INFOTEHNOLOOGIA TEADUSKOND
AUTOMAATIKAINSTITUUT
TEADUS- JA ARENDUSTEGEVUSE AASTAARUANNE 2013

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*

Proaktiivsus ja situatsiooniteadlikkus */ Proactivity and situation-awareness / (SF0140113As08, 01.01.2008-31.12.2013, teema juht: prof Leo Mõtus).*

Three simultaneously on-going and interacting threads are studied - proactive modelling, technology platforms and tools, and pilot applications and assessment methods. The emergent behaviour in proactive systems and their relationship to complex systems theory are of special interest. Research in proactive modelling focuses on models of situation-aware interactive computing, emergent behaviour in enterprises and organisations, self-learning and adaptation methods in control systems, and nano-components. Research on technology and tools covers agent-based and smart dust technologies, plus tools and methods for interface technologies for exchanging situational information. Pilot applications and study of methods for their assessment are divided into three parts

- cases applying MATLAB/Simulink models, cases applying real world environment and physical devices, and preparatory work on set-up of verification studies.

Aruandeaastal saadud tähtsamad teadustulemused:
The research has been carried out in three simultaneously on-going and interacting threads -- proactive modelling methodology, development of technological platforms and tools, and pilot applications for assessment of results. The emergent behaviour in complex proactive systems and possibilities of its early detection, assessment of its influence to system's performance and elimination if necessary has been of paramount importance. Research in proactive modelling continues in the Lab and focuses on models of situation-aware interactive computing, emergent behaviour in enterprises and organisations, self-learning and adaptation methods in control systems, and components. Research on technology and tools has covered agent-based and smart dust technologies, plus tools and methods for interface technologies fostering exchange of situational information. Pilot applications and assessment of developed methods and technological tools were divided into three parts - cases applying MATLAB/Simulink models, cases applying real world environment and physical devices, and preparatory work on set-up of verification studies.

Uurimisgrupi olulisemad publikatsioonid aruandeaastal:
Astrov, I.; Pikkov, M.; Paluoja, R. (2013). Motion control of an autonomous surface vessel for enhanced situational awareness. In: ICCME 2013 CD-ROM Proceedings: International Conference on Computer and Mechatronics Engineering (ICCME 2013, Malaga, Spain, November 28-29, 2013). WASET, 2013, 1246 - 1251.

Astapov, S.; Berdnikova, J.; Preden, J.-S. (2013). A Method of Initial Search Region Reduction for Acoustic Localization in Distributed Systems. In: Proceedings of the 20th International Conference "Mixed Design of Integrated Circuits and Systems": 20th International Conference "Mixed Design of Integrated Circuits and Systems" MIXDES 2013, Gdynia, Poland, 20-22 June 2013. (Toim.) A. Napieralski. IEEE, 2013, 451 - 456.

Tomson, T.; Preden, J. (2013). Simulating System of Systems using MACE. In: Processings of UKSim 15th International Conference on Mathematical/Analytical Modelling and Computer Simulation: UKSim 15th International Conference on Mathematical/Analytical Modelling and Computer Simulation, Cambridge, UK, april 2013. (Toim.) Al-Dabass, D.; Orsoni, A.; Yunus, J.; Cant, R.; Ibrahim, Z.. IEEE, 2013, 155 - 160.

Ibala, C.; Astapov, S.; Bettens, F.; Escobar, F.; Chang, X.; Valderrama, C.; Riid, A. (2013). Combining Multiple Sound Sources Localization Hybrid Algorithm and Fuzzy Rule Based Classification for Real-time Speaker Tracking Application. International Journal of Microelectronics and Computer Science IJMCS, 4(1), 12 - 25.

Iseorganiseeruv intelligentne vahevara platvorm tootmis- ja logistikaettevõtete jaoks */Self-organizing middleware platform for ad-hoc networks in the domain of manufacturing and logistics/ (ARTEMIS, projekt SIMPLE /GART5, 01.05.2010 - 30.04.2013, vastutav täitja: prof Leo Mõtus).*

Development of a self-organizing middleware platform for ad-hoc networks in the domain of manufacturing and logistics.

Aruandeaastal saadud tähtsamad teadustulemused:
SIMPLE is a three year project, whose result is a smart self-organising platform for integrating wireless sensors and their networks, smart RFID, and other devices. The platform enables on-line control of manufacturing and logistics processes, providing the details of component interaction and fostering dynamic reconfiguration of processes. ARTEMIS has assessed the final results of this project and is extremely satisfied – recommending the use of technological solutions elaborated in SIMPLE project in the other (coming) ARTEMIS projects. The Research Lab for Proactive Technologies developed and implemented proactive middleware (RROWARE) that governs the component interactions – exchanging messages according to subscriptions, providing localisation tags to sensor data and messages, and checking temporal and spatial consistency of data.

Uurimisgrupi olulisemad publikatsioonid aruandeaastal:
Astapov, S.; Preden, J.-S.; Berdnikova, J. (2013). Simplified Acoustic Localization by Linear Arrays for Wireless Sensor Networks. In: Proceedigns of the 2013 18th International Conference on Digital Signal Processing (DSP 2013): IEEE 2013 18th International Conference on Digital Signal Processing (DSP 2013). IEEE, 2013, 1 - 6.

Preden, J.; Motus, L.; Pahtma, R.; Meriste, M. (2013). Reducing Bandwidth Requirements and Optimizing Data Flow in Distributed Data Acquisition and Processing. In: Proceedings of the 2013 IEEE International Multi-Disciplinary Conference on Cognitive Methods in Situation Awareness and Decision Support (CogSIMA): 2013 IEEE International Multi-Disciplinary Conference on Cognitive Methods in Situation Awareness and Decision Support (CogSIMA), San Diego, Ca, USA. IEEE Publishing , 2013, 178 - 185.

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).*
Contemporary command and control in large-scale joint operations involving multiple stakeholders critically depends on adequate situation awareness. The main challenge in such settings is to achieve accurate and timely situation awareness by each of the stakeholders. 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, specific military and civilian agencies as well as sources from purely civilian domains, such as social media. 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.

Aruandeaastal saadud tähtsamad teadustulemused:
Within the scope of the project that started just in September 2013 the methods were selected that are applicable for information processing and exchange in the project. The application scenario, utilizing distributed data acquisition and fusion in an ad-hoc network, was specified.
Based on the scenario the system requirements were specified, including the description of components and requirements of the information exchange middleware. The development and tuning of middleware components was started to fit the needs of the project. The performed work builds a foundation for the work that will be continued in 2014.

Uurimisgrupi olulisemad publikatsioonid aruandeaastal:
Preden, J; Llinas, J.; Rogova, G.; Pahtma, R.; Motus, L. (2013). On-line data validation in distributed data fusion. In: 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. (Toim.) T. Pham; M. A. Kolodny; K. L. Priddy. SPIE, 2013, (Proceedings of SPIE; 8742)

- *Chair of Automatic Control and Systems Analysis*

Keeruliste mittelineaarsete süsteemide juhtimine ja analüüs tehisintellekti meetoditega */Artificial intelligence methods based analysis and control of complex nonlinear systems/ (ETF grant G8738, 01.01.11 - 31.12.13, vastutav täitja: dots Eduard Petlenkov).*

The aim of the project is to develop a control strategy combining advantages of classical analytical and different artificial intelligence based methods. The designed system should be capable of automatic control of complex multidimensional and hardly analyzable systems.
An intelligent control system should be able not only to make decisions according to a predefined algorithm or/and scenario but also to adapt to changing environment. The adaptive system has

- to be able to react to changes in its environment. It means be reactive;
- to analyze and predict the behavior of its environment. It means be proactive;
- to adjust itself and change its own behavior in response to disturbances and changes in environmental conditions.

Modern time complex intelligent control system consists of two main parts: adaptive control algorithm plus situation awareness.
There exist a number of classical control techniques the robustness and high reliability of which is proven by decades. Nevertheless, nowadays in more and more applications we need to control complex systems and processes which cannot (or it is not a trivial task) be represented by classical models. In these applications we need algorithms combining advantages of classical and artificial intelligence based methods.
During the last ten years has significantly grown the demand for automatic systems and devices in live-critical applications. This dramatically increases the requirements imposed to the quality of the control system. It means that more and more advanced control systems, precise and as simple as

possible control task oriented models of very complex multidimensional and highly nonlinear systems are required.

In the framework of this project research is conducted in two directions, which are connected to each other:

1. reliable and satisfying high quality demands control algorithms for complex nonlinear multidimensional systems;
2. artificial intelligence based methods for precise recognition of environmental situation by real-time analysis of observed image, video and numerical data.

Aruandeaastal saadud tähtsamad teadustulemused:

Mathematical model usually becomes the basis for describing behavior of the real-life processes. Therefore, structural identification represents a challenging problem, especially when one deals with complex system involving large number of parameters. Compared to classical methods, one of the main strengths of non-classical methods in structural identification is generally better robustness in achieving global optimum. Usually, non-classical methods are used separately. However, we do believe that using benefits of various techniques from different areas can lead to development of a new and more reliable algorithm.

Combination of three typical techniques such as neural networks of specific structure, statistics and genetic algorithm allows to design a controller directly from parameters of the identified model. The control strategy based on reference model is presented in [1]. Further, one of the earlier developed methods based on the parameters of neural networks Simplified Additive Auto Regressive eXogenous models and feedback linearization was successfully applied to control liquid level in the upper tank of multitank laboratory plant [2].

Another direction where computational intelligence methods can be used, is the analysis of the system dynamics. For example, combining neural networks and genetic algorithms, the optimal structure of the model can be found which detects "right" or "wrong" performance of the therapeutic exercises during human limb rehabilitation process. That approach gives possibility to find balance between the accuracy of the model and sensors needed to capture patient’s behavior [3].

Fractional-order calculus offers mathematical tools to model complex systems with memory-like or hereditary properties and has found many applications in the field of control engineering. During our research, fractional-order dynamics have been identified in a laboratory model of an industrial system of coupled tanks. A suitable fractional-order PID level controller has been designed subject to a set of performance specifications, digitally implemented, and successfully tested on a real-time prototyping platform. This contribution is relevant to improving the quality of industrial level control loops [4].

While fractional-order models provide improvement of dynamical system description, the implementation of such systems is a difficult task. It is possible to practically realize fractional-order systems and controllers using analog electronic filters. The resulting circuits are called fractances. In [5] we develop a general method which may be applied to generating complex fractance-based control circuits. The results of this work can be applied in manufacturing of analog fractional-order systems and controllers.

Uurimisgrupi olulisemad publikatsioonid aruandeaastal:

J. Belikov, E. Petlenkov, S. Nõmm, and K. Vassiljeva, “Computational intelligence methods based design of closed-loop system,” in Neural Information Processing: 20th International Conference, ICONIP 2013, Daegu, Korea, November 3-7, 2013, Proceedings, Part I, M. Lee, A. Hirose, Z.-G. Hou, and R. Kil, Eds. Springer, Lecture Notes in Computer Science, 8226, 2013, pp. 215–224.

J. Belikov, E. Petlenkov, K. Vassiljeva, and S. Nõmm, “Application of neural networks based SANARX model for identification and control liquid level tank system,” in IEEE 12th International Conference on Machine Learning and Applications ICMLA 2013, Miami, Florida, USA, December 2013, pp. 246–251.

S. Nõmm, K. Vassiljeva, and A. Kuusik, “Human limb model structure selection with genetic algorithm,” in EMS2013 : UKSim-AMSS 7th European Modelling Synposium on Mathematical Modelling and Computer Simulation, Manchester, UK, November 2013, pp. 124–129.

A. Tepljakov, E. Petlenkov, J. Belikov, and M. Halás, “Design and implementation of fractional-order PID controllers for a fluid tank system,” in Proc. 2013 American Control Conference (ACC), Washington DC, USA, June 2013, pp. 1780–1785.

A. Tepljakov, E. Petlenkov, and J. Belikov, “Efficient analog implementations of fractional-order controllers,” in Proc. of the 14th International Carpathian Control Conference (ICCC), 2013, pp. 377–382.

- *Chair of Circuit Theory and Design*

Komptentsjuhtimisega õpikeskkonna arendus */Development of competence-driven learning environment/ (ETF grant G9463, 01.01.12 - 31.12.13 , vastutav täitja: prof Vello Kukk).*

The main goal of the project is developing appropriate models for learning process that enable efficient control of learning process and developing prototypes of knowledge structures to be used as base of learning. The work is based on learning log files collected in previous years consisting more than 200 thousand records, and from 2010/2011 when first implementation of competence-driven environment was launched. This first launch confirmed efficiency of that approach but also raised several problems that must be solved along with essential development of the environment. New model of tasks connecting them with competences will be developed. This model considers task as a multipole with nodes representing competencies and having different nature. Higher levels of competences will be developed not as tree structure but combining lower level elements in overlapping mode. It is assumed that those structures can also be built as personal ones to enable creation of personal learning paths. New generic models for analysis of answers will be developed. Scripts produced from old tasks appeared to be usable but far from perfect solutions. The scripts are extremely important components as they determine changes in learner’s state (both knowledge level and forgetting parameters). As the number of tasks is huge, any economy and automation in producing of scripts is vary valuable. Development of new structures, methods, and tools must be verified in real learning processes. Therefore, remarkable part of the work is creation and testing new tasks, competencies, scripts, and control mechanisms. All main types of tasks will be implemented: theoretical, conventional labs (both home kits and fixed locations), distant and virtual labs. Developing combinations of those activities is also to be considered.

Aruandeaastal saadud tähtsamad teadustulemused:

1. Formation of multilevel knowledge structure.
   Two-level structure has been built and implemented in part of learning control process. The idea behind that structure is that second level entities are formed as sets of first-level competences (groups) so that number of tasks which are based on a group is acceptable.
2. Creation of competence-task model as relationships between competencies and tasks (problems).
   Competence-task model has been built that has served as basis for two-level knowledge model. This model assumes that every task has accompanying competences part of which are considered as input ones and some may serve as output: it is not guaranteed that they can be evaluated when processing the answer.
3. Improving forgetting model as part of controller to achieve more efficient learning.
   The model has been analyzed for periods from 1 hour to 1 year. It is based on power law, exhibited good performance even for periods up to 1 year, and therefore only minor corrections were introduced into model. New data will be analyzed by the end of 2013 and it is expected that this model will be corrected for medium-time behavior. A guess exists that for periods from 1 day to 3 months improvements must be introduced.
4. Implementing environment - creating tasks (theoretical, conventional labs, virtual labs, and distant labs).
   During this project, new tasks were created and modified: Number of new theoretical tasks is 3606 in 84 classes; number of new lab tasks and new or modified classes is 100. This was accompanied by introduction of 60 new competences and 9 new groups. Absolutely new experiment was carried out when a professional standard (related to civil engineering) was implemented with 26 competences and 509 tasks in 4 groups.
5. Testing of elaborated models and data structures in real learning process.
   One new course was developed (Microprocessor Systems), one course was substantially modified to bring it into new environment and 8 courses modified by reconfiguration based on two-level competence model and improving answers processing.

Uurimisgrupi olulisemad publikatsioonid aruandeaastal:

Jaanus, M.; Udal, A.; Kukk, V.; Umbleja, K. (2013). Using Microcontrollers for High Accuracy Analogue Measurements. Electronics and Electrical Engineering, 19(6), 51 - 54.

Umbleja, K.; Kukk, V.; Jaanus, M. (2013). Competence-Based Approach to Learning. In: IEEE EDUCON2013: IEEE EDUCON2013, Berlin, Germany, March 13-15, 2013. IEEE, 2013, 552 - 559.

Umbleja, K.; Kukk, V.; Jaanus, M.; Shvets, O. (2013). Laboratory Experience with Competence Based Learning. In: ICEER'13 CONFERENCE PROCEEDINGS: ICEER 13, Marrakesh, Morocco; 1-5.06.13. , 2013, 487 - 494.

2.2 Loetelu struktuuriüksuse töötajate rahvusvahelistest tunnustustest.

2.3 Loetelu struktuuriüksuse töötajatest, kes on välisakadeemiate või muude oluliste T&A-ga seotud välisorganisatsioonide liikmed.

2.4 Soovi korral lisada aruandeaastal saadud T&A-ga seotud tunnustusi (va punktis 2.3 toodud tunnustused), ülevaate teaduskorralduslikust tegevusest, teadlasmobiilsusest ning anda hinnang oma teadustulemustele.

<u>Teaduskorralduslik tegevus ja teadlasmobiilsus</u>

Prof. Leo Mõtus:
Eesti Teaduste Akadeemia - peasekretär
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
Kaitseministeeriumi Teadusnõukogu - aseesimees

Van. teadur Jürgo–Sören Preden:
Kaitseministeeriumi Teadusnõukogu – liige (Tallinna Tehnikaülikool, NATO STO SCI paneeliesindaja)

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)

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

Prof. Vello Kukk:
Institute of Electrical and Electronics Engineers, Inc. (IEEE) - liige
IEEE Estonia Section, Education Society Chapter – Chair (esimees)