INFOTEHNOLOOGIA TEADUSKOND
AUTOMAATIKAINSTITUUT
TEADUS- JA ARENDUSTEGEVUSE AASTAARUANNE 2014

1. Instituudi struktuur

Automaatikainstituut, Department of Computer Control
Instituudi direktor Boris Gordon

- Automaatjuhtimise ja süsteemianalüüsi õppetool, Chair of Automatic Control and Systems Analysis, Ennu Rüstern
- Reaalajasüsteemide õppetool, Chair of Real Time Systems, Leo Mõtus
- Siduteooria ja –disaini õppetool, Chair of Circuit Theory and Design, Vello Kukk
- Proaktiivtehnoloogiate teaduslaboratoorium, Laboratory for Proactive Technologies, Jürgo-Sören Preden

2. Instituudi teadus- ja arendustegevuse (edaspidi T&A) iseloomustus

Automaatikainstituudi teadus- ja arendustegevus on viidud proaktiivtehnoloogiate teadus-laboratooriumi alla. Teaduslaboratoorium koondab instituudi teadureid, insenere ja doktorante, kes on seotud sihtfinantseeritava teadusteemaga, ETF grantide põhitäitjaid ja muude uurimisprojektide põhitäitjaid. Teadustööga tegelevad õppejõud teevad koostööd (nt ühised publikatsioonid) labori teadustöötajatega ning on seotud sihtfinantseeritava teadusteemaga (kuuluvad põhitäitjate nimekirja).

2.1 Instituudi koosseisu kuuluvad uurimisgrupid

- ***Laboratory for Proactive Technologies***
- ***Chair of Real Time Systems***

Aruandeaastal saadud tähtsamad teadustulemused: (inglise keeles)
Research activities were continued along the main research topinc of the Research Laboratory for Proactive Technologies, which is Cyber-Physical Systems (CPS) in changing environments.
The research can be partitioned to the following subtopics:

- Modelling of CPS
- Architectures for CPS
- Data processing for cognition

Progress was made in all of the sub-topics, more specifically in the area of CPS modelling the work was continued in the models of interactive computation, the input to this area coming from practical more practical reseacrh activities conducted in the lab. In the area of architectures for CPS work was continued in the development of ProWare, which refelects the results of practical and theoretical

work in this domain. The most significant result in this area is agreement with the company Cittyntel to apply ProWare in the Smart Street light application, which Citytnel will be deploying in various installations across the world, the first larger deployment being the installation of 600 luminaire controllers in the Old Town of Tallinn.
In the area of data processing for data processing for cognition work was continued in the signal processing and fuzzy classification areas. The most significant result in this domain is the finalization of the research agreement with the US Army Research Lab in the domain of signal processing and classification of PIR sensors. More details on the project are presented below.

Hajutatud klassifitseerimine kasutades hägusat klassifitseerimist/ *Distributed classification based on fuzzy classification* (välisleping VA680;26.09.2014-25.09.215, vastutav täitja: van.tead Jürgo-Sören Preden).
The project focuses on a distributed classification approach using heterogeneous multi-modal sensor sources. The sensor modalities in the first phase of the project are pyroelectric infrared, in the later stage ultrasonic and seismic sensors. Feature extraction from the sensors is performed using model-based feature extraction. Feature extraction and classification is performed both at individual sensor nodes as well as on a central fusion node. Communication of classification results from individual sources is performed using the proactive middleware (ProWare). ProWare will be customized and extended to satisfy the needs of the given application. The classification at individual sensor nodes as well as classification based on the fusion of several sources is based on different versions of the fuzzy classifier, which has been previoulsy developed at ProLab as well.

Informatsiooni ühilduvus ja luure ühilduvus, kasutades statistikat, agente, arutlemist ja semantikat */ INformation INteroperability & INtelligence Interoperability by STatistics, Agents, Reasoning and Semantic* (välisleping VA598, 15.09.13 -15.09.2016, vastutav täitja: van.tead Jürgo-Sören Preden).
The main challenge in modern Intelligence, Surveillance and Reconnaissance (ISR) systems is to achieve accurate and timely situation awareness for every stakeholder. This situational awareness must be based on large quantities of the relevant data obtained from disparate sources. Information sources include heterogeneous sensor systems, intelligence provided by the forces in the field (HUMINT), specific military and civilian agencies as well as sources from purely civilian domains, such as social media (OSINT). IN-4-STARS2.0 tackles the challenges of large-scale analysis of heterogeneous information and secure information flows between heterogeneous information sources by combining advanced tools/methods with research on novel approaches to heterogeneous information fusion, multi level security and semantic interoperability in distributed settings.
Within the context of the IN4STARs project ProLab is involved in an experimental tactical system development. This work involves sensor integration, sensor signal processing, classification and communication of information using ProWare. ProLab is able to apply results in all of its research fields in the context of the project.

Uurimisgrupi olulisemad publikatsioonid aruandeaastal:

Preden, J.-S.; Motus, L.; Llinas, J.; Pahtma, R.; Savimaa, R.; Meriste, M.; Astapov, S. (2014). Improvised Explosive Devices in Asymmetric Conflicts: Multisource Data Fusion for Providing Situational Information. A. Gorod, B. E. White, V. Ireland, S. J. Gandhi, B. Sauser (Toim.). Case Studies in System of Systems, Enterprise Systems, and Complex Systems Engineering (407 - 443).Taylor & Francis

Preden, J.-S.; Pahtma, R.; Astapov, S.; Riid, A.; Suurjaak, E.; Ehala, J.; Motus, L. (2014). Distributed fusion and automated sensor tasking in ISR systems . In: ProceedinGs of Ground/Air Multisensor Interoperability, Integration, and Networking for Persistent ISR IV: SPIE Defense, Security and Sensing: Ground/Air Multisensor Interoperability, Integration, and Networking for Persistent ISR IV: SPIE Defense, Security and Sensing. (Toim.) T. Pham; M. A. Kolodny; K. L. Priddy. SPIE, 2014.

Astapov, S.; Ehala, J.; Preden, J.-S. (2014). Collective Acoustic Localization in a Network of Dual Channel Low Power Devices. In: Proceedings of the 21st International Conference "Mixed Design of Integrated Circuits and Systems": 21st International Conference "Mixed Design of Integrated Circuits and Systems" MIXDES 2014, Lublin, Poland, 19-21 June 2014. (Toim.) A. Napieralski. IEEE, 2014, 430 - 435.

Riid, A.; Preden, J.; Astapov, S. (2014). Detection, identification and tracking of mobile objects with distributed system of systems. In: System of Systems Engineering (SOSE), 2014 9th International Conference on: 2014 9th International Conference on System of Systems Engineering (SOSE), Adelaide, Australia. IEEE, 2014, 224 - 229.

Astapov, S.; Preden, J.; Ehala, J.; Riid, A. (2014). Object detection for military surveillance using distributed multimodal smart sensors. In: Digital Signal Processing (DSP), 2014 19th International Conference on: 2014 19th International Conference on Digital Signal Processing (DSP). Hong Kong, Hong Kong: IEEE, 2014, 366 - 371.

Preden, J.; Pahtma, R.; Tomson, T.; Motus, L. (2014). Solving Big Data: Distributing Computation Among Smart Devices. Robal T.; Kalja A.; Haav H.-M. (Toim.). Databases and Information Systems (245 - 258).IOS Press

Preden, J. (2014). Generating situation awareness in cyber-physical systems: creation and exchange of situational information. In: Proceedings of the 2014 International Conference on Hardware/Software Codesign and System Synthesis (CODES '14): 2014 International Conference on Hardware/Software Codesign and System Synthesis (CODES '14), New Delhi, India, October 2014. ACM, 2014, 21:1 - 21:3.

• ***Chair of Automatic Control and Systems Analysis***

Info- ja kommunikatsioonitehnoloogia doktorikool *Doctoral School in Information and Communication Technologies* (SA Archimedes toetus, DAR9086; 01.01.2009- 31.08.2015; vastutav täitja dotsent Eduard Petlenkov)

Research of advanced system modeling and control design methods (www.a-lab.ee).
Core competences:

- Control of complex nonlinear systems;
- Self-learning and adaptation methods in control systems;
- Computational intelligence based methods in control (artificial neural networks, genetic algorithms, fuzzy logic);
- Fractional-order modeling and control (FOMCON project http://fomcon.net/).

Aruandeaastal saadud tähtsamad teadustulemused: (inglise keeles)

Artificial Neural Network based ANARX-tipe model was applied to identification of a model of a real-life process. Parameters of the identified model were used to design a controller based on dynamic feedback linearization. The designed neural network based controller was verified on mathematical model within MATLAB/Simulink environment and applied to the real-time control of a plant. The static error was eliminated retuning input signal in the steady-state mode. Liquid level tank system was chosen as a case study to illustrate the applicability of the proposed approach. Experimental results have shown a good performance of the proposed technique. The designed controller is capable of tracking the desired water level for all set points with high degree of accuracy and without significant over/undershoot.

A design of a controller based on the NN-SANARX (Neural Network based Simplified Additive Autoregressive eXogenous) model is considered on the basis of a prototype of the real liquid level tank system. Structure of the neural network is chosen using two different methods of genetic algorithms with multi-objective optimization: Weighted Sum approach and Fast Non-dominated Sorting Genetic Algorithm. Experiments showed that both methods of neural network structure selection for controller design have good control performance of a liquid level tank system.

A water boiler process was studied based on real process data. Process was identified and modelled. An MPC controller was developed for process control and tested in virtual (Matlab) environment.

Fractional-order calculus presents a novel modeling approach for systems with extraordinary dynamical properties by introducing the notions of derivatives and integrals of noninteger order. In system theory this gives rise to extensions to linear, time invariant systems to enhance the description of complex phenomena involving memory or hereditary properties of systems. Standard industrial controllers, such as the PID controller and lead-lag compensator, have also been updated to benefit from the effects of noninteger integration and differentiation, and have advantages over classical controllers in case of both conventional and fractional-order process control. However, given the definitions of fractional operators, accurate digital implementation of fractional-order systems and controllers is difficult because it requires infinite memory. In our work we study the digital implementation of a fractional-order PID controller based on an infinite impulse response (IIR) filter structure obtained by applying the Oustaloup recursive filter generation technique. Software for generating digital fractional-order is developed and tested on an Atmel AVR

microcontroller. The results are verified using a MATLAB/Simulink based real-time prototyping platform.

Closed-loop identification methods attract significant interest because they grant the possibility to obtain industrial process models without the need to perform separate open-loop experiments thus avoiding potential production losses. We study the problem of identifying a fractional-order process model of a plant working in a closed control loop. We consider both the direct and the indirect identification approaches. Identification is performed offline by means of minimizing the model output error and is based on data collected in the time domain. We provide the description of the software implementation of the proposed identification procedure. All necessary computations are performed in FOMCON toolbox for MATLAB. An exemplary closed-loop system is studied. It comprises a real-life fractional-order PID controller prototype, and a simulated model of a plant running on a personal computer based real-time prototyping platform. Experimental results are analyzed.

Gain scheduling is widely regarded as an effective nonlinear control technique, and its extension to fractional-order control is a natural step. Thus we investigate a particular method based on a gain and order scheduling approach for fractional-order PID controllers. The method is applied to the control of a real-life laboratory model of an industrial multi-tank system. Gain and order scheduling is realized by means of a control law comprising two static PID controllers and an appropriate control blending rule providing this way means for stability analysis of the control system. The design of controllers for level control in the first tank is carried out by considering linear fractional-order approximations of the nonlinear model of the process with locally applicable frequency-domain robustness specifications. The controller for the second tank is obtained using time-domain optimization of the transient response. In addition, an extended Kalman filter is designed to reduce measurement noise propagation into the control law thereby enhancing the performance of the pump. The majority of necessary computations, including those related to controller design, are performed numerically in the FOMCON toolbox for MATLAB.

We study the problem of fractional-order PID controller design for an unstable plant—a laboratory model of a magnetic levitation system. To this end, we apply model based control design. A model of the magnetic levitation system is obtained by means of a closed-loop experiment. Several stable fractional-order controllers are identified and optimized by considering isolated stability regions. Finally, a nonintrusive controller retuning method is used to incorporate fractional-order dynamics into the existing control loop, thereby enhancing its performance. Experimental results confirm the effectiveness of the proposed approach. Control design methods obtained during this study are general enough to be applicable to a variety of control problems.

Uurimisgrupi olulisemad publikatsioonid aruandeaastal:

Vassiljeva, K.; Belikov, J.; Petlenkov, E. (2014). Application of genetic algorithms to neural networks based control of a liquid level tank system. *In: 2014 International Joint Conference on Neural Networks [IJCNN] : July 6-11, 2014, Beijing, China:* Piscataway, NJ: IEEE, 2014, 2525 - 2530.

Belikov, Juri; Petlenkov, Eduard (2014). Model based control of a water tank system. *In: 19th IFAC World Congress, IFAC 2014 : Cape Town, South Africa, 24-29 August 2014, Proceedings: (Toim.) Boje, Edward; Xia, Xiaohua.* Cape Town: IFAC, 2014, (IFAC Proceedings Volumes), 10838 - 10843.

Vansovitš, Vitali; Petlenkov, Eduard; Vassiljeva, Kristina; Tepljakov, Aleksei; Belikov, Juri (2014). Application of MPC to industrial water boiler control system in district heat plant. *In: ICARCV 2014 : The 13th International Conference on Control, Automation, Robotics & Vision, December 10-12, 2014, Marina Bay Sands, Singapore, [Proceedings]:* IEEE, 2014, 1609 - 1614.

Tepljakov, Aleksei; Petlenkov, Eduard; Belikov, Juri; Gonzalez, Emmanuel A. (2014). Design of retuning fractional PID controllers for a closed-loop magnetic levitation control system. *In: ICARCV 2014 : The 13th International Conference on Control, Automation, Robotics & Vision, December 10-12, 2014, Marina Bay Sands, Singapore, [Proceedings]:* IEEE, 2014, 1345 - 1350.

Tepljakov, Aleksei; Petlenkov, Eduard; Belikov, Juri (2014). Fractional-order digital filter approximation method for embedded control applications. International Journal of Microelectronics and Computer Science, 5(2), 54 - 60.

- **Chair of Circuit Theory and Design**

Optimiseeritud hinnatasemega hääljuhitavate sensorlülitite teostatavusuuring hooneautomaatika rakendusteks /*Feasibility study of the voice command sensor switches of the optimized price level for the Smart House applications* (siseriiklik leping Projekt Lep14114; 19.08.2014- 15.09.2016; vastutav täitja teadur Andres Udal)

"Bluetooth sensortehnoloogia elektrooniliste lahenduste optimiseerimine"./ *Optimization of the electronical solutions of the Bluetooth sensor technology* (siseriiklik leping Projekt Lep14160; 01.12.2014- 01.12.2017; vastutav täitja teadur Andres Udal)

Uurimisgrupi teadustöö kirjeldus (inglise keeles)

Development of competence-based learning system was continued. New models for tasks and processing were developed and implemented in real learning processes.

The problems of nanoscale and quantum information technology were continuously studied in order to improve the respective e-learning courses for graduate students. The new application oriented themes of voice control devices and wireless RF communication sensor devices were initiarted together with Estonian small eneterprices.

Aruandeaastal saadud tähtsamad teadustulemused: (inglise keeles)

New algorithms for answer evaluation were developed and tested. Twodimensional representation of competences was analysed, algorithms building higher level competences were developedincuding probablity-based model for evaluation of difficulty level of a low-level competences.

Discussion of the new challenges of the nanoscale and quantum information technology. Development of quantum cascade laser simulation software in cooperation of the Leeds University. Proposal of one hypothetical quantum optical communication protocol based on entangled photon pairs. Starting the preliminary studies of the approaches of the design the voice command controlled sensor switches.

Uurimisgrupi olulisemad publikatsioonid aruandeaastal:

Umbleja, K.;Kukk, V.;Jaanus, M.;Udal, A. (2014). New Concepts of Automatic Answer Evaluation in Competence Based Learning. In: IEEE EDUCON 2014: IEEE EDUCON2014, Istanbul, Turkey, April 3-5, 2014. IEEE, 2014, 922 - 925.

Jaanus, M.; Udal, A.; Kukk, V.; Umbleja, K. (2014). Competence Based Interactive Learning with HomeLabKits: experience and work in progress. EDUCON2014 – IEEE Global Engineering Education Conference. IEEE, 2014, 1082 - 1084.

Kukk, V. (2014). Student's Behavior in Free Learning Environment and Formal Education System. In: Learning Technology for Education in Cloud. MOOC and Big Data: Third International Workshop, LTEC2014 Santiago, Chile, September 2-5, 2014. (Toim.) L. Uden, J. Sinclair, Y-H. Tao, D. Liberona. Springer, 2014, 187 - 194.

Jaanus, M.; Udal, A.;Vello, K.;Umbleja, K. (2014). Implementation of the robot arm in the interactive learning environment. ICSES 2014 International Conference on Signals and Electronic Systems, Poznań, Poland, 11-13 September 2014. IEEE, 2014, 1 - 4.

Udal, A.; Jaanus, M.; Umbleja, K.: Reeder, R. (2014). The Method of Quantum Optical Communication Based on Entangled Photon Pairs. In: Proceedings of the 14th Biennial Baltic Electronics Conference: BEC2014, Tallinn, Estonia, Oct. 6-8, 2014 . Tallinn: IEEE, 2014, 4– pp.33-36.

2.3 Teaduskorralduslik tegevus ja teadlasmobiilsus

Prof. Leo Mõtus:

- Eesti Teaduste Akadeemia Kirjastus, Proceedings of the Estonian Academy of Sciences, Estonian Journal of Engineering - toimetaja (computer and systems science)
- Eesti Teaduste Akadeemia - liige
- The Institution of Engineering and Technology (IET) – liige (fellow)
- Kaitseministeeriumi Teadusnõukogu – aseesimees
- Eesti Teaduste Akadeemia küberkaitse komisjoni esimees
- Eesti Teaduste Akadeemia energeetika nõukogu liige
- Euroopa Kaitseagentuuri „Information Superiority“ direktoraadi Eesti poolne koordinaator
- Haridus- ja Teadusministeeriumi teaduspoliitika komisjoni liige

Van. teadur Jürgo–Sören Preden:

- Kaitseministeeriumi Teadusnõukogu – liige (Tallinna Tehnikaülikool,)
- NATO Science and Technology Organization (STO), System Concepts and Integration (SCI) paneeli esindaja
- NATO STO exploratory team SCI-014 "Requirements, Concepts and Challenges for Integrating Defense and Homeland Security Systems", grupi juht, Eesti esindaja
- NATO STO task group SCI-206 "System Design Considerations and Technologies For Safe High Tempo Operations In Degraded Environments" Eesti esindaja
- NATO STO task group SET-189 "Battlefield Acoustics, Multi-modal Sensing, and Networked Sensing for ISR Applications", Eesti esindaja
- NATO STO exploratory team SCI-012 "Affordable Robotics for Military Operations", Eesti esindaja
- NATO STO task group IST-124 "'Heterogeneous tactical networks improving connectivity and network efficiency", Eesti esindaja
- Institute of Electrical and Electronics Engineers, Inc. (IEEE) – liige
- Eesti Süsteemiinseneride Selts - liige

Van.teadur Igor Astrov:

- Institute of Electrical and Electronics Engineers, Inc. (IEEE) - vanem liige (*Senior member*)
- The International Institute of Informatics and Systemics, USA (IIIS) - liige

Van.teadur Andres Udal:

- Infotehnoloogia ja Telekommunikatsiooni Kutsenõukogu - liige (Eesti Kõrgkoolide, Teadus- ja Arendusasutuste Ametiliitude Ühendus UNIVERSITAS esindaja)
- 2014 - 2017 Euroopa teaduskoostöö COST aktsiooni IC1208 (Uute seadiste ja materjalide integratsioon info- ja kommunikatsioonitehnoloogias) juhtkomitee liige Eestist
- 2013 - 2017 Euroopa teaduskoostöö COST võrgustiku aktsiooni BM1205 (Nahavähi detekteerimine laserkuvamise abil) juhtkomitee liige Eestist
- 2013 - 2016 Euroopa teaduskoostöö COST võrgustiku aktsiooni MP1204 (THz & MIR tehnoloogiad) juhtkomitee liige Eestist

Prof. Ennu Rüstern:

- Institute of Electrical and Electronics Engineers, Inc. (IEEE) - liige
- The Institution of Engineering and Technology (IET) - liige
- Eesti Süsteemiinseneride Selts - liige

Dots. Boris Gordon:

- European Society for Engineering Education (SEFI), Working Group on Ethics in Engineering Educations (EiEE) - liige

Dots. Eduard Petlenkov:

- Info- ja kommunikatsioonitehnoloogia doktorikool – projektijuht
- Doktorikoolide Nõukogu juhatuse liige
- Eesti Süsteemiinseneride Selts – liige
- ABB ja TTÜ koostöönõukoda – liige
- IFAC Computational Intelligence in Control Technical Committee – liige

Prof. Vello Kukk:

- Institute of Electrical and Electronics Engineers, Inc. (IEEE) – vanem liige (*Senior member*)
- IEEE Estonia Section, Education Society Chapter – Chair (esimees)
- COST IC1401 „Memristors - Devices, Models, Circuits, Systems and Applications (MemoCiS)" "Memristorid – seadised, mudelid, sidud, süsteemid ja rakendused (MemoCiS)" juhtkomitee Eesti-poolne liige