile omni-directional platform for high payload transportation in production spaces, storage areas, of both the indoor and outdoor cases. The navigation system has been developed as an independent software component, allowing use of diverse platforms and allowing these systems to safely move to requested destination places without human attendance. The system is able to plan an optimal and safe path to the target destination, handling autonomously variations and unexpected events in the workspace, i.e. temporary closures of some possible paths and resolving these possible collisions. The system safely navigates along the planned optimal path with the possibility to avoid previously unknown obstacles and exhibits feasible and safe behaviour even in presence of human entities in place.

Safety is the most important factor of the system design. Since the vehicle should be able to transport payload of several tons, it is essential that any collision possibility has to be avoided in order to prevent any serious damage or injuring people working nearby. Therefore, the safety is handled at several different levels, allowing guaranteed safe operation even in case of sensor or software malfunction.

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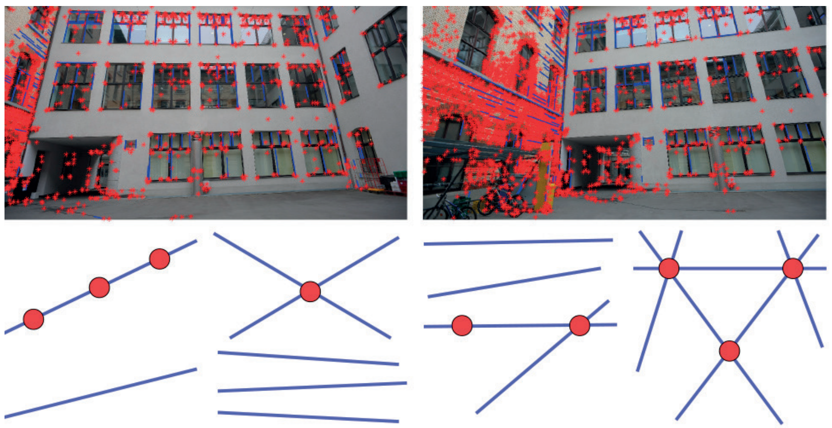
The CreoBot experimental prototype

Applied Algebra and Geometry
(AAG)

PLMP – Point-Line Minimal Problems in Complete Multi-View Visibility

Co-authored by Tomas Pajdla from Applied Algebra and Geometry Group of the CIIRC CTU in Prague won the Best Student Paper Award at the IEEE/CVF International Conference on Computer Vision 2019 (ICCV 2019) that took place in Seoul from October 29 until November 1, 2019. ICCV is the premier bi-annual international computer vision conference. The paper presents a complete classification of all minimal problems for generic arrangements of points and lines fully observed by calibrated perspective cameras. This theoretical result makes an important contribution to understanding the space of geometrical problems in 3D reconstruction that can be efficiently solved. It is based on techniques from nonlinear algebra, such as basic algebraic geometry, symbolic elimination using Groebner bases computation, and numerical solving of polynomial systems using Homotopy Continuation and Monodromy.
This is an important result as it finalizes the understanding of certain class of geometrical problems that are important in computer vision.
In applications, this classification of minimal problems opens-up new paths for developing faster and more accurate algorithms for 3D reconstruction of scenes from images, building 3D maps, motion computation for autonomous driving, and in special effects for the movie industry.

The ICCV conference (IEEE/CVF International Conference on Computer Vision) is a premier international computer vision conference and one of the top three conferences in the field (together with CVPR and ECCV). It is listed among the top 75 most cited journals and conferences over all areas of science by Google Scholar. A total of 1075 papers were accepted in 2019 from 4303 submissions (25% acceptance rate). The best papers including the Best Student Paper Award were selected by the Award Committee as the top 4 papers from all submissions. The best papers were presented to all 7500 attendees at a prize session during the opening of ICCV 2019.



Matching points and lines between two photographs

Publication: DUFF, T. et al. PLMP – Point-Line Minimal Problems in Complete Multi-View Visibility. In: 2019 IEEE International Conference on Computer Vision (ICCV 2019). IEEE International Conference on Computer Vision 2019, Seoul, 2019-10-27/2019-11-02. Los Alamitos: IEEE Computer Society Press, 2019. p. 1675–1684. ISSN 1550-5499. ISBN 978-1-7281-4804-5.

Contact: Doc. Ing. Tomáš Pajdla, Ph.D.
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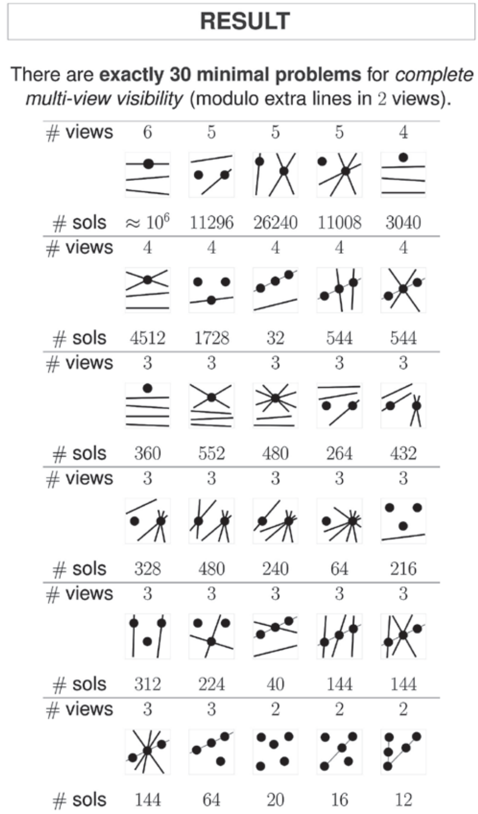

Complete classification table of all minimal point and line configurations

Automatic Reasoning and Formal Methods (AIF)

Efficient Neural and Gradient-Boosted Inference Guidance for E:

Three papers at three main (rank A) automated reasoning conferences in 2019 (CADE, ITP, TABLEAUX) about efficient learning-based modifications of one of today's main automated theorem provers called E. We have developed the first practically convincing application of gradient-boosted and neural clause guidance in state-of-the-art automated theorem provers based on the saturation paradigm. The strongest version of the system shows that several iterations of learning and proving over the large Mizar Mathematical Library improves the final performance of the prover by 70%. Additionally, semantic features based on tracking the completion of related proofs further improve the convergence. This is one of the largest improvements of existing proof automation reported in recent years. The resulting system is openly available to practitioners working on formal verification of mathematics and software and hardware designs.
The result is part of AI4REASON – Artificial Intelligence for Large-Scale Computer-Assisted Reasoning (ai4reason.org) Project.

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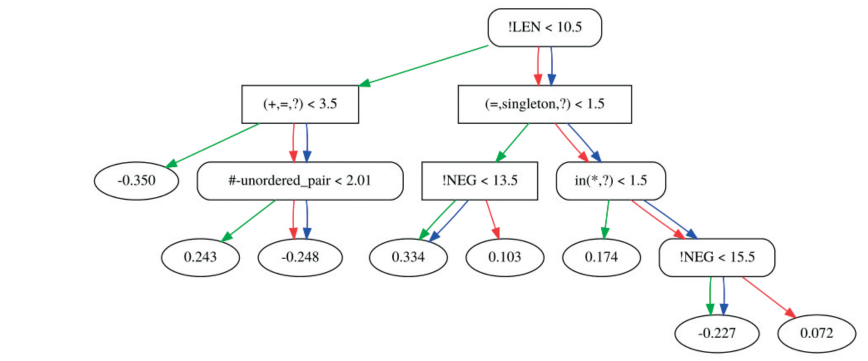

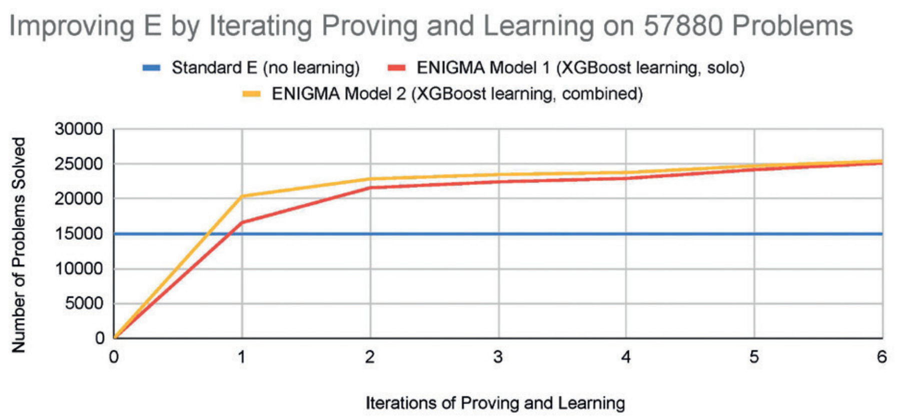

Intelligent Systems for Industry and Smart Distribution Network

Flexible Production Systems: Automated Generation of Operations Plans Based on ISA-95 and PDDL

Model-driven engineering (MDE) provides tools and methods for the manipulation of formal models. In this paper, we leverage MDE for the transformation of production system models into flat files that are understood by general purpose planning tools and that enable the computation of "plans", i.e., sequences of production steps that are required to reach certain production goals. These plans are then merged back into the production system model, thus enriching the formalized production system knowledge.

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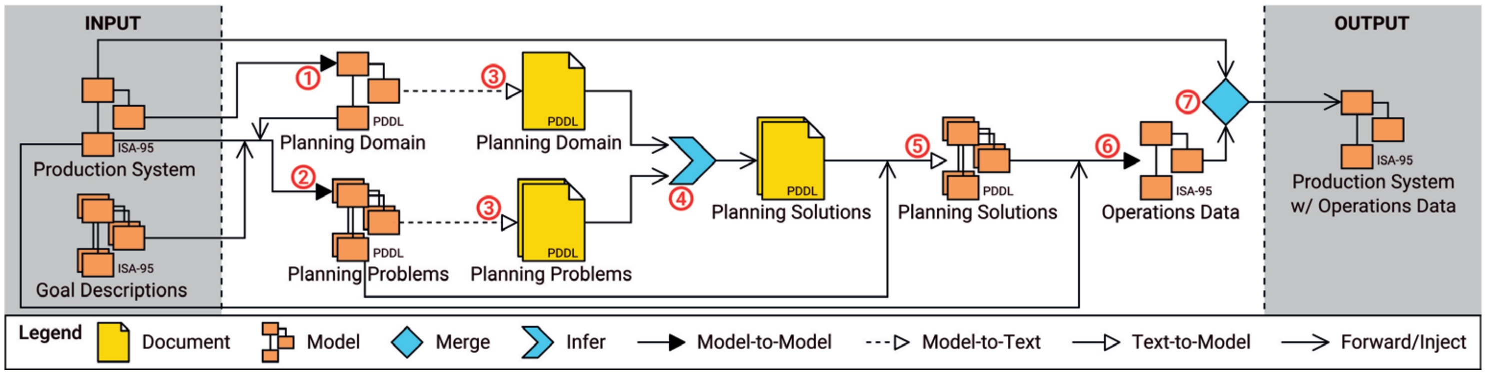

Machine Learning (MLE)

Plant Layout Optimization Using Evolutionary Algorithms

Facility layout problems (FLP), e.g., optimal placement of production units in a plant, become an inseparable part of manufacturing systems design and management. They are known to greatly impact the system performance. A good placement of facilities contributes to overall efficiency of operations and can significantly reduce total manufacturing costs. In this work, we propose a new formulation of the FLP where workstations are to be placed into a hall so that all constraints imposed on the generated floorplan are satisfied. Within the hall, obstacles and communications are defined. Each workstation has its working area and can also have multiple handling spaces. Input/output dependencies between workstations can be defined.

A new multi-objective evolutionary-based approach to solve this FLP is proposed. It uses an indirect representation of candidate solutions. So-called priority list encodes the order in which workstations will be added to the developed floorplan using placement heuristics designed for the problem. Typically, a set of various high-quality solutions is generated in a single run. Out of these, a user can choose the best one according to their expert knowledge and preferences.

Publication: KUBALÍK, J. et al. Plant Layout Optimization Using Evolutionary Algorithms. In: Mařík, V. et al., eds. Industrial Applications of Holonic and Multi-Agent Systems. 9th International Conference, HoloMAS 2019, Linz, 2019-08-26/2019-08-29. Wien: Springer, 2019. p. 173–188. LNAI. vol. 11710. ISSN 0302-9743. ISBN 978-3-030-27877-9.

Contact: Ing. Jiří Kubalík, Ph.D.
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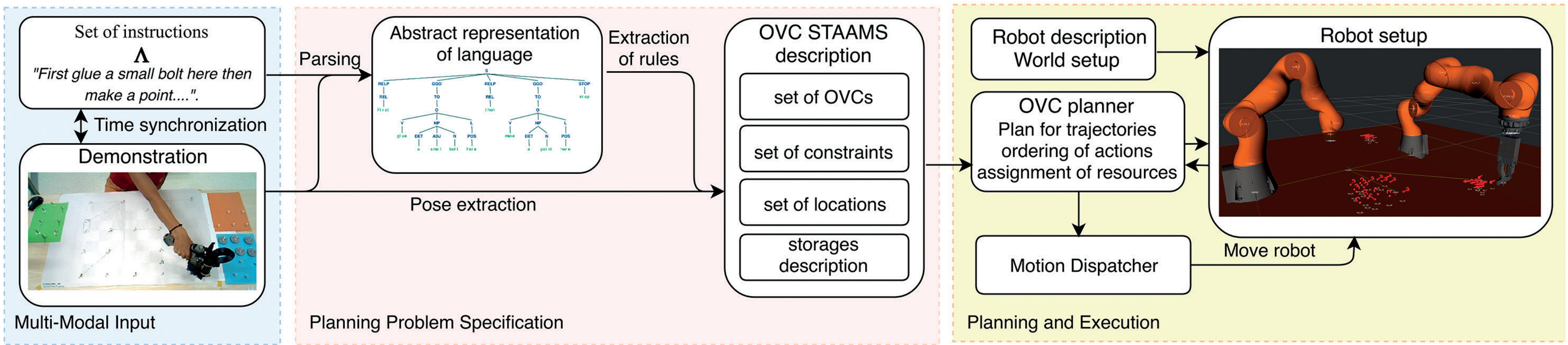
Specifying Dual-Arm Robot Planning Problems through Natural Language and Demonstration

Multi-modal robot programming with natural language and demonstration is a promising technique for efficient teaching of manipulation tasks in industrial environments. In particular, with modern dual-arm robots designed to quickly take over tasks at typical industrial workbenches, the direct teaching of task sequences hardly utilizes the robots' capabilities. We therefore propose a two-stage approach that combines natural language instructions and demonstration with simultaneous task allocation and motion scheduling based on constraint programming. Instead of providing a task description and demonstrations that are replayed to a large extent, the user describes tasks to be scheduled with all relevant constraints and demonstrates relevant locations relative to workpieces and other objects. With explicitly stated constraints on the partial ordering of tasks, the solver allocates the tasks to the robot arms and schedules them in time while avoiding self-collisions and reducing the makespan in our experiment by 33%. The linguistic concepts of naming and grouping enable systematic reuse of sub-task ensembles. The proposed approach is evaluated with four variants of a gluing use-case from furniture assembly in user studies with ten participants. In these user studies, we observed a speed-up for the task definition of more than six times compared to a textual specification of the planning problems using the Python-based planner API.

https://ieeexplore.ieee.org/mediastore_new/IEEE/content/media/7083369/8668830/8638957/stepa2-2898714-large.gif

Publication: J. K. Behrens, K. Stepanova, R. Lange and R. Skoviera, Specifying Dual-Arm Robot Planning Problems Through Natural Language and Demonstration, in IEEE Robotics and Automation Letters, vol. 4, no. 3, p. 2622–2629, July 2019, doi: 10.1109/LRA.2019.2898714.



Power Engineering

Secure Flex

Scheduled time plan: 2018–2024

Partners:

The project develops analytics, computation and optimization tools and is to bring specialized research reports. The goal is to bring innovative and systematic energy solution for utilization of power flexibility enabled by new technologies and market stakeholders' integration into Czech energy domain. The project timeline is aligned with the expected mid-term schedule of fourth energy package implementation (Winter package).
Six deep studies were carried and 3 software prototypes were developed till the end of 2019. New market model is under construction to help the government enable power flexibility utilization.

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Dflex

Scheduled time plan: 2019–2022

Partners:

Concepts and tools developed in SecureFlex project are to be piloted in DFLEX project. The options for incorporating decentralized generation, demand side management systems and distributed accumulation into the operation of the power system will be explored. Additionally, flexibility parameters and the possibility to aggregate flexibility providers under various operational conditions for TSO purposes will be assessed. Demand side flexibility potential will be determined using smart meter data. Co-operation between aggregator, supplier, DSO and TSO will be defined. The TSO's operational and business rules for demand side management and its integration into the Czech power system operation will reflect the real flexibility potential, general flexibility market entry requirements and the TSO and DSO needs in different scenarios. Appropriate mathematical methods will be selected and requirements on telco parameters will be articulated.

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Mafri

Scheduled time plan: 2018–2020

Partners:

The aim of the project is to design and validate the methodology of the reliability standard for CZ power system, which is intended to replace the current N-1 reliability approaches that are no longer able to describe uncertainty continuously growing in European energy systems. Specific objectives:

- Definition of new reliability characteristics of electric power systems focused on the national energy system of the CR in the context of a pan-European network.
- Validation of the proposed characteristics on the real scenarios of the future development of the pan-European energy system, (within Generation Adequacy framework).
- Design of the methodology to set reference (critical) values of reliability characteristics to reliably depict the risks of generation nonadequacy scenarios.

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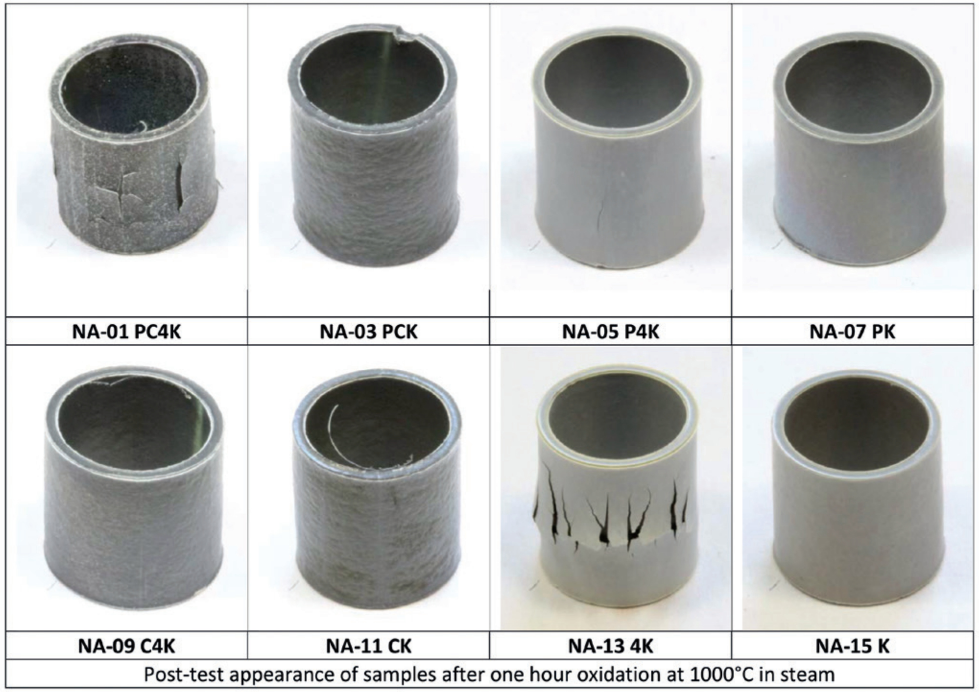
Alloy Protection Against High-temperature Oxidation

In this work, a new concept of zirconium alloy metal surface protection against degradation caused by high-temperature oxidation in water environment was presented. Zirconium alloys, generally used as fuel cladding in nuclear reactors, suffers from high temperature oxidation at elevated temperatures (above 800 °C) present during loss-of-coolant-accidents (LOCAs). A double-layered coating was prepared, consisting of an active and passive layer to protect Zr alloy surface against high-temperature oxidation. Double layer consists of 500 nm nanocrystalline diamond (NCD) as the bottom layer and 2 μm chromium-aluminium-silicon nitride (CrAlSiN) as the upper layer. We have shown that the NCD coating protects the Zr alloy surface against oxidation in an active way: carbon from NCD layer enters the Zr alloy surface and, by changing the physical and chemical properties of the Zr cladding tube surface, limits the Zr oxidation process. In contrast, the passive CrAlSiN coating prevents the Zr cladding tube surface from coming into physical contact with the hot steam. The advantages of the double layer were demonstrated, particularly in terms of accident-temperature oxidation kinetics: in the initial stage, CrAlSiN layer with low number of defects acts as an impermeable barrier. But after a longer time (more than 20 min) the protection by more cracked CrAlSiN decreases. At the same time, the carbon from NCD strongly penetrates the Zr cladding surface and worsen conditions for Zr oxidation. For the double-layer coating, the underlying NCD layer mitigates thermal expansion, reducing cracks and defects in upper layer CrAlSiN.



Post-test appearance of samples after one hour oxidation at 1000 °C, in steam

Publication: Kratochvílová, I.; Škarohlíd, J.; Škoda, R. et al. Zr alloy protection against high-temperature oxidation: Coating by a double-layered structure with active and passive functional properties. Corrosion Science 163, 15–25 (2020).

Contact: Ing. Jan Škarohlíd, Ph.D. (jan.skarohlid@cvut.cz)

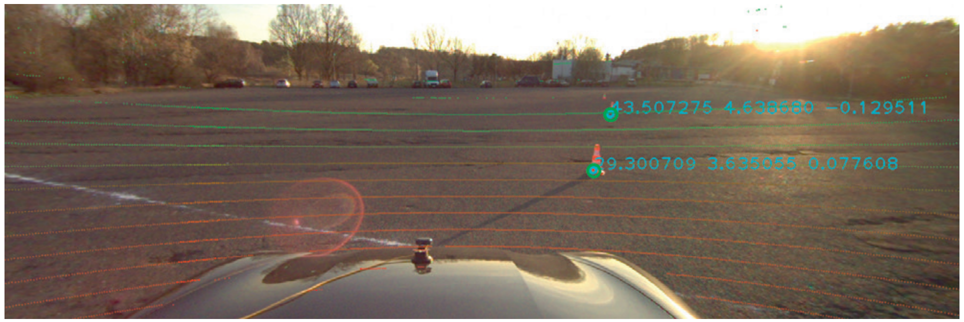
Department of Industrial informatics

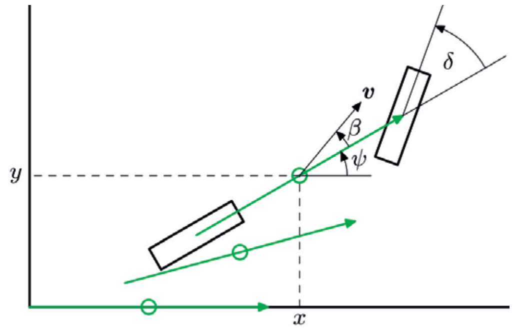
Automated Car – Design, Implementation and Experiment

Performed in cooperation with: Porsche Engineering Services Prague

This work presents the algorithms and system architecture of an automated car aimed at performing a slalom use-case. Besides the sensors integrated into the Panamera car, the system is equipped with additional Differential GPS, mono camera, and 16-layers Lidar. The algorithms run on NVIDIA TX2, they are integrated using ROS middleware and interfaced with the car ECUs via FlexRay. HOG descriptor is used to create a feature vector, and SVM is used for cones classification. Data from the camera, Lidar, and DGPS are used to localize the cones and generate the map. Kalman filter derives an accurate car position and heading from DGPS and the car odometry. The bicycle model is used to formulate a nonlinear optimization problem with quadratic criterion aiming at optimal trajectory planning while respecting the car kinematics. Finally, the trajectory following and lateral & longitudinal controllers are driving the car in the slalom. Substantial work was devoted to the experiments with a real vehicle and the fine-tuning of the system parameters. Validation of the system reveals exciting observations related to the precision, frequency, and sensitivity of the system components.

Contact: Prof. Dr. Ing. Zdeněk Hanzálek (zdenek.hanzalek@cvut.cz)





Optimizing energy consumption of robotic cells

Nowadays, robotic cells are mostly designed with the main goal to meet the desired production rate without any consideration of the energy efficiency, therefore, it is often possible to achieve significant energy savings without downsizing the production. Our group developed a novel parallel Branch & Bound algorithm to optimize the energy consumption of robotic cells without deterioration in throughput. The energy saving is achieved by changing robot speeds and positions, applying robot power-saving modes (brakes, bus power off), and selecting an order of operations. The core part of the algorithm is our tight lower bound, based on convex envelopes. Besides the bounding, a Deep Jumping approach is introduced to guide the search to the promising parts of the Branch & Bound tree, and the parallelization accelerates the exploration of the tree.

The experiments on a real robotic cell with six robots revealed that the energy consumption of robot drives can be reduced by 20%.
Libor Bukata, a member of the group who participated on this project, obtained Werner von Siemens award in category Industry 4.0 for his work.

Publication: L. BUKATA, P. ŠŮCHA and Z. HANZÁLEK. Optimizing Energy Consumption of Robotic Cells by a Branch & Bound Algorithm. Computers & Operations Research. 2019, 102 52–66. ISSN 0305-0548.

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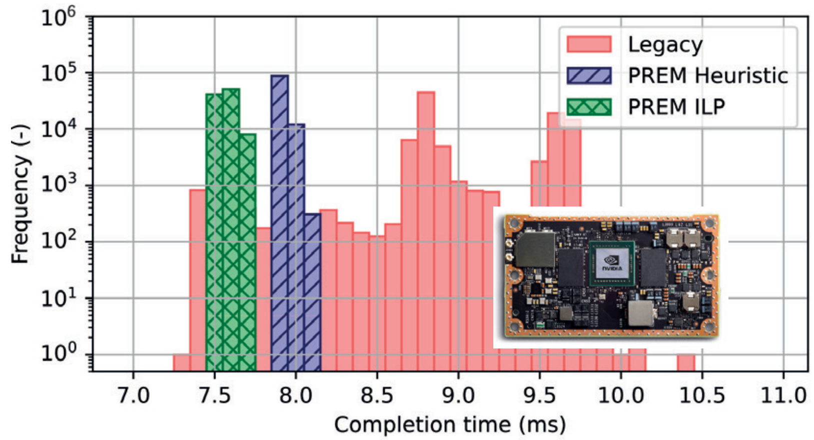
Time-predictability of high-performance multi-core systems on chip

Many cyber-physical applications, such as autonomous driving, require both high performance and predictable timing. Currently available Multi-Core Systems on Chips (MPSoC) can provide high performance, but as cores in these systems share the main memory, they are susceptible to interference from each other, which is a problem for timing predictability. We achieve predictability on multi-cores by employing the predictable execution model (PREM).

We present a toolchain consisting of a PREM scheduling tool and a compiler. Our compiler transforms application code into PREM-compliant binaries, and the scheduling tool schedules access to the shared main memory. The scheduling tool uses a state-of-the-art heuristic algorithm and can schedule industrial-size instances. For smaller instances, we compare the results of the scheduler with optimal solutions found by solving an Integer Linear Programming model.
We evaluate our toolchain on Advanced Driver Assistance System (ADAS) application workloads running on an NVIDIA Tegra X1 embedded system-on-chip (SoC). The results show that our approach maintains similar average performance to the original (unmodified) program code and execution while reducing the variance of completion times by a factor of 9 with the identified optimal solutions and by a factor of 5 with schedules generated by our heuristic scheduler.



Performed in collaboration with: ETH Zurich (CH)

Project: Hercules – High-Performance Real-time Architectures for Low-Power Embedded Systems, https://hercules2020.eu/

Publication: MATĚJKA, J. et al. Combining PREM Compilation and Static Scheduling for High-Performance and Predictable MPSoC Execution. Parallel Computing. 2019, 85 27–44. ISSN 0167-8191

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Scheduling Jobs with Stochastic Processing Time on Parallel Identical Machines

Many real-world scheduling problems are characterized by uncertain parameters. In this paper, we study a classical parallel machine scheduling problem where the processing time of jobs is given by a normal distribution. The objective is to maximize the probability that jobs are completed before a common due date. This study focuses on the computational aspect of this problem, and it proposes a Branch-and-Price approach for solving it. Furthermore, we have proved NP-hardness of the inner Pricing problem and we proposed an efficient lower bound heuristics. The advantage of our method is that it scales very well with the increasing number of machines and is easy to implement. The experimental results show that our method outperforms the existing approaches.

Publication: ŠTEC, R. et al. Scheduling Jobs with Stochastic Processing Time on Parallel Identical Machines. In: Proceedings of the Twenty-Eighth International Joint Conference on Artificial Intelligence. IJCAI 2019: 28th International Joint Conference on Artificial Intelligence, Macau, 2019-08-10/2019-08-16. International Joint Conferences on Artificial Intelligence Organ-ization, 2019. s. 5628–5634. ISSN 1045-0823. ISBN 978-0-9992411-4-1.

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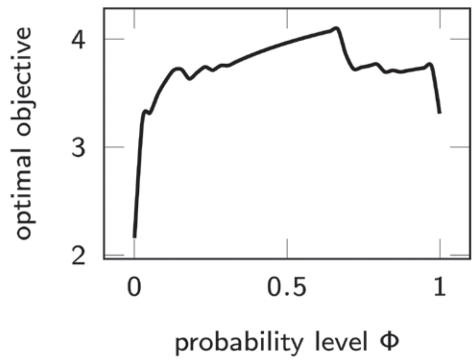
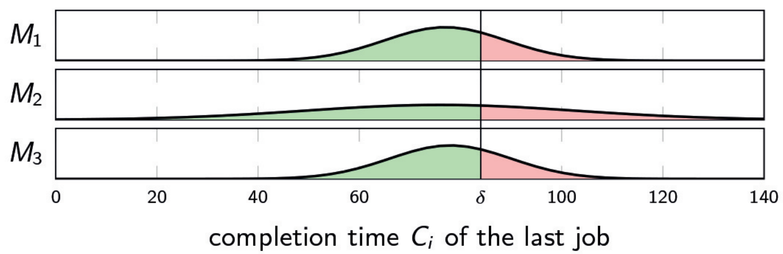
$$\boldsymbol{p}^\star = \arg \max_{\boldsymbol{p}\in\{0,1\}^n} \log \Phi \left(\frac{\delta - \boldsymbol{\mu}^T \boldsymbol{p}}{\sqrt{\boldsymbol{\sigma}^T \boldsymbol{p}}} \right) + \boldsymbol{\psi}^T \boldsymbol{p}$$





Department of Biomedical Engineering and Assistive Technology (BEAT)

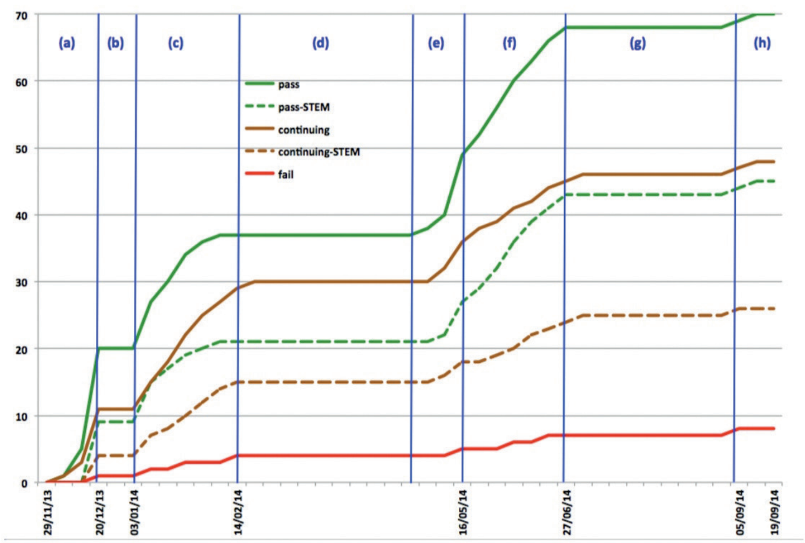


Figure 1. Average number of credits earned by different groups in time

Average number of ECTS credits earned before and during the winter exam period

Research in Learning Analytics at Faculty of Mechanical Engineering

According to the report of the European Commission, in EU countries up to 54% of students fail to complete their degrees. In distance education, the failure rate can be up to 78%. Though Higher Educational institutions have different progression rules, the general approach to improving the student success is the same: to identify i.e. predict students at risk of failing as early as possible so that the tutor interventions would be efficient and meaningful. The key issue is to have enough data and good algorithms for the prediction and well-elaborated intervention strategy.

Since 2012 the team led by Zdeněk Zdráhal at the Open University (UK), investigated in the project called OUAnalyse how to use student interactions with educational resources and their demographic data to identify students at risk and inform their tutors weekly. The Open University is providing distance education and the students interact with the study resources mainly over the internet. Their project proved to be very successful, see e.g. the report of the Higher Education Commission for the British Parliament from 2016 (https://www.policyconnect.org.uk/research/bricks-clicks).

In 2019, the OUAnalyse project was selected as one of 4 finalists for the British THE Awards 2019 in the category "Technology or Digital Innovation of the Year" (https://www.the-awards.co.uk/2019/en/page / shortlist).

In 2015, CIIRC and the Faculty of Mechanical Engineering (FME), Czech Technical University in Prague decided to join forces and apply the Learning Analytics approach in the face-to-face education to improve the retention at FME. The CIIRC team led by Zdenek Zdrahal developed a predictive model StudentAnalyse that was utilized by CTU staff to monitor FME first-year students and organize interventions. The number of ECTS credits earned by students during the academic year proved to offer crucial input for predictions. At FME there are the following critical time points:

D1 – the start of the winter term exam period,
D2 – end of the winter exam period, and
D3 – the end of the summer exam period.

The progression rules are: Students with fewer than 15 credits at D1 fail, students with fewer than 30 credits at D3 fail, 60 or more credits at D3 mean pass – the student completed the academic year. Students with fewer than 60 credits at D3 may continue but must earn the missing credits later.

From historical data, the predictive model has been built to allow predicting whether the students will fall into the fail/continue/pass group. As shown in the picture, reliable predictions can be made even before the start of the winter exam period using the credits earned in the last weeks of the winter term.

Thanks to the systematic use of this model, the FME CTU has achieved a significant reduction in the students' drop-out. The financial benefit for FME was CZK 27.9 million received over the last 4 years. This is calculated by multiplying the number of saved students by the contribution provided by the government per student. The number of saved students is calculated by comparing the percentage of failed students in a given year with the best failure rate before the use of StudentAnalyse (academic year 2013/14 with a drop-out rate of 33.2%). The significant share of this positive outcome is due to the staff of the CTU FME who developed and applied successful intervention methods that use the predictions.

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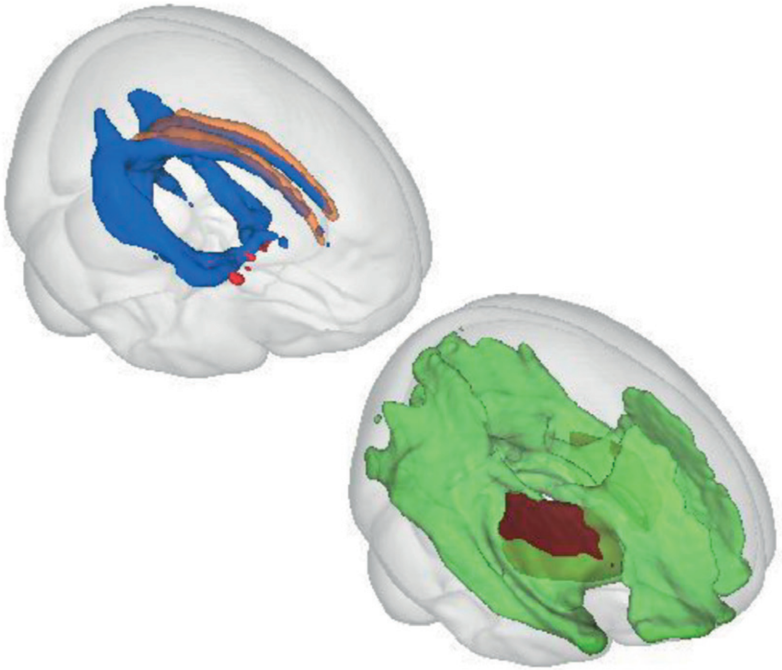
Cholinergic white matter pathways make a stronger contribution to attention and memory in normal aging than cerebrovascular health and nucleus basalis of Meynert



Cholinergic white matter medial (blue) and lateral (green) pathways in healthy brain

In 2019, our group strived for new approaches to gauge the health of the human cholinergic system (brain circuitry heavily affected in Alzheimer's disease) using state-of-the-art machine learning techniques. Our training data consisted of diffusion tensor images from 262 healthy volunteers between 39 to 77 years of age, and their full-range demographical and psychological profile. First, we designed a model of the axonal projections that spring forth from the basal forebrain using enhanced fibre-tracking algorithms. Most importantly, we employed advanced techniques for computing conditional variable importance based on conditional inference trees to prove a crucial link between these tracked pathlines and cognitive functioning of the brain. Even though a high degree of multicollinearity is usually present in this type of data, this importance analysis was able to decipher the relationship between variables in question and show that poorer performance on memory and attention was specifically connected to erosion of the cholinergic system, and not to other brain systems or vascular pathology. The results and conclusions of our study were recently published in NeuroImage (Nemy et al., 2020).

Publication: Nemy M., Cedres N., Grothe M. J., Muehlboeck J. S., Lindberg O., Nedelska Z., Stepankova O., Vyslouzilova L., Eriksdotter M., Barroso J., Teipel S., Westman E., Ferreira D. Cholinergic white matter pathways make a stronger contribution to attention and memory in normal aging than cerebrovascular health and nucleus basalis of Meynert. Neuroimage. 2020 May 1;211:116607. Epub 2020 Feb 6 PubMed.

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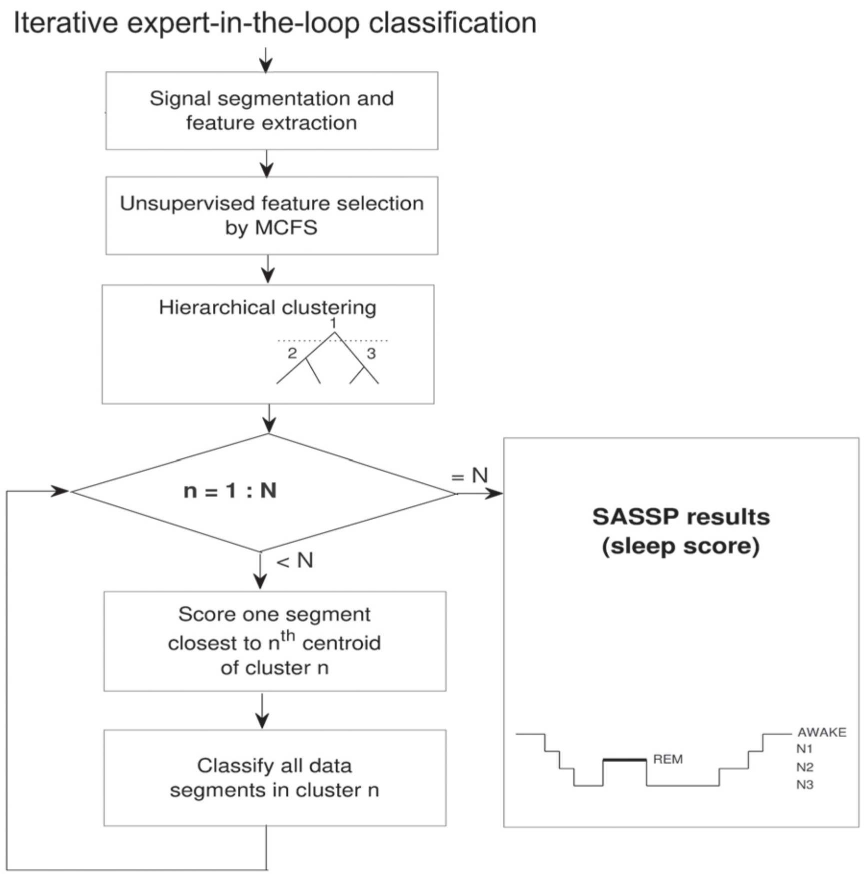
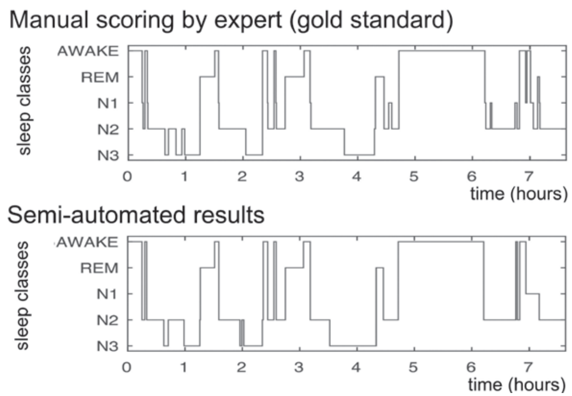
Department of Cognitive Systems and Neurosciences Department (COGSYS)

Iterative expert-in-the-loop classification of sleep PSG recordings using a hierarchical clustering



Approach used for semi-automated sleep scoring procedure (SASSP)

The classification of sleep signals is a subjective and time consuming task. A large number of automatic classifiers have been published in the past decade but a sleep community has no strong confidence to use them in clinical practice and still remains using a standard manual scoring.
We have developed a semi-supervised data--driven approach for objective and efficient evaluation of polysomnographic (PSG) data. The proposed algorithm finds a representative set of signal segments that are subsequently scored by a sleep neurologist. The remaining part of the recording is then automatically classified using these templates.



Example of classification results in graphical form for one PSG recording

We show a faster and objective evaluation of PSG data compared to the manual scoring that is over-performing automated classifiers. This method allows the evaluation of PSG recordings in more general terms and across different recording devices and standards. The proposed solution is not based on a single-purpose rules or heuristics and training model is not trained on other patient's sleep recordings. The method is applicable to wide range of similar tasks and various types of physiological signals.

Publication: GERLA, V. et al. Iterative expert-in--the-loop classification of sleep PSG recordings using a hierarchical clustering. Journal of Neuroscience Methods. 2019, 317 61–70. ISSN 0165-0270.

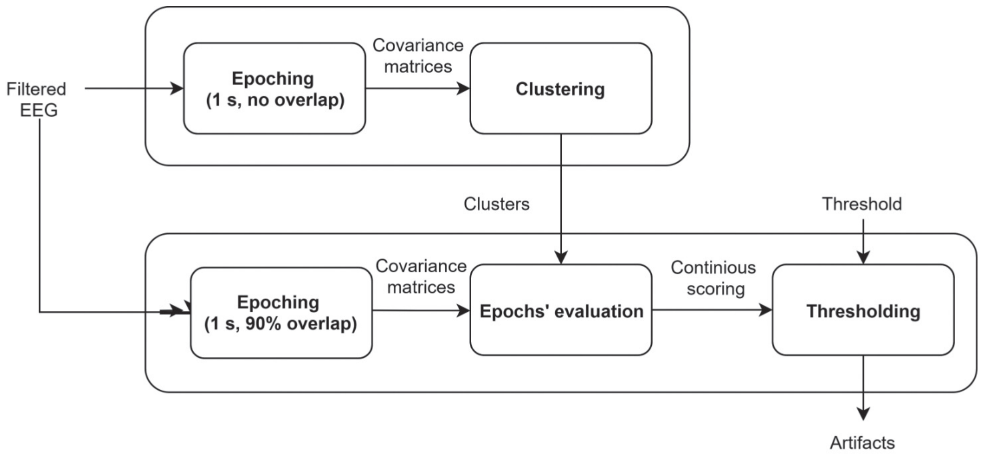
Contact: Doc. Ing. Lenka Lhotská, CSc. (lenka.lhotska@cvut.cz), Head of Department of Cognitive Systems and Neurosciences

An Unsupervised Multichannel Artifact Detection Method for Sleep EEG Based on Riemannian Geometry

In biomedical signal processing, we often face the problem of artifacts that distort the original signals. This concerns also sleep recordings, such as EEG. Artifacts may severely affect or even make impossible visual inspection, as well as automatic processing. Many proposed methods concentrate on certain artifact types. Therefore, artifact-free data are often obtained after sequential application of different methods. Moreover, single-channel approaches must be applied to all channels alternately. The aim of this study is to develop a multichannel artifact detection method for multichannel sleep EEG capable of rejecting different artifact types at once. The inspiration for the study is gained from recent advances in the field of Riemannian geometry. The method we propose is tested on real datasets. The performance of the proposed method is measured by comparing detection results with the expert labeling as a reference and evaluated against a simpler method based on Riemannian geometry that has previously been proposed, as well as against the state-of-the-art method FASTER. The obtained results prove the effectiveness of the proposed method.
The presented method forms clusters of artifact-free EEG data considering their spatial patterns. Application of the proposed method to sleep recordings brings significant benefits. The method is scalable, fully unsupervised and adaptive, independent of artifact types, and the outcome is easily interpreted. In comparison to the Riemannian potato artifact detector, it demonstrates better performance on complex sleep data in terms of agreement with human scoring and reduces the number of events incorrectly identified as artifacts

Publication: SAIFUTDINOVA, E. et al. An Unsupervised Multichannel Artifact Detection Method for Sleep EEG Based on Riemannian Geometry. Sensors. 2019, 19(3), ISSN 1424-8220.

Contact: Doc. Ing. Lenka Lhotská, CSc., Head of Department of Cognitive Systems and Neurosciences (lenka.lhotska@cvut.cz)



The method overview

Semi-Automated Sleep EEG Scoring with Active Learning and HMM-Based Deletion of Ambiguous Instances

Sleep scoring is an important tool for physicians. Assigning of segments of long biomedical signal into sleep stages is, however, a very time consuming, tedious and expensive task which is performed by an expert. Automatic sleep scoring is not well accepted in clinical practice because of low interactivity and unacceptable error, which is often caused by inter-patient variability. This is solved by proposing a semi-automatic approach, where parts of the signal are selected for manual labeling by active learning and the resulting classifier is used for automatic labeling of the remaining signal. The active learning is disturbed by noisy ambiguous data instances caused by continuous character of the sleep stage transitions and a removal of such transitional instances from the training set prior to active learning can improve the efficiency of the method. This paper proposes to use the hidden Markov model for the detection of the transitional instances. It shows experimentally on 35 sleep EEG recordings that such a method significantly improves the semi-automatic method. A complete methodology for semi-automatic sleep scoring is proposed and evaluated, which can be better accepted as a decision support tool for sleep scoring experts.

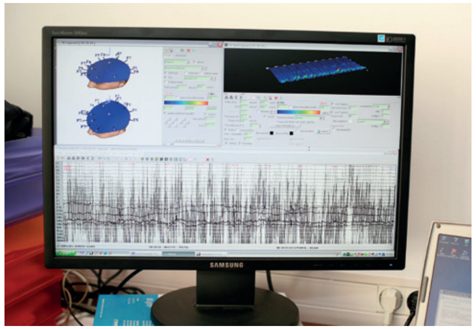
The paper confirms that the active learning outperforms the random sampling in semi-automatic EEG-based sleep scoring in terms of mean class error. Its main conclusion is, however, a solution of problem of detection of potentially ambiguous data instances that should be not queried for labeling. It was shown that the method based on most probable state sequence of HMM can find data instances whose deletion from training set can statistically significantly improve both the random sampling and the active learning procedure.

An interesting finding is that the HMM-based method supports the active learning better than label-based method. It means that even if all labels would be theoretically known (which does not make a sense), the deletion of label transitions improves the semi-automatic scoring less than the deletion of HMM state transitions. This can be caused by the fact that the transitions provided by human expert do not correspond to real transitions that exist in EEG signal. Such transitions are better detected by HMM method.

Although we demonstrated the use of our method in the sleep staging application, it can be relevant to many other fields. First, if a time series is classified and classes change continuously in transitional manner, the problem with ambiguity can be avoided by the proposed detection and removal of transitions. Second, if it is needed to minimize an interaction with human oracle during training data acquisition, active learning can help to choose data to be labeled efficiently. The combination of those two properties is common in ambient intelligence applications, where adaptive models of time series coming from sensors are often required that avoid an excessive disturbance of human users.

Publication: MACAŠ, M. et al. Semi-Automated Sleep EEG Scoring with Active Learning and HMM-Based Deletion of Ambiguous Instances. In: Proceedings of 13th International Conference on Ubiquitous Computing and Ambient

Contact: Doc. Ing. Lenka Lhotská, CSc., Head of Department of Cognitive Systems and Neurosciences (lenka.lhotska@cvut.cz)



Department of Industrial Production and Automation (IPA)

Development of new control system for machine tools

Control system is a true brain of the machine tool. The control system involves an interpolator. The interpolator is responsible for planning of the machine movement according to geometrical requests of CNC code. Quality of interpolation significantly influences quality and productivity of the machining process. A new type of interpolator for the Czech CNC control system for production machines M E F I has been developed. The new interpolator uses advanced trajectory planning techniques where the NC program is compressed and interpolated with higher order curves to achieve higher production quality and productivity. The velocity profile on a given path is designed so that the NC program is processed as quickly as possible, but with respect to speed, acceleration and jerk limitation. The interpolator core has been successfully compared to state-of-the-art interpolators. Moreover, it is allowed manual modification of machine movement in real-time, e.g. override change.

In addition, tools for NC program simulation using the developed virtual core of the system including the influence of control and dynamic parameters of the mechanical structure were created. This enables accurate verification and optimization of the NC program before running on a real machine. This solution gives an advantage for machine end-user in improved workpiece quality and high productivity of machining.

The research was performed under collaboration of CTU in Prague (Faculty of Mechanical Engineering and CIIRC) and producer of control systems M E F I, s.r.o. The project has received financial support from the Ministry of Industry and Trade of the Czech Republic through project number FV10646.

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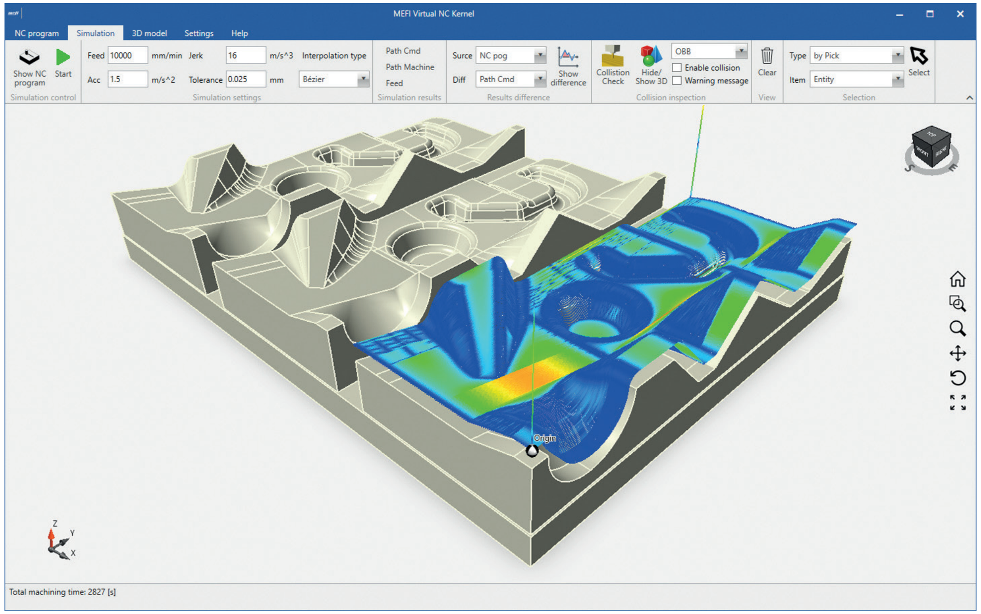
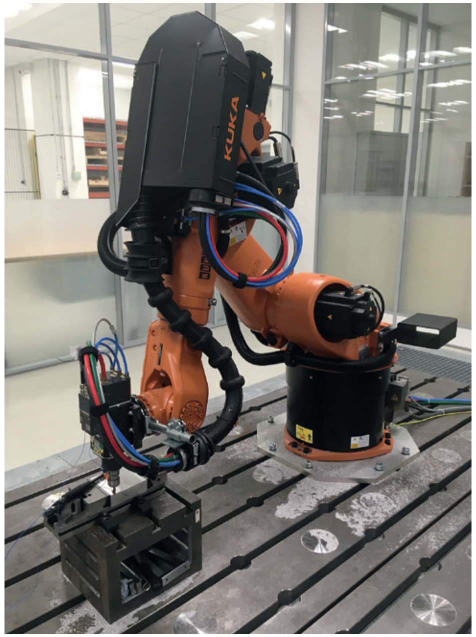


Software for virtual simulation of machining with CNC MEFI
Test machine AXA VCC1000 in IPA CIIRC laboratory equipped with the developed control system of the MEFI company

Robotic machining head for machine tools

Large machine tools such as horizontal boring machines or portal milling machines use spindle heads for increasing their kinematic possibilities as well as enhancing the available spindle parameters. The joint CTU team collaborated on a visionary project – using an industrial robot as a multi-axis spindle head. The overall process productivity can be improved with combining the machine tool large workspace and versatility of the industrial robot.
The development was focused to build a replaceable machining head of a horizontal boring machine consisting of an industrial robot with a working spindle. Compared with standard machining heads, the proposed solution enables a low cutting force machining applications even in complicated places without the need to manipulate the workpiece. The main activities were focused on complex head development and interaction with the machine control system.

Robot stiffness measurement within its working space



Machining tests with industrial robot

The robot is controlled directly from the machine tool CNC control system together with the machine axes. It also includes the development of a software module for a standard CAM for trajectory planning with respect to the stiffness of the robot, which varies significantly depending on the kinematic configuration. The advantage of the proposed solution is its complexity, where the robot can be used for machining applications and after putting off the head, e.g. for standard tool change.
The research has been conducted under collaboration of CTU in Prague (Faculty of Mechanical Engineering and CIIRC) and company TRATEC – CS, s. r. o. with the financial support of TAČR – the Technology Agency of the Czech Republic through the project TH02010942.

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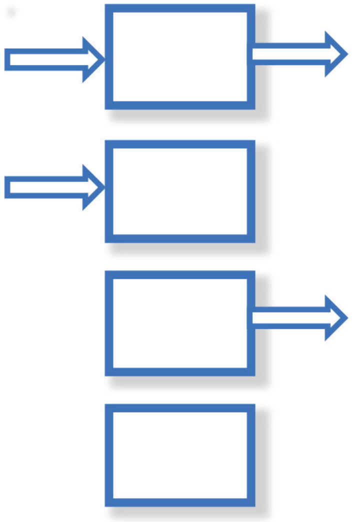
Scientific Management of Platforms Department (PLAT)



Stability-Preserving Morse Normal Form

The purpose of control is to alter a given system so as to achieve design specifications. It is therefore crucial to know which system properties can and which cannot be changed in the process of control design.
Consider a linear system giving rise to a proper rational transfer matrix. The largest group of transformations of interest in linear control theory consists of state feedback, output injection, and coordinate transformations in the input, output and state spaces.
In 1973, A.S. Morse (Yale University) discovered the canonical form and the complete invariant of linear systems with respect to this transformation group. The recipe to obtain the result is to apply the transformations in such a manner as to destroy system properties as much as possible; then what remains is the invariant. Because state feedback can destroy observability, and output injection can destroy controllability of the system, the invariant can be determined by making the system maximally unobservable by state feedback and, at the same time, maximally uncontrollable by output injection.

Stability of the system, however, is not invariant under the action of the transformation group. In problems where stability matters, one needs a more specific result. With stability being on the list of design specifications, it is convenient to stabilize the system first and then transform it while preserving stability. Thus, the result one needs is a stability-preserving Morse normal form for stable linear systems.
This new form applies to stable linear systems, whose transfer matrix is proper and stable rational. The form is canonical with respect to the subgroup of stability-preserving state feedback, stability-preserving output injection, and coordinate transformations. The canonical system representation consists of four decoupled subsystems. The first subsystem is invertible, controllable and observable, and its transfer matrix is the system transfer matrix in Smith normal form over the ring of proper and stable rational functions. The second one is controllable and has no output, whereas the third one is observable and has no input. The fourth subsystem has neither input nor output.

The canonical subsystems show the complete invariant, which consists of three lists of integers and two lists of polynomials. The integers are the infinite zero orders of the first subsystem, the controllability indices of the second subsystem, and the observability indices of the third subsystem. The two lists of polynomials are the elementary divisors associated with unstable and with stable invariant zeros of the system. The former determines the finite zeros of the first subsystem, whereas the latter are the eigenvalues of the fourth subsystem.
The discovery of the canonical form and the complete invariant of a stable linear system with respect to the subgroup of stability-preserving operations is a fundamental result of broad interest in control theory. The result seems to be indispensable in the solution of the decoupling problem with stability for linear systems, which is a long-standing open problem of control theory.

Publication: V. Kučera, "Stability-preserving Morse normal form," IEEE Transactions on Automatic Control (Early Access).
DOI: 10.1109/TAC.2020.2967465.

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CCF

The Centre of the City of the Future

The Centre of City the Future (CCF) was inaugurated on May 23, 2018. In 2019, the CCF had 45 partners, including commercial companies, municipal representatives and other experts. The Central Bohemian Region became a strategic municipal partner.
CCF is a professional and independent platform connecting the academic sphere, the commercial sector, and municipal representatives. Its objective is to seek the optimal development of urban structures of all types and sizes. It is a partner of cities, municipalities, regions and other entities in making strategic decisions about the further development of their location. Along with CCF partners and external experts from all areas of technical and human interest, it provides expert information on products, services, business models and other innovations with the innovative potential to enable stakeholders to increase their competitiveness as well as to enhance the urban resilience of the structures concerned. The result should be a more attractive space for its users to share it efficiently with other users. At the same time, it can assess the optimal implementation of new technologies in existing and planned infrastructure and development.
CCF is conceived as an experimental and virtual testbed of the city, the region, the landscape and the technical infrastructure deployed in it, creating a complex and interconnected system.
The goal of the CCF platform is to explore all phenomena and processes in these systems and subsystems. In addition to regular meetings of all CCF partners, partners collaborate on several projects to simulate the potential development of "smart" streets and squares, and a small community or city district and the region to implement their products. These simulations will be mainly performed using augmented and virtual reality.
CCF organizes regular monthly meetings of CCF partners where joint projects are solved and other planned activities are discussed.
In April 2019 CCF and the Central Bohemian Region organized the first year of the Future City made by IoT Conference at CIIRC CTU premises. The conference was accompanied by an exhibition of products of CCF partners. The aim of the conference was to create, within the CCF, a permanent platform for discussing the development of different urban structures and the whole of society in the near and distant future, and to specify the changes caused, inter alia, by technologies with different levels of digital intelligence.

Another important CCF event was the Open Day held in October 2019, where CCF partners exhibited their technology and smart solutions. In 2020, we would like to concentrate, together with all CCF partners, on complementing our showroom in CIIRC with various sensors. We want to interconnect the acquired data on various data platforms and use it for a smart city/street work model offering CCF partner technologies.
We started to prepare the second year of the international conference Future City 2020, which will take place on September 8th and 9th, 2020 in the Žofín Palace, including an exhibition and other accompanying events.
CCF is aiming to become a recognizable entity not only in the Czech Republic, but also beyond its borders, and link up with similar platforms around the world.

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NATIONAL CENTRE FOR INDUSTRY 4.0

National Centre for Industry 4.0

Inspire & Create an ecosystem for Industry 4.0 in the Czech Republic

National Centre for Industry 4.0 (NCI4.0) is an open platform joining innovation leaders from universities, corporations and different industry organizations, including start-ups and SMEs in order to promote and support the advance of Industry 4.0. The aim of NCI4.0 is to create and inspire an ecosystem for Industry 4.0 in the Czech Republic and cooperation with similar centres/organizations abroad. NCI4.0 wishes to be the main author as well as a carrier of technological visions and industry digitization principles in the Czech Republic. It wishes to encourage cooperation among universities and shared use of their research capacities with an emphasis on industry implementation.

NCI4.0 builds upon critical infrastructure of Testbed for Industry 4.0, which is located at CIIRC CTU and though RICAIP Centre is connected to Testbeds in Brno and Saarbruecken. It is not only a showcase of the latest technology but also a digital playground for projects realised in cooperation with our industrial partners. The potential of Testbed in this respect will be utilised in the future also as a part of Digital Innovation Hub where especially SMEs and other companies could make use of the state-of-the-art technological facility, expert knowledge of network of academic and industrial partners supported by the European Comission Network.

During the year 2019 NCI 4.0 acquired more than 50 partners that help us make our vision live and without whom NCI 4.0 would not be able to reach its ambitious goals. We carried our numerous conferences and events for general or professional public and school youth including Open House Days, Expert Workshops and Business Breakfasts. We also publish Bulletin of Industry 4.0 which is a platform for information and sharing of knowledge, good practice, use cases and technological advances across the whole ecosystem.

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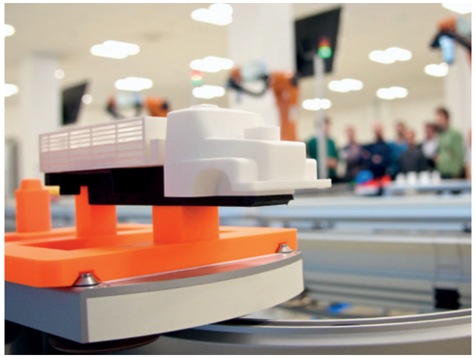
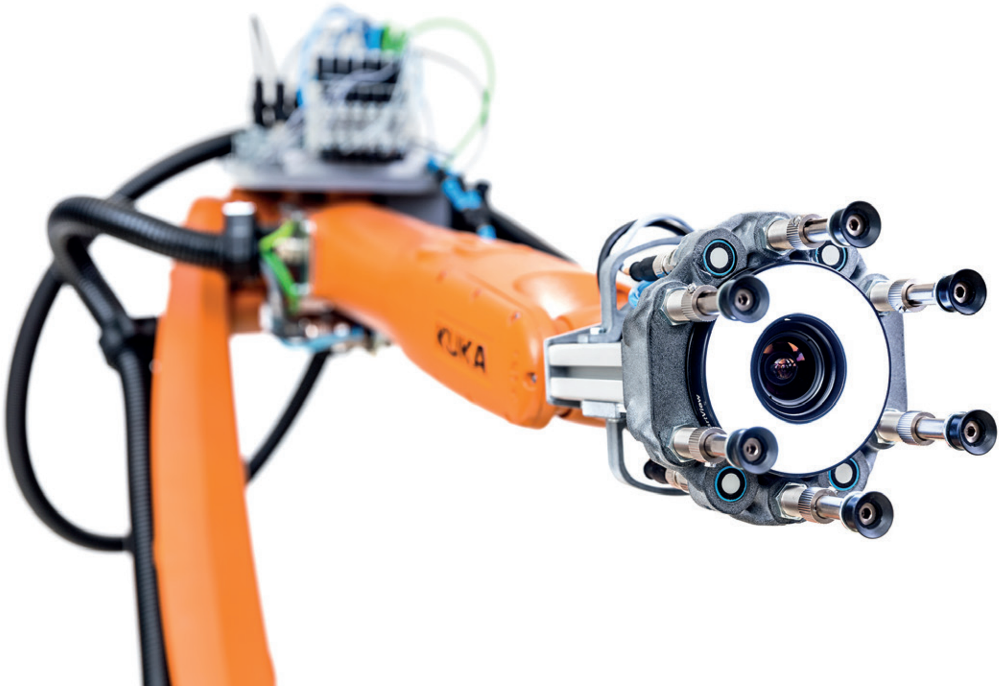


NCI4.0 Testbed

Testbed for Industry 4.0

Testbed for Industry 4.0 is a research and experimental laboratory aimed at transferring the research results of CIIRC to an industry-like environment with the aim of developing and promoting the principles of Industry 4.0. Testbed is based on a flexible production line and additional production machines, which resemble the scenarios existing in industrial production lines and processes. It is possible to test and verify the compatibility, functionality and effectiveness of new solutions for smart factories. Various technologies are utilized here, such as additive manufacturing, machine tooling, robotic manipulation, vision systems, collaborative and mobile robots, intelligent conveyor systems and others.



Testbed has been inspired by the modern laboratories in our partners' facilities, especially at leading research institutes including DFKI and ZeMA in Saarbrücken, Germany, who are our research partners in several projects such as RICAIP or Cluster 4.0. The partnership has helped us to build Testbed as a futureproof concept for advanced and distributed manufacturing.

Currently, Testbed is focused on building infrastructure for flexible manufacturing together with the concept of digital twins, which allows utilizing the same production resources to execute various operations, which are planned and scheduled as needed, and test the production scenarios before they are actually implemented in production.
We aim at developing integration platform to design and optimize production lines.
The platform is going to be focused on flexible manufacturing and incorporating various phases of the product life cycle.
Since its establishment in 2017, Testbed has proved to be very well accepted by industrial companies, which get inspired by the integration of individual tools and resources of the value chain to form digitalized and interconnected production. This has resulted in starting several research projects such as Cluster 4.0: Methodology of System Integration and RICAIP: Research and Innovation Centre on Advanced Industrial Production, as well as starting industrial cooperation with companies such as Siemens, Skoda Auto, LEGO, Sidat, and others. Several other research projects have utilized the Testbed infrastructure to build demonstrators of their research results such as DAMiAS: Data-driven Asset Management in the Automobile Industry and DIGICOR: Decentralized Agile Coordination Across Supply Chains.

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RICAIP

RICAIP – Research and Innovation Centre on Advanced Industrial Production

RICAIP is a newly established international distributed research Centre of Excellence (CoE) with maximum degree of autonomy, hosted as a new unit at CIIRC CTU with the direct participation of its four founding partners – Czech and German research institutions: **CIIRC CTU, CEITEC BUT, DFKI, and ZeMA**. RICAIP focuses on research areas related to Industry 4.0, notably to multi-site advanced industrial production and production development. RICAIP will conduct research in the field of artificial intelligence, machine learning, and robotics for advanced industry, evolving new manufacturing concepts for geographically distributed production and production as a service. The centre will connect testbeds in Prague, Brno, and Saarbrücken and will enable rapid adaptation of the production according to the customer's current needs or available means of production. Already in 2016, the grounds of the Czech-German strategic research partnership were set. In 2019, RICAIP achieved an exceptional success as it was evaluated as the 2nd best project proposal in the H2020 Teaming Phase 2 Call competition. The European Commission and complementary to this, the Czech Ministry of Education, Youth and Sports decided to support the RICAIP CoE with a grant in the total amount of EUR 48,25 mil. for the period 09/2019 – 12/2026. CIIRC CTU as the coordinator shall draw nearly EUR 27 M. Currently, RICAIP is one of the largest running EU projects in the field of AI and Industry 4.0. RICAIP aims to build a unique distributed research and experimental workplace, the **RICAIP Industrial Testbed Core**, the first of its kind in Europe to develop EU R&D Infrastructure for advanced industrial production. RICAIP will also provide support for SMEs, facilitating technology and knowledge transfer from academia to industry.

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OFFICES AND HUBS

CLAIRE Office Prague

Confederation of Laboratories for Artificial Intelligence Research in Europe – CLAIRE Office Prague was established in February 2018. The Symbolic opening was on the 26th September 2019. CLAIRE Office Prague has currently 3 staff members – the head of the office, Dr. Vít Dočkal and two additional support staff members – Anna Tahovská and Markéta Iffland. Moreover Dr. Josef Urban is a member of CLAIRE Extended Core Team.
CLAIRE Office Prague was one of the first CLAIRE Offices to be established. Nowadays there are 7 offices across Europe (NL, DE, NO, CZ, IT, CH, BE), which work together to fulfill the CLAIRE Mission of "Excellence across all of AI. For all of Europe (and the world). With a human-centered focus."
CLAIRE is an initiative by the European AI community that seeks to strengthen European excellence in AI research and innovation. To achieve this, CLAIRE proposes the establishment of a pan-European Confederation of Laboratories for Artificial Intelligence Research in Europe that achieves "brand recognition" similar to CERN.

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ELLIS Unit Prague

European Laboratory for Learning and Intelligent Systems (ELLIS) established on December 6th 2018 during NeurIPS 2018, is a pan-European scientific organization which focuses on research and the advancement of modern AI, which relies heavily on machine learning methods such as deep neural networks that allow computers to learn from data and experience. The ELLIS Unit Prague was established on Dec 10, 2019 along with 16 other units in 10 different countries. ELLIS aims to offer European researchers outstanding opportunities to carry out their research in Europe, and to nurture the next generation of European young researchers in this field of strategic importance. Its goal is to enable Europe to be competitive in modern AI and benefit from its positive economic and societal impact. The establishment of the ELLIS units is the next step towards the realization of the ELLIS vision of an intergovernmental European AI program with multiple ELLIS institutes performing world-class multi-disciplinary research.
The Czech ELLIS unit brings together five internationally recognized researchers – Josef Šivic, Josef Urban, Robert Babuška, Tomáš Pajdla and Tomáš Mikolov. Together with their research teams they will form the basis for active collaboration with ELLIS as well as other research teams in the Czech Republic. The objective it to create an environment that will further attract outstanding researchers in artificial intelligence to the Czech Republic.

Contact: Dr. Ing. Josef Šivic,
Head of IMPACT (josef.sivic@cvut.cz)

AI DIH Network

CIIRC CTU got enrolled into AI Digital Innovation Hub (DIH) initiative in 2019, when the representatives of the European Commission and the Steering Committee of the DIHs have confirmed the selection of CIIRC CTU among 150 other applications. The DIH project has provided assistance in the modelling of a cross-border cooperation blueprint for DIHs and has supported the creation of a network of DIHs allowing for the transfer of technical knowledge. The AI DIH members met for a collaborative workshop at CIIRC CTU premises on May 31, 2019.
The DIH project enabled the development of an integration and cooperation plan between hub/networks with DIHs and stakeholders at the EU level. In November 2019, AI DIH Network members signed a high-level Framework Cooperation Agreement. The cooperation with DIHs will also continue under DIH-world project (2020-2023), which aims at providing DIHs access to harmonized tools, well proven technologies, effective methodologies, sound knowledge, smart investment sources, rich training assets and overall a vibrant innovation environment.

Contact: Ing. Markéta Iffland
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SELECTED ESIF PROJECTS

AI4REASON – Artificial Intelligence for Large-Scale Computer-Assisted Reasoning (ai4reason.org)

AI4REASON is an ERC Consolidator project (no. 649043) running from 2015 to 2020, whose principal investigator is Josef Urban. The project is funded by the European Research Council under the European Union's Horizon 2020 research and innovation program. The project's goal is to develop new combinations of AI, Machine Learning and Theorem Proving methods that learn reasoning guidance from large proof corpora and use such guidance to steer automated reasoning processes at various levels of granularity. The work includes close collaboration with several international partners: The University of Innsbruck, Google Research, The University of Miami, DHBW Stuttgart, The University of New Mexico, and others.
The research and development activities include:

- machine learning procedures over large proof libraries
- methods that propose useful intermediate lemmas for long proofs
- methods that efficiently apply learned knowledge in proof searches
- feedback loops between learning and automated reasoning
- statistical and deductive methods for the automated formalization of informal mathematics

Contact: Mgr. Josef Urban, Ph.D.,
Principal Investigator (josef.urban@cvut.cz)

IMPACT – Intelligent Machine Perception

The IMPACT project focuses on fundamental and applied research in computer vision, machine learning and robotics to develop machines that learn to perceive, reason, navigate and interact with complex dynamic environments. For example, people easily learn how to change a flat tire of a car or perform resuscitation by observing other people doing the same task. This involves advanced visual intelligence abilities such as interpreting sequences of human actions that manipulate objects to achieve a specific task. Currently, however, there is no artificial system with a similar level of cognitive visual competence.
Breakthrough progress in intelligent machine perception will have profound implications on our everyday lives as well as science and commerce, with smart assistive robots that automatically learn new skills from the Internet, safer cars that autonomously navigate in difficult changing conditions, or intelligent glasses that help people navigate never seen before environments.

Contact: Dr. Ing. Josef Šivic,
Principal Investigator (josef.sivic@cvut.cz)

Robotics for Industry 4.0

CZ.02.1.01/0.0/0.0/15_003/0000470, 2017–2022

Robot learning, autonomy and mobility. Machine learning will ease robot adaptation to new tasks and environments, including robot-human cooperation. Effective and safe machine learning algorithms are an important prerequisites for autonomy in robotics, which has been recognized as a strategic bottleneck for smart industrial applications. High-level reasoning in robotics needs a suitable representation of the environment, which continues to be a challenging task. We deal with robot learning, mobility, and with the mechanical aspects essential for effective human-robot collaboration.

Perception, grasping and manipulation in industrial environments. Reliable sensing and perception methods for mobile industrial robots are essential for the use of robots in modern industrial applications. However, the ability of robots to perceive and understand their environment is still very limited. Additional challenges are present when it comes to combining perception and dexterity. We therefore address the integration of perceptual systems with dexterous manipulation in the context of cooperative robots. Advanced perception, calibration and hybrid sensor-fusion are studied Robotics for Industry 4.0 in conjunction with the mechatronic side of the problem.

Networked control systems. Strongly interconnected systems, which are the backbone of the Industry 4.0 concept, give rise to additional complexity due to the interaction of the subsystems. Having a profound understanding of the phenomena arising in networked systems is a prerequisite for the successful implementation of the Industry 4.0 paradigm. We are developing methods for control-theoretic understanding of 'systems of systems' and also research mechanisms constituting mechanical networks in two areas – controlled mechanical impedance to increase the mechanism's stiffness and mechatronic solutions for grasping and manipulation.

This project, supported by the European Regional Development Fund, focuses on advanced robotics for future industrial applications. The scope includes perception, machine learning, human robot collaboration, distributed control and advanced mechatronics solutions.

Contact: Prof. Dr. Ing. Robert Babuška, Principal Investigator (robert.babuska@cvut.cz)

SELECTED PROJECTS

Project Title	Agency/Call	Start	End	Acronym
Intelligent Machine Perception	ESIF	01. 08. 2016	31. 10. 2022	IMPACT
Robotics 4 Industry 4.0	ESIF	01. 08. 2016	31. 10. 2022	Rob4Ind4.0
Artificial Intelligence and Reasoning	ESIF	01. 06. 2017	31. 10. 2022	AI&Reasoning
Engineering applications of microworld physics	ESIF	01. 09. 2017	31. 10. 2022	INAFYM
Cluster 4.0 – Methodology of System Integration	ESIF	01. 07. 2018	30. 09. 2022	Cluster 4.0
Research and Innovation Centre on Advanced Industrial Production – Phase 2	ESIF	01. 07. 2019	31. 12. 2022	RICAIP
UP-Drive: Automated Urban Parking and Driving	European Comission	01. 01. 2016	31. 12. 2019	UP-Drive
SafeLog: Safe human-robot interaction in logistic applications for highly flexible warehouses	European Comission	01. 01. 2016	31. 12. 2019	SafeLog
Dementia: Intersectorial Strategy for Training and Innovation Network for Current Technology	European Comission	01. 01. 2019	31. 12. 2021	DISTINCT
DIH-World – Accelerating deployment and matureness of DIHs for the benefit of Digitisation of European SMEs	European Comission	01. 09. 2020	31. 08. 2022	DIH-World
Foundations of Trustworthy AI – Integrating Reasoning, Learning and Optimization	European Comission	01. 09. 2020	31. 08. 2022	TAILOR
European Learning and Intelligent Systems Excellence	European Comission	01. 09. 2020	31. 08. 2022	ELISE
Value and Impact through Synergy, Interaction and cooperation of Networks of Centres of Excellence in AI	European Comission	04. 05. 2020	04. 05. 2023	VISION
Socially Pertinent Robots in Gerontological Healthcare	European Comission	01. 02. 2020	31. 01. 2024	SPRING
Big data pRocessing and Artificial Intelligence at the Network Edge	European Comission	01. 04. 2020	31. 03. 2023	BRAINE
EIT Manufacturing RIS hubs	Other foreign provider	01. 01. 2020	31. 12. 2021	EIT M RIS Hubs
Digital transformation in RIS	European Comission	01. 01. 2020	31. 12. 2020	DigTrafoRis
Citizen Scientists Investigating Cookies and App GDPR compliance	European Comission	01. 01. 2020	30. 04. 2022	CSI-COP
An AR cloud and digital twins solution for industry and construction 4.0	European Comission	01. 04. 2019	31. 03. 2022	ARtwin
DIH-AI Platform, Digital Innovation Hubs network	European Comission	01. 01. 2019		DIH-AI
Research and Innovation Centre on Advanced Industrial Production – Phase 2	European Comission	01. 07. 2019	31. 12. 2025	RICAIP
Thermal-aware Resource Management for Modern Computing Platforms in the Next Generation of Aircraft	European Comission	01. 04. 2019	30. 09. 2021	THERMAC
Deep Speech Analysis for Cognitive Assessment in Clinical Trials	European Comission	01. 01. 2019	31. 12. 2019	DeepSpA
Arrowhead tools	European Comission	01. 04. 2019	01. 04. 2022	Arrowhead tools
RoboCom Plus Plus	European Comission	01. 03. 2017	28. 02. 2020	RoboCom Plus Plus
DIGICOR: Decentralised Agile Coordination Across Supply Chains	European Comission	01. 10. 2016	30. 09. 2019	DIGICOR

Project Title	Agency/Call	Start	End	Acronym
AI4REASON	European Comission	01. 09. 2015	31. 10. 2020	AI4REASON
Equipment for non-invasive automatic analysis of hemodynamic parameters	TA CR	01. 01. 2019	31. 12. 2021	
Development of a modern modular system for teaching mechatronics in line with the Industry 4.0 challenge	TA CR	01. 01. 2018	31. 12. 2020	TAČR MERKUR
Research and realization of prototype of a breakthrough solution of multifunctional autonomous modular Creobot Modular for transport and manipulation in sophisticated manufacturing and assembly operations	TA CR	01. 01. 2018	31. 12. 2020	TAČR CREOBOT
Centre for Applied Cybernetics 3	TA CR	01. 03. 2012	31. 12. 2019	CAK3
Predictive modeling of student performance using learning resources	GA CR	01. 01. 2018	31. 12. 2020	
Research and project concept of a multifunctional robotic effector of an underground multirobot for storage of disposal casks in deep geological repository, and realization of a prototype of dual robotic effector module and its master control system	Ministry of Industry and Trade	01. 06. 2017	31. 12. 2019	
Time-delay control laws for upcoming transportation UAV systems	Ministry of Education, Youth and Sports	01. 09. 2017	31. 12. 2019	QUADSHAPE
Powering SMT Solvers by Machine Learning	Ministry of Education, Youth and Sports	01. 01. 2020	31. 12. 2024	POSTMAN
Exposure to stressful situations in a virtual city environment	TA CR	01. 04. 2020	31. 12. 2023	VRETCity
Development and research of synthetic equipment with artificial intelligence for automatic preselection and screening of pilots	TA CR	01. 01. 2020	31. 12. 2022	SynDevAI
New diagnostic procedures in the examination of auditory changes caused by aging	Ministry of Health CR	01. 05. 2020	31. 12. 2023	AgingEars
Improving Automatic Theorem provers (ATP) by methods of machine learning	GA CR	01. 01. 2020	31. 12. 2022	
Enhancing Robotic Physiotherapeutic Treatments using Machine Learning	Ministry of Education, Youth and Sports	01. 07. 2019	31. 07. 2022	Robfyz
Enabling the participation of research organizations in the European Energy Research Alliance (EERA)	Ministry of Education, Youth and Sports	01. 07. 2019	31. 12. 2021	EERA-CZ 2
Optimization of Dry Storage for Spent Nuclear Fuel	TA CR	01. 07. 2019	31. 12. 2022	Storage NF
Energy Storage in Electricity Generation	TA CR	01. 07. 2019	31. 12. 2023	Energy Storage
DC Microgrid for apartment houses	TA CR	01. 05. 2019	30. 04. 2022	DC Microgrid
Proving usability of flexibility aggregation including demand side management for power system regulation purposes.	TA CR	01. 08. 2019	31. 12. 2022	DFlex
Collaborative robotic platform of the future	Ministry of Industry and Trade	01. 01. 2019	31. 12. 2021	
Supplementary platform PKPB	Ministry of Industry and Trade	01. 09. 2019	30. 06. 2022	PKPB
Virtual Reality in Keeping the Elderly Active	TA CR	01. 02. 2019	31. 01. 2022	VIREAS

Project Title	Agency/Call	Start	End	Acronym
Ideas to Practice	TA CR	01. 01. 2019	28. 06. 2021	
The use of humanoid robot for active ageing of older people	TA CR	01. 01. 2019	31. 12. 2021	HUMR
National Centre of Competence – Cybernetics and Artificial Intelligence	TA CR	01. 11. 2018	31. 12. 2020	NCK KUI
Interactive Perception-Action-Learning for Modelling Objects	TA CR	01. 04.2019	31. 03. 2022	IPALM
Secure power flexibility for grid control and market purposes (SecureFlex)	TA CR	01. 06.2018	31. 05. 2024	SecureFlex
Transposition of MAF-type reliability indicators into the national reliability standards applicable in the corrective measures planning and evaluation in case of indication of generation inadequacy within the CZ grid	TA CR	01. 07. 2018	31. 12. 2020	MAFRI
Involvement of Czech research organizations in the European Alliance for Energy Research EERA	Ministry of Education, Youth and Sports	01. 01. 2018	31. 12. 2019	EERA-CZ 2
GenomKit – Progressive technologies for rationalization of personalized pharmacogenomics, nutrigenomics and sports medicine	Ministry of Industry and Trade	01. 01. 2018	31. 12. 2021	GenomKit
Research and realization of a testing robotic multi-wheel platform, with a focus on its centration and symmetrical passage through circular profiles of disposal boreholes for storage of disposal casks with SNF using multifunctional robotic technology	Ministry of Industry and Trade	01. 01. 2018	31. 12. 2020	ZAJADOT
MWPharmASIA – database extension of drug substances and their MWPharm modelsfor East Asian population and development of NGS diagnostic panel and algorithm for predicting statin pharmacokinetics/dynamics	TA CR	01. 01. 2018	31. 12. 2019	MWPharmASIA
Data-driven Asset Management in Automobile Industry Based on Semantic Modelling	TA CR	01. 01. 2018	31. 12. 2019	DAMiAS
Anisotropic character of hygroexpansion in modified wood	Ministry of Education, Youth and Sports	01. 01. 2018	31. 12. 2019	
Imitation learning of industrial robots through language	TA CR	01. 10. 2017	30. 09. 2019	ImitRob
KnowDrift: Knowledge-Driven Industrial Robotics for Flexible Production	Other Foreign Provider	01. 03. 2017	31. 08. 2019	KnowDrift
Personal Health Assistance Systems	Ministry of Industry and Trade	01. 07. 2017	30. 06. 2021	OZAS
Control Platform for High-Accuracy Microelectronics Assembly	Ministry of Industry and Trade	01. 07. 2017	30. 06. 2021	COPA
Robotic machine head	TA CR	01. 01. 2017	30. 06. 2020	
Temporal context in analysis of long-term non. stationary multidimensional signal	GA CR	01. 01.2017	31. 12. 2019	
NaoSkin: Robotic self-calibration and safe physical human-robot interaction inspired by body representations in primate brains	GA CR	01. 01. 2017	31. 12. 2019	
Technology for industrial robots integration into production systems based on Industry 4.0	Ministry of Industry and Trade	01. 09. 2016	31. 08. 2019	
Smart Camera: New Generation Monitoring Center	Ministry of the Interior	01. 01. 2017	31. 12. 2019	Smart Camera
Kassandra: Multi-camera vehicles' undercarriage security scanner	Ministry of the Interior	01. 01. 2017	31. 07. 2020	Kassandra
Fusion and Modeling Algorithms	Other Foreign Provider	13. 04. 2015	31. 12. 2019	FUMA
CRT: Features of Electromechanical Dyssynchrony that Predict Effect of Cardiac Resynchronization Therapy	Ministry of Health CR	01. 05. 2015	31. 12. 2019	Kardio

Automotive Lab R&D 4.0: Joint laboratory between CTU CIIRC, CTU FTS and Škoda Auto a. s.

In 2019, the joint laboratory performed several contracted research projects with industrial partners – Škoda Auto and Volkswagen. There was an intensive development of hardware and software tools for interactive simulation, extensive testing of various research topics, data analysis and further development of a Hardware-In-the-Loop (HIL) specialized workplace in cooperation with Škoda Auto departments and researches. The laboratory is capable of performing complex experimental activities based on research assignments from the automotive industry.
Group of permanent researchers and developers work in the laboratory, five of whom are Ph.D. students; selected students from master's and bachelor's degree programs at CTU FTS are also participating in projects under the guidance of experienced staff, associate professors. There are specialized workplaces with advanced vehicle simulators, a workplace focused on using virtual reality and HMD (Head Mounted Display), as well as HIL (Hardware-In-the Loop) simulation.

Projects in 2019 dealt with ADAS (Advanced Vehicle Driving Assistants), user interface topics and user interface ergonomics, Eye-Tracking technology application in automotive industry and physical biosensor applications in cars. The Automotive Lab R&D 4.0 leads several multidisciplinary teams, which were formed in close partnership with other laboratories and institutions such as CIIRC BEAT, CTU FBMI, VSB TUO and UWB.

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Rockwell Automation

The long-time joint research conducted within the RA-DIC laboratory is focused on the facilitation of flexible manufacturing. Semantic Big Data Historian (SBDH), an enabler of flexible production, was proposed and implemented. This prototype has many innovative features, e.g., the Plug&Play concept of cyber-physical systems and the exploitation of Apache Spark for the rapid and robust processing of data streams produced from shop floor sensors. The actual research being conducted at RA-DIC deals with the utilization of the OPC UA discovery concept for enabling the Plug&Play concept, which is a possible deployment of SBDH as a cloud-cyber physical system and means for dashboarding.

Contact: Prof. Ing. Vladimír Mařík, DrSc., dr.h.c., Principal Investigator (vladimir.marik@cvut.cz)

Eaton

One of the topics that Eaton lab is working with is safety-critical embedded control systems, where the utility of computations is sensitive to the timing behaviour of applications comprising the system. To reduce the cost, manufacturers minimize the number of platform components on which the applications are running. As a result, applications share platform resources, which causes conflicts and worsens their timing behaviour. Applications can be scheduled on platform resources during the design time to guarantee that their time requirements are satisfied. In the Eaton lab, we are dealing with this time-triggered scheduling problem, both from the theoretical and practical points of view. We have developed algorithms that automatically construct schedules with guaranteed certain time-related behaviour have and implemented the protocol on suitable hardware to run such schedules.

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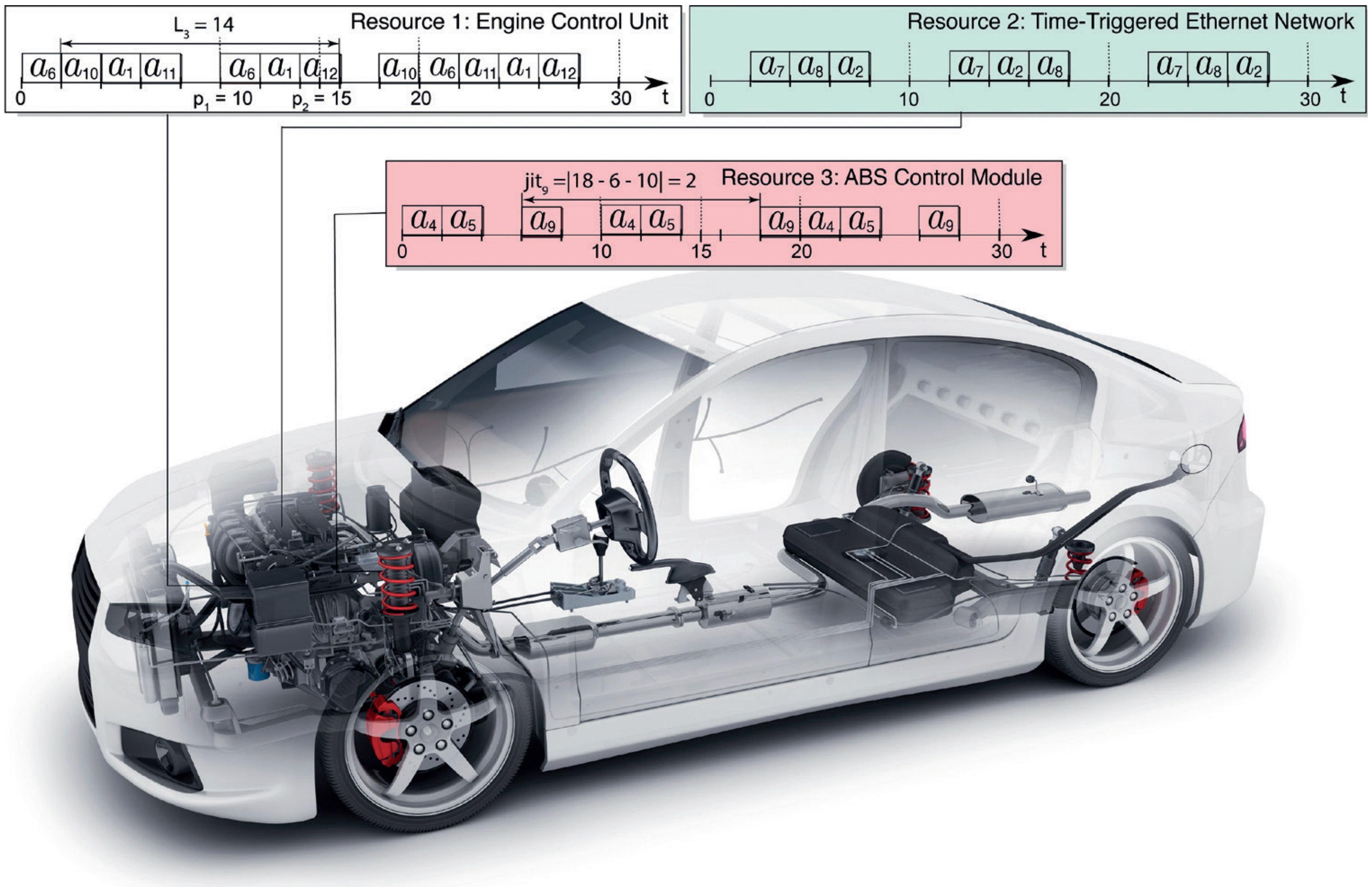


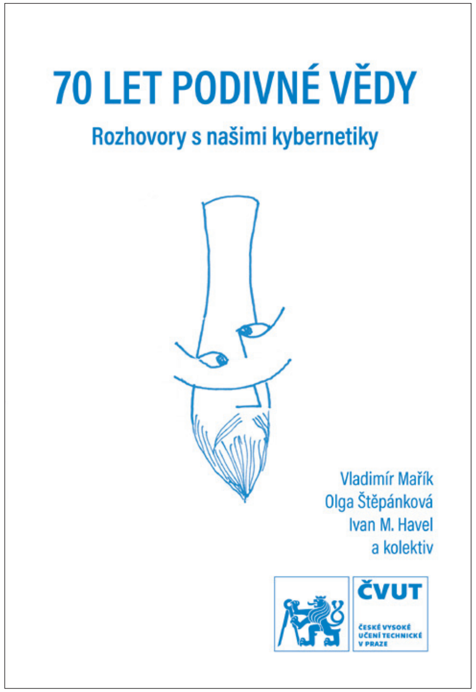
SELECTED PUBLICATIONS

Exceptional Publication

Vladimír Mařík, Olga Štěpánková,
Ivan M. Havel et al.
70 Years of a Weird Science:
Dialogs with our Cyberneticians

The book 70 Years of a Weird Science was formed at the Czech Institute of Informatics, Robotics and Cybernetics and is actually a memorial written in honour of Norbert Wiener on the occasion of the 70th anniversary of his key publication Cybernetics. The ideas of cybernetics as a scientific discipline have fundamentally influenced several generations of researchers – they changed the way we perceive the world and the way we reason about it, they contributed to the creation of many new research directions, such as artificial intelligence, machine learning, automatic control of robotics and they contributed to significant advance in modern informatics. This publication is about opinions on this development.

Through twenty-three contributions, the book documents the ways in which cybernetics evolved in the world, and especially in our country. It confirms that our cybernetics has never stood apart from the world trends and has been of excellent standard even in times that did not support free research. It shows that ties with the world have never been ceased to exist and that they have ever been the key to our research at all times.



All at the same time, the diversity of contributions shows the breadth of cybernetics and its implications: one can read not only about the use of cybernetics in robotics, machine perception or industrial automation (as the reader might expect), but also contribution to Egyptology and the arts. Due to the diversity of the content and the form of the contributions linked with unique drawings by Ivan M. Havel, the publication offers an interesting holistic view of cybernetics as well as an insight into cyberspace from different angles including even styles of thinking as well as the professional life of individual personalities.

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2020 OUTLOOK

While preparing the annual report for 2019, we were already quite actively working on 2020 projects as part of our long-term strategy. Let us briefly mention some of what we expect of this both exceptional and extreme year.

Towards an AI Ecosystem at CIIRC CTU

CIIRC CTU aims to conduct top foundational and applied research in the field of AI. From the very beginning, we intend to combine research excellence with the applicability of results in the industrial environment. To achieve this goal we are building an efficient **AI ecosystem at CIIRC**, bringing together several hundred researchers and engineers with different backgrounds and specializations, and combining various funding sources. The core basic research activities are concentrated in the fields of **machine learning, machine perception, reasoning, and robotics**. There are several strong and growing teams in each of these domains at CIIRC. Around the large **manufacturing testbed** – the experimental infrastructure backbone being strongly enhanced in 2020 and leveraged by the RICAIP Project – several new EU Horizon projects are being addressed (e.g. within the framework of the EIT Manufacturing programme) in combination with existing and new (in 2020) research and application projects funded from the Czech national grant agencies. The most important of these is the **"AI and Cybernetics" National Centre of Competence** of the Technology Agency of the Czech Republic, which has been strongly enhanced in 2020 through additional funding and a new subproject aimed at intelligent power distribution. The basic research is primarily organized around the three ESFRI "Excellent Teams" projects being managed, inter alia, by two ERC grant recipients. The close links to leading EU research bodies are principally expressed through our strong participation in the prestigious ELLIS and CLAIRE organizations, which established their Prague offices at CIIRC in 2019 and 2020. The transfer of know-how is intensively organized mainly through the **National Centre for Industry 4.0**, which is growing rapidly and has acquired several new partners since the beginning of 2020, and the **Centre of the City of the Future**. The European **AI Digital Innovation Hub**, which is hosted and managed by CIIRC, is playing a more and more important role. Its practical importance has grown rapidly in 2020 in connection with the pan-European COVID-19 initiatives.

Global Involvement in AI Structures – Participation in European AI Centres of Excellence

CIIRC CTU will continue in its efforts to enhance its AI research. All of us understand the importance of involvement in both European and global structures shaping developments within the AI discipline worldwide.
We will be involved in three out of five successful EU projects within the **"AI Centres of Excellence"** programme announced by the European Commission in March 2020. Four of the winning projects will form large European networks of specialized excellence centres. The fifth one – in which CIIRC CTU will play a significant role – will coordinate these networks and shape the European AI ecosystem. The aim of the European Commission (EC) is to build EU autonomy in key technologies, notably through strengthening AI research in Europe. "AI Made in Europe" is becoming a trademark for ethical and trustworthy artificial intelligence. For this purpose, 50 million euros have been allocated within Horizon 2020 (ICT48-2020 Call), preparing the ground for much larger investments in the near future. The goals are to expand existing research capacities and reduce fragmentation of the scientific community through the creation of tighter networks of existing AI centres. The successful networks include the best AI researchers in Europe, and we are glad to be part of this EU mainstream.
CIIRC CTU will be involved in projects covering a wide range of areas and activities. The **ELISE** *(European Learning and Intelligent Systems Excellence)* project brings together the best European researchers in machine learning-driven fields. The **TAILOR** *(Foundations of Trustworthy AI – Integrating Reasoning, Learning and Optimization)* project will develop an ambitious research and innovation roadmap for trustworthy AI and address great challenges in health, mobility, and resource management. The **VISION** *(Value and Impact through Synergy, Interaction and Cooperation of Networks of AI Excellence Centres)* project will coordinate activities among the four new networks of centres of excellence in AI mentioned above, as well as with the European Commission.

Attracting Top Talent from Abroad to CIIRC CTU

As part of our long term strategy, CIIRC CTU aims to create attractive conditions and provide research opportunities for successful foreign and Czech researchers who have been working abroad. We seek to both stop the so called "brain drain" and also create a multinational and open environment for top researchers. Besides Tilman Becker – a RICAIP Centre director since 2019 – three outstanding researchers are coming to build their teams as part of their tenure track at CIIRC through the RICAIP project in 2020. **Tomáš Mikolov**, coming from Facebook AI, will focus on strong artificial intelligence, **Mikoláš Janota** from Instituto Superior Técnico Lisboa will build a team in the field of automatic reasoning and, last but not least, is **Torsten Sattler** from the Chalmers University of Technology who will build his group in the field of computer vision and machine perception.
Being part of the ELLIS network will also enable CIIRC to create yet more opportunities, as one of the goals of the organisation is to support activities such as student and faculty exchanges, and joint ELLIS research programmes.

Large Events

- **National Industry Summit 2020**
  An annual meeting for Czech leaders from the fields of science, government, and industry. Empowered by National Centre for Industry 4.0.
- **Future City 2020, Connected and Resilient**
  Urban resilience is becoming a more and more prominent issue, and not only due to the current pandemic. An international conference empowered by the Centre of the City of the Future.

Helping out in crisis

Something nobody could have expected, the coronavirus pandemic has heavily impacted our lives since the beginning of 2020. With the research teams being flexible and always rapidly reacting to current events, we have managed to create two exceptional contributions.
The first was the **CIIRC protective mask with the highest level of protection (RP-95)**, which is 3D printable and was developed and certified within 2 weeks – we have shared the data worldwide, and these masks are currently being printed in more than 30 countries. This is also the first use case of flexible distributed production within RICAIP and an exceptional example of technology transfer, as the masks are being mass produced under licence.

The second achievement was the **development of the "Pipeťák" pipetting robotic station**, which helps test samples for COVID-19 at Na Bulovce Hospital.
The robot can manage as many as 700 samples a day. Several other similar robots have been prepared in cooperation with our ROP department.
As we have managed to obtain additional COVID-focused funds, we will continue with our activities in this area of research throughout 2020.

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