

INFOTEHNOLOOGIA TEADUSKOND
INFORMAATIKAINSTITUUT
TEADUS- JA ARENDUSTEGEVUSE AASTAARUANNE 2014

1. Instituudi struktuur

Informaatikainstituut, Department of Informatics

Instituudi direktor Prof Rein Kuusik

- Informaatika aluste õppetool, Chair of Foundations of Informatics, Prof Rein Kuusik
- Infosüsteemide õppetool, Chair of Information Systems, Dr Erki Eessaar
- Infoturbe õppetool, Chair of Information Security, Prof Ahto Buldas
- Tarkvaratehnika õppetool, Chair of Software Engineering, Prof Kuldar Taveter
- Teadmussüsteemide õppetool, Chair of Knowledge-Based Systems, Prof Jaak Tepandi
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2. Instituudi teadus- ja arendustegevuse (edaspidi T&A) iseloomustus

(NB! punktid 2.1- 2.6 täidab struktuuriüksus)

2.1 Struktuuriüksusesse kuuluvad uurimisgrupid *(kõik uurimisgrupid näidatakse aruandes eraldi, järgides alltoodud ülesehitust).*

Uurimisgrupi nimetus (eesti ja inglise keeles) ja juhi nimi

- uurimisgrupi teadustöö kirjeldus *(inglise keeles)*;
- uurimisgrupi aruandeaastal saadud tähtsamad teadustulemused *(inglise keeles)*;
- uurimisgrupi kuni 5 olulisemat publikatsiooni aruandeaastal.

Sotsiotehniliste süsteemide ja e-riigi uurimisrühm – Research Group of Sociotechnical Systems and e-Governance (Leader: Prof Kuldar Taveter, Members: Dr Alexander Norta, Dr Enn Õunapuu, Dr Innar Liiv, Dr Tarmo Veskiõja, Dr Mati Tombak, Prof Rein Kuusik, Dr Lea Elmik, Dr Ingrid Pappel, Gretet Lind, Ingmar Pappel, Mart Roost, Karin Rava).

- Description: This goal of the research group is creating a synergy between engineering, technology, exact, natural, health and social sciences. Accordingly, the research group applies in ICT exact sciences as well as social sciences, healthcare, and psychology. In 2014 the research work by this group was centred on the research project by the Department of Informatics “Model-based Creation and Management of Evolutionary Information Systems” (SF0140013s10, 2010-2014) funded by the Estonian Ministry of Education and Research. The goal of the project was to create a method for developing information systems that evolve in an evolutionary way jointly with businesses by means of constant development. For achieving that goal, we took an approach of sociotechnical systems by which we mean systems that support social processes by hardware and software within and between organisations. Our research work in the project combined four research topics represented at the Department of Informatics: archetypes-based software engineering (led by Prof Jaak Tepandi, please see also the Research Group of Robust and Cooperative Evolving Systems), data mining (led by Dr

Innar Liiv, please see also the Industrial Data Mining Laboratory), service-oriented architectures (led by Dr Enn Õunapuu, please see also the Laboratory of Web Services and Sensor Networks), and agent-oriented modelling (led by Prof Kuldar Taveter, please see also the Laboratory of Socio-Technical Systems).

- Results: The main results were as follows:
 - i) Our researchers have proposed reference architecture for managing dynamic business and governmental processes. The reference architecture can be easily turned into domain-specific architectures and concrete architectures. A resulting domain-specific or concrete architecture can be easily changed and evolved with the help of the reference architecture (publication 1).
 - ii) The researchers of the research group have proposed the framework for the transition of local governments to e-Governance (e-LocGov model) and have created an implementation methodology for the launch of paperless management in local governments. A PhD thesis by Ingrid Pappel was defended on this topic (publication 3). In the same research direction of e-governance, we have also addressed the area of privacy protection by software agents and its possible support by regulation (publication 4).
 - iii) The research group has been developing experimental data mining tools that can compare and apply different structural pattern mining algorithms (serialization, matrix reordering, etc.), and generate relevant hypotheses, where the datasets analysed consist of events recorded in different information systems. Using such approach enables the researchers to analyse the usage of the sociotechnical system in the bottom-up manner, proceeding from separate events in logs generated by the system to meaningful chains of events, i.e., processes, representing detection of “social trails” in sociotechnical systems. Process mining of this kind helps to decide how the information system should be evolved (publication 2).
 - iv) Experimental data mining tools for information systems’ logs analysis described under iii) require powerful pattern matching algorithms. This need has prompted the research of pattern matching for superpositional graphs. Superpositional graph (SPG) is a special subclass of binary graphs. Binary graph is a skeleton of binary decision diagrams and SPG is a skeleton of structural decision diagrams. We have defined four versions of the pattern matching problem for SPG, which have different degrees of freedom. For the most general version of the pattern matching problem we have developed a dynamic programming algorithm with caching that tests pattern matching and has time complexity $O(nk)$ where n is the length of the text and k is the length of the pattern. We have proven through implementing prototype software that every match of SPG is a match of the corresponding separable permutations (we used a bijection function between SPG and separable permutations that was established by our research group in 2011). This result allowed solving an open question about the existence of a linear time algorithm for pattern matching of separable permutations.
 - v) Based on the pattern matching described above, an algorithm for the mining of frequent closed itemsets has been developed. This is an algorithm of zero-factor-free determinacy analysis for finding out how to detect by a monotone systems’ algorithm if an object belongs to a class. It is based on simultaneous finding of closed sets and their generators.

For describing the underlying data, three types of rules can be found: class detection rules, (positive) association rules, and negative association rules. The methodology of using the algorithm was developed in collaboration with the Estonian social and market research company Saar Poll LLC. The algorithm has been implemented by Liisa Jõgiste and is presented in her Master's thesis that was defended in January of 2014. In addition, a paper by Liisa Jõgiste and her co-authors, which describes zero-factor-free determinacy analysis and the relevant algorithm, has been submitted to a conference. Two more Master's theses concerning monotone systems' algorithms were defended in 2014: one by Martin Rebane on the topic "Solving rule set optimization problem of the MONSA family of algorithms and implementation in Java" and the other one by Meelis Pruks on "Realization of Equivalence Class Based Clustering". The latter uses an algorithm based on monotone systems for finding equivalence classes (that algorithm has not yet been published).

– *Publications:*

1. Norta, A.; Grefen, P.; Narendra, N. (2014). A reference architecture for managing dynamic inter-organizational business processes. *Data and Knowledge Engineering*, 91, 52 - 89.
2. Liiv, I.; Lepik, O. (2014). Business Process Mining in Warehouses: a Case Study. In: *Databases and Information Systems: Proceedings of the 11th International Baltic Conference, Baltic DB&IS 2014, Tallinn, Estonia, 8-11 June 2014*. (Toim.) Haav, H.-M.; Kalja, A.; Robal, T. Tallinn: Tallinn University of Technology Press, 2014, 387 - 394.
3. Pappel, I. (2014). Paperless Management as a Foundation for the Application of e-Governance in Local Governments. Doctoral thesis, Tallinn University of Technology. Tallinn University of Technology Press.
4. Rull, A; Täks, E; Norta, A. (2014). Towards software-agent enhanced privacy protection. Kerikmäe, T. (Eds.). *Regulating eTechnologies in the European Union: Normative Realities and Trends (73 - 94)*. Springer.

Usaldusväärsete ja koostöötavate arenemisvõimeliste süsteemide uurimisgrupp – Research Group of Robust and Cooperative Evolving Systems (Leaders: Prof Jaak Tepandi, Dr Gunnar Piho, Members: Pille Haug, Jekaterina Ivask, Tõnis Pihlakas, Viljam Puusep, Stanislav Vassiljev).

- *Description:* Evolving information systems are able to change according to changes in organizations and their business processes. Technologies needed for evolving systems development are powerful and when widely deployed without sufficient control, may potentially lead to disruptive results in economy and well-being of humans. The work by this research group aims to develop techniques for enterprise applications that software end users, in collaboration with software developers, are able to change safely and easily according to changing requirements, ensuring at the same time robustness and cooperation of the systems through verification, validity, security and control. The techniques developed and applied by the research group have been introduced at the following different levels of system architecture: enterprise domain modelling for evolutionary software based on the mathematical formalism of P-systems; utilization of archetypes and archetype patterns in the development of domain models, requirements, and software; simulation of agent behaviour for evolving systems; designing the overall system architecture to achieve maximum usability;

domain model specification directly in a general purpose programming language to make modifying a system easier; finding and formalizing a set of meta-information sufficient for an efficient coupling of segregated data models; visualization of big data for providing feedback for the evolution process. The research has been performed in partnership with CBPG (Clinical and Biomedical Proteomics Group, Leeds Institute of Cancer and Pathology, University of Leeds), Cancer Research UK, and Stockholm University.

- Results: The main results achieved in 2014 were the following ones:
 - i. The business archetype patterns (Product, Party, Order, Inventory, Quantity and Rule), composed of business archetypes (e.g. Person's Name, Address, etc.) have been presented as information models describing the problem domain of businesses. This enables satisfying evolutionary criteria of the second order – achieving the possibility to change requirements and domain models easily and safely at runtime without damaging the working systems and causing losses for businesses (publication 1).
 - ii. A study on data linking has been conducted considering that semantic interlinking of data directly supports the development of evolving e-Government services. The study identified proposals for and obstacles to presenting data in a linked form for e-Government services in Estonia (publication 2).
 - iii. The ongoing research on usability testing has focussed on case studies for analysing interconnections between the system architecture and usability properties.
 - iv. The research on domain model specification has demonstrated that the sentence patterns written in the RAISE Specification Language are semantically equivalent to the patterns expressed in the C-SHARP language.
 - v. Validation of evolving systems has so far resulted in a method for using genetic algorithms for system testing. These research results in this area are subject to publication in the next two years.
- Publications:
 1. Piho, G.; Tepandi, J.; Thompson, D.; Tammer, T.; Parman, M.; Puusep, V. (2014). Archetypes based Meta-modeling towards Evolutionary, Dependable and Interoperable Healthcare Information Systems. The 4th International Conference on Current and Future Trends of Information and Communication Technologies in Healthcare (ICTH 2014), Halifax (Canada), September 22-25, 2014. Elsevier, 2014, (Procedia Computer Science; 37), 457 - 464.
 2. Kūngas, Peep; Haav, Hele-Mai; Tepandi, Jaak; Tepandi, Lauri; Lauk, Mihkel; Tars, Triin (2014). Study "Linked Estonia". ISBN 978-9949-33-722-4, Tallinn, Ministry of Economic Affairs and Communications (In Estonian).

Andmebaaside uurimisrühm – Research Group of Databases (Leader: Dr Erki Eessaar, Members: Rünno Sgirka, Mart Karu).

- Description: This research group conducts research in the following directions:
 1. How to semi-automate the process of achieving good database design and evaluating existing database designs? The results would allow developers to come up with better designed databases and facilitate the evolution of databases. The focus of the research is on the design of relational databases and SQL databases, which are not equivalent in our view. However, the approach in general would be usable also in case of other kinds of databases. According to our approach, *firstly* the implicit knowledge about good and bad/questionable database designs must be made explicit. One can do this by specifying domain-independent and domain-specific database design patterns and antipatterns which respectively describe good and bad/questionable design practices. One can use the patterns and antipatterns as important “goodness” criteria in evaluating existing database designs, selecting the best design for a new database, or selecting the best refactoring for an existing database. One can also use the patterns as building blocks for specifying database designs and later on for generating the code (and possibly tests) to implement the designs. It is also possible to search, based on the system catalogue, for possible occurrences in a database schema of domain-independent database design patterns and antipatterns. *Secondly*, design decisions depend on the context where the designed database will be used. The context determines the relative importance of criteria for selecting the best design. We are interested in how to apply the Analytic Hierarchy Process or a similar process for comparing database designs and selecting the best design for a given context.
 2. Specification, formalization, evaluation, and application of the set of practices for the development of data-centric transactional information systems. The practices use data models and the lifecycles of the main entity types to drive the modelling of information systems, including process modelling. These practices are based on the years of experience of teaching the development of information systems to university students with the focus on database development.
 3. Experiments about using the full power of modern database management systems (DBMS) to implement complex, functionally rich systems based on the architectural principle of the “fat database”. *Firstly*, server DBMSs are like virtual operating systems that can be deployed on many different platforms and locations. *Secondly*, DBMSs have many built-in features and extensibility mechanisms (including powerful query language, semantic query optimization, transaction support, triggers, possibility to create federated systems, user-defined types, support for JSON and XML etc.) that simplify the development and optimization of information systems. For instance, currently we are building a metamodelling (meta-CASE) system by using this approach. In addition, we are interested in the anchor modelling approach. The usage of the latter results in a database design that elegantly supports dealing with missing information and addresses recording of historic data values and schema changes due to evolution of the information system at hand. Consequently, the anchor modelling approach for database design could be applied for evolutionary information systems.

– Results:

- i. In the context of the research direction 1, *firstly* we have extended the set of queries for detecting design problems in PostgreSQL databases. In total, there are now about 50 queries. We have successfully used the queries for the partial automation of the assessment of about 50 student projects in the course “Databases II”. At the end of 2014, a Bachelor’s student (as a part of his Bachelor’s thesis) completed the first version of a web-based interface for students (or in principle for any developer). It allows students to evaluate the designs of their databases and enables continuous feedback during the design process. We plan to start using the tool in the course “Databases II”. *Secondly*, we have also studied more generally how to detect the orthogonality problems of software languages based on their metamodels using the example of a data model. This work was prompted by the fact that a database language that is not well designed makes it more difficult to teach, study, and use the language, and possibly leads to bad decisions on database design. In other words, this work is about abstract languages that one can use to create databases. However, the general theme is the same – how to find semi-automatically design problems in database-related artefacts? The results were presented at the virtual conference “International Conference on Systems, Computing Sciences and Software Engineering” (SCSS 14). The proceedings of this conference will be published later in 2015. *Thirdly*, two Master’s theses were supervised that completed investigating different design solutions (“The Influence of Views to the Creation of Query Execution Plans in the Example of Two Database Management Systems” and “Representing Hierarchical Data in SQL Databases in the Example of Three Design Solutions”). Works of this kind that also include experimentation offer a valuable input to the process of specifying domain independent design patterns and selecting the best possible design for a given context.
- ii. In the context of the research direction 2, we have continued elaborating the specification of the development practices and have tested the specification on the students taking the course “Databases I”. We have also investigated how to integrate our approach with the emerging theory of normalized systems. More specifically, we have studied how to use the theory of normalized systems to evaluate the quality of information systems’ business architectures. We have published two papers on this topic (publications 1 and 2). The use of the development practices reduces combinatorial effects between subsystems of an information system but does not eliminate the effects and hence the result is not a normalized system. Nevertheless, the use of the development practices lays the groundwork for the design and implementation of an information system as a normalized system. However, the result largely depends on the selection of platforms and on the design of more fine-grained elements of the system. This work helps us to identify certain problems in the information systems’ business architectures forming the foundation for the database development. Therefore this work is also related to the research direction 1.

- iii. In the context of the research direction 3, a complete rewriting of the metamodelling system continued by a Master's student based on the results of the paper by Eessaar and Sgirka from 2013. The new system will extensively use database triggers for implementing the main functionality of the DBMS
 - iv. In the context of the research direction 3, at the end of the year 2014 another Master's student completed the first version of a code generator based on anchor models as a part of his Master's thesis. The generated code implements anchor models in PostgreSQL databases. The code generator accompanies an existing web-based anchor modelling system and is created by using the system's existing framework for developing code generators. The implemented generator will allow us to conduct experiments about using anchor modelling for the design and evolution of transactional databases. Related also to the research direction 1, the queries have been created for detecting possible occurrences of SQL database design antipatterns within the conceptual schemas of existing databases. The queries are based on a database's system catalogue but some queries also take into account data in the existing tables of the database. The queries were implemented in PostgreSQL. They are based on the standardized information schema views and were evaluated based on a set of databases to find frequencies and reasons of false positive results. In addition, a prototype tool for executing the queries has been developed. The tool and the queries can be used in the database programming courses. Students can use both to get quick and continuous feedback about their database designs. At the same time academics can use the tool and the queries to speed up the assessment of student databases. The results were presented at the virtual conferences International Conference on Systems, Computing Sciences and Software Engineering (SCSS 12 and SCSS 13). The proceedings of these conferences will be published later in the year 2015.
- *Publications*: The publication about the orthogonality problems will appear in 2015. Below are presented the publications that appeared in 2014. Papers 1 and 2 were presented in 2014 and Paper 3 was presented in 2013. All the publications listed below support the research direction 2:
1. Eessaar, E. (2014). On Applying Normalized Systems Theory to the Business Architectures of Information Systems. *Baltic Journal of Modern Computing*, 2(3), 132 - 149.
 2. Eessaar, E. (2014). Specifying Business Architecture as a Step Towards Achieving Normalized Systems. In: *Databases and Information Systems: 11th International Baltic Conference on DB and IS*, June 8-11, 2014, Tallinn, Estonia. (Eds.) Haav, H.-M.; Kalja, A.; Robal, T. Tallinn: Tallinn University of Technology Press, 2014, 425 - 432.
 3. Eessaar, E. (2014). A Set of Practices for the Development of Data-Centric Information Systems. In: *Information System Development. Improving Enterprise Communication: 22nd International Conference on Information Systems Development (ISD2013)*, Seville, Spain, September 2-4, 2013. (Eds.) José Escalona, M.; Aragón, G.; Linger, H.; Lang, M.; Barry, C.; Schneider, C. Switzerland: Springer, 2014, (Information System Development), 73 - 84.

Arvutilingvistika uurimisrühm – Research Group of Computational Linguistics (Leader: Professor Emeritus Leo Võhandu, Members: Kairit Sirts, Ahti Lohk, Andre Veski, Ottokar Tilk, External collaborators: Addi Rull (Tallinn Law School of TUT), Tõnu Tamme (Tartu University))

- *Description*: The research group is active in the field of multidimensional scaling of large matrixes and tensors. The research group has created and applies a novel unifying method for solving three NP-hard tasks: multidimensional scaling, obtaining minimal crossing number within binary graphs, and graph bandwidth minimising.
- *Results*:
 - i. Kairit Sirts will defend in mai of 2015 her PhD dissertation about unsupervised clustering of words according to their fine-grained morphosyntactic functions. The approach proposed by her is very useful for building natural language processing systems for languages for which there is no annotated training data or linguistic description of morphology. Kairit Sirts has demonstrated in an article with her collaborators from Edinburgh University, UK, the applicability and utility of this model for the English language. In June of 2014 she presented the results at a very high-level conference in the USA (publication 1).
 - ii. Ahti Lohk will likewise defend in February of 2015 his PhD dissertation about an experimental system for hierarchical relational systems. He has created a nice formal methodology for studying polysemy in WordNet-like dictionaries with multiple inheritance between the terms. The work by Ahti Lohk from 2014 has been reported in the publications 2 and 3.
 - iii. Andre Veski has followed up his study of formal matching methods. His research has addressed resource allocation mechanisms without money – fair division and matching markets. Fair division often arises in collective decision-making. For example, the task of allocating resources to a project has recently become more relevant in the context of allocating computational cloud resources. The allocation mechanism of matching markets is needed when resources are indivisible and are allocated with two-sided preferences, like school seats or job positions. Andre Veski is currently looking at trade-offs with different objective criteria for fair division like equality, efficiency, envy-freeness etc., and efficiency and stability in matching markets. He has shown how bad an uncoordinated matching market can be compared to a fully centralised clearing house under various market conditions. The most interesting research results by Andre Veski from 2014 have been reported in the publication 4.
 - iv. Ottokar Tilk has been focusing on the language models for multi-domain neural networks to improve performance in the target domain. He has extended the work by Tanel Alumäe from recurrent networks to less sensitive additive factors. The proposed architecture provides good estimates for performance on unseen (test) data. The research results by Ottokar Tilk from 2014 have been reported in the publication 5.
 - v. Leo Võhandu, Tõnu Tamme and Addi Rull have used the Markov Chain Model with Mosteller normalisation to study the Estonian regulatory system. The aim of the study was to identify the core of the Estonian Constitution. Theoretical verification and experiments have been performed to determine the grammatical similarity between the fundamental

rights of citizens and Penal Law. The results achieved suggest that the core of the Constitution lies in the first level of citizens' fundamental rights. Our claim can be further tested by calculating the impact of fundamental rights, individual freedoms, and constitutional principles in relation to case law. This would yield us the reflection on how widely the norms on citizens' fundamental rights are used in daily practice as opposed to the rest of the norms included by the Constitution. The identification of the core of the Constitution offers interesting leads for the future. The results of the described research effort have been reported in the article "Identifying Core Norms of the Constitution" which was submitted to the 15th International Conference on AI and Law (ICAAIL 2015) to be held at the University of San Diego in California, USA, on June 8-12, 2015.

– *Publications:*

1. Sirts, Kairit; Eisenstein, Jacob; Elsner, Micha; Goldwater, Sharon (2014). POS induction with distributional and morphological information using a distance-dependent Chinese restaurant process. In: The 52nd Annual Meeting of the Association for Computational Linguistics. Proceedings of the Conference. Volume 2: Short Papers: ACL 2014, June 22-27, Baltimore, USA, 22-27 June, 20: Stroudsburg, PA: Association for Computational Linguistics, 2014, 265 - 271.
2. Lohk, A.; Vöhandu, L. (2014). Independent Interactive Testing of Interactive Relational Systems. A. Gruca, T. Czachórski, S. Kozielski (Eds.). Man-Machine Interactions 3 (63 - 70).Springer
3. Lohk, A; Norta, A; Orav, H; Vöhandu, L. (2014). New Test Patterns to Check the Hierarchical Structure of Wordnets. G. Dregvaite, R. Damasevicius (Eds.). Information and Software Technologies: 20th International Conference, ICIST 2014, Druskininkai, Lithuania, October 9-10, 2014. Proceedings (110 - 120).Springer
4. Veski, A. (2014). Price of Invisibility: Statistics of centralised and decentralised matching markets. In: Proceedings of the 5th. World Congress on Social Simulation: 5th. World Congress on Social Simulation (WCSS 2014), Sao Paulo, Brazil, 2014. (Edit.) E. MacKerrow, T. Terano, F. Squazzon, J. Simão Sichman., 2014, 18 - 29.
5. Tilk, Ottokar; Alumäe, Tanel (2014). Multi-domain recurrent neural network language model for medical speech recognition. Human Language Technologies - the Baltic Perspective : Proceedings of the Sixth International Baltic Conference, Baltic HLT 2014. (Eds.)Utka, Andrius; Grigonytė, Gintarė; Kapočiūtė-Dzikienė, Jurgita; Vaičenonienė, Jurgita. Amsterdam: IOS Press, 2014, (Frontiers in Artificial Intelligence and Applications; 268), 149 - 152.

Tööstusliku andmekaeve labor – Industrial Data Mining Lab (Leader: Dr Innar Liiv, Members: Dr Jaan Übi, Anton Vedeshin, Ott Lepik, Natalia Järv)

- *Description:* Industrial Data Mining Lab performs joint research and training projects with various companies from the industry in the areas of banking, telecommunication, supply chain management, warehousing etc., and teaches similar topics (data mining, business intelligence, customer behaviour analysis) to students in logistics, IT and business.
- *Results:* For the Industrial Data Mining Lab the highlights of the year 2014 were the following ones:

- i. Industrial Data Mining Laboratory signed a new contractual research agreement with Mitsubishi Motors Corporation on the mining and analysis of big data generated by 507 electric cars of the i-MieV type from Mitsubishi, which were bought by the Estonian government under the auspices of the Green Investment Scheme created by the United Nation's Kyoto Protocol.
 - ii. Jaan Übi (supervised by Dr Innar Liiv and Dr Mati Tombak) successfully defended his PhD thesis (publications 1 and 2).
- Publications:
1. Übi, J.; Ubi, E.; Liiv, I.; Murtazin, K. (2014). Predicting Student Retention by Linear Programming Discriminant Analysis. International Journal of Technology and Educational Marketing, 4(2), 43 - 53.
 2. Übi, J. (2014). Methods for Coopetition and Retention Analysis: An Application to University Management. Doctoral thesis, Tallinn University of Technology. Tallinn University of Technology Press.

Veebiteenuste ja sensorsüsteemide labor – Laboratory of Web Services and Sensor Networks (Leader: Dr Enn Õunapuu, Members: Kristo Klesment, Irina Kelder, Viljam Puusep, Einar Polis)

- Description: The goal of the laboratory is to develop solutions for the era of Internet of Things (IoT). Main components of these solutions are smart devices, processes, and services. For the students we have developed a course „Internet of Things Solutions: Smart Devices, Processes, and Services“. The focus of the research work is on model-driven development of smart solutions in the application domains of smart home, e-billing, and power engineering.
- Results: The objective of the research conducted in 2014 was proposing a methodology for teaching and implementing smart IoT-solutions. In particular, the following results have been achieved in 2014:
 - i. A model-driven development method for IoT-solutions usable on mobile devices has been proposed. The method prescribes defining an IoT-solution through the usage of the goal model, decision model, process model, data model, user interface model, and integration model. Based on correctly composed models of these kinds, the user can begin testing the solution.
 - ii. For teaching IoT-solutions we have applied a serious gaming approach. In serious gaming, the simulations of real world events and processes are used for analysing complex situations and for proposing solutions. The usage of serious games is entertaining, but their primary goal is training and educating people. Simultaneously, serious games may have other goals, such as marketing or advertising.
 - iii. A tool has been further developed for enterprise information systems' development targeted at SMEs, where information systems' development and evolution occur through developing various models at the business level, such as models of goals and business rules, and organisation model, and generating solutions consisting of appropriate components from the set of models. Different business rules' engines have been experimented with for increasing the adaptability of the tool. The tool is rooted

in the ARCHI tool for describing enterprise architectures and in the Bizagi tool for business process modelling.

– Publications:

1. Õunapuu, E. (2014). Teaching and promoting smart internet of things solutions using the serious game approach. L. Jain (Ed.). FUSION OF SMART; MULTIMEDIA and COMPUTER GAMING TECHNOLOGY: RESEARCH, SYSTEMS and PERSPECTIVES (1 - 20). Berlin, Germany: Springer-Verlag [forthcoming].

Sotsiotehniliste süsteemide labor – Laboratory of Socio-Technical Systems (Leader: Prof Kuldar Taveter, Members: Dr Alexander Horst Norta, Dr Ermo Täks, Dr Ants Torim, Dr Tarmo Veskioja, Lixin Ma, Inna Shvartsman, Kristi Kirikal, Tanel Tenso, Msury Mahunnah, Andrus Kanarbik, Stanislav Vassiljev).

- Description: The lab focuses on software engineering methods for designing systems that support humans in their everyday activities. Such systems include educational (training) systems and systems for simulating real-world phenomena combined with them, intelligent digital assistants for social networking services and systems for individualised healthcare and smart home and office. The lab applies the methodology of agent-oriented modelling for designing sociotechnical systems.

- Results: In 2014 the lab has achieved the following results in designing sociotechnical systems:

- i. We have elaborated the agent-oriented method proposed by Sterling & Taveter in 2009 for engineering requirements for sociotechnical systems (publication 1).
- ii. Shvartsman and Taveter have advanced the method for generating “human-in-the-loop” training scenarios for winning by the foreign aid and/or peacekeeping troops the “hearts and minds” of local people living amidst military conflicts in the countries like Afghanistan and Republic of Central Africa (publication 2).
- iii. Under the leadership of Dr Alexander Norta, the research group has pushed forward the method of agent-oriented modelling by Sterling & Taveter towards designing large sociotechnical service ecosystems (publication 3).
- iv. Agent-oriented models proposed by Sterling & Taveter have been mapped to Coloured Petri Nets and the relevant methodology has been proposed and applied in the problem domain of individualised healthcare (publication 4).
- v. Several members of the research group have participated in the project by the EU 7th Framework “Modelling crisis management for improved action and preparedness” (CRISMA). In the project the Laboratory of Sociotechnical Systems has been engaged in creating an agent-based sociotechnical “human-in-the-loop” simulation system for resource management and decision-support in crisis management. In the context of the project, the software engineering method of agent-oriented modelling by Sterling & Taveter has been used and extended by PhD student Tanel Tenso and Prof Kuldar Taveter in the direction of agile software engineering. In parallel, junior researcher Lixin Ma has been studying in the project representing and utilizing Key Performance Indicators of crisis mitigation. Also, Stanislav Vassiljev has designed and implemented an evacuation simulation in the project using the NetLogo platform.

- vi. In 2014 a Master Scientific Consulting Agreement was signed between Jeppesen GmbH, a subsidiary of Boeing, and Tallinn University of Technology. In the scope of the agreement, two M.Sc. students have been working on their respective topics “Analysis & Modelling of Cross-Organizational Airline Workflows” and “Agent-Oriented Modelling and Simulation of Airline Workflows” under the supervision of Dr Alexander Nortä and Prof Kuldar Taveter, respectively. The collaboration has so far resulted in the successful defence of a Master’s thesis by Jekaterina Balashova on the topic “Agent Oriented Modelling and Simulation of Airline Workflows”.
- vii. Prof Kuldar Taveter, Dr Ermo Täks, Dr Tarmo Vesikioja and PhD student Msury Mahunnah have been involved in the 12-month joint application-oriented research project with the Software Technology and Applications Competence Centre (STACC) and the industry partner Quattromed HTI on the topic “Individualised healthcare decision support system”. The project is funded by Enterprise Estonia.
- viii. Prof Kuldar Taveter and Dr Ants Torim have performed the case study on the influence of continuous sitting on one’s health in collaboration with the Department of Mechatronics of TTU and Tallinn City Council.

– Publications:

1. Miller, T.; Lu, B.; Sterling, L.; Beydoun, G.; Taveter, K. (2014). Requirements Elicitation and Specification Using the Agent Paradigm: The Case Study of an Aircraft Turnaround Simulator. IEEE Transactions on Software Engineering, VOL. 40(No. 10), 1007 - 1024.
2. Shvartsman, I.; Taveter, K. (2014). From Agent-Oriented Models to Profile Driven Military Training Scenarios. In: Intelligent Distributed Computing VII: 7th International Symposium on Intelligent Distributed Computing -IDC 2013, Prague, Czech Republic, September 2013. (Eds.)F. Zavoral, J. J. Jung, C. Badica. Springer, 2014, (Studies in Computational Intelligence; 511), 317 - 322.
3. Nortä, A.; Mahunnah, M.; Tenso, T.; Taveter, K.; Narendra, N.C. (2014). An Agent-Oriented Method for Designing Large Sociotechnical Service-Ecosystems. IEEE 10th World Congress on Services (242 - 249).IEEE
4. Mahunnah, M.; Nortä, A.; Ma, L.; Taveter, K. (2014). Heuristics for Designing and Evaluating Socio-Technical Agent-Oriented Behaviour Models with Coloured Petri Nets. Proceedings of the IEEE COMPSAC 2014 (438 - 443). IEEE.

2.2 Loetelu struktuuriüksuse töötajate rahvusvahelistest tunnustustest.

Ei ole.

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

1. Enn Õunapuu; Association for Computing Machinery (ACM); Liige
2. Enn Õunapuu; Institute of Electrical and Electronics Engineers (IEEE); Liige
3. Enn Õunapuu; IARIA scientific committee member of the Journal Editorial Board
4. Mart Roost; IFIP WG8.2 Information Systems and Organizations töögrupi liige

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

Teadlasmobiilsus:

1. Lixin Ma Shanghai Teaduse- ja Tehnoloogiaülikoolist Hiinast töötas nooremteadurina informaatikainstituudi sotsiotehniliste süsteemide labori juures ajavahemikul veebruar 2014 – veebruar 2015. Lixin Ma osales Euroopa Liidu 7. raamprogrammi projektis “Modelling crisis management for improved action and preparedness” (CRISMA).
2. Alexander Norta: osalemine 2 ettekandega konverentsil „2014 IEEE 10th World Congress on Services“ ja 1 ettekandega konverentsil „2014 IEEE 11th International Conference on Services Computing“ ja 3 sessiooni juhatamine, Anchorage, Alaska, USA, 27.06.-02.07.2014.
3. Msury Mahunnah: osalemine ettekandega „Heuristics for Designing and Evaluating Socio-Technical Agent-Oriented Behaviour Models with Coloured Petri Nets“ konverentsil „The 38th Annual International Computers, Software & Applications Conference (IEEE COMPSAC 2014)“, Västerås, Rootsi, 20.07.-26.07.2014.
4. Olga Mironova: osalemine ettekandega "Strategies for the Individualization of an Informatics Course" konverentsil „Federated Conference on Computer Science and Information Systems (FedCSIS 2014)“, Warsaw, Poola, 06.09.-11.09.2014.
5. Alexander Norta: Osalemine Horizon 2020, ICT30-2015 projekti planeerimiskoosolekul, (http://beaware-aero.eu/information/?event_id_1=19), Bukarest, Rumeenia, 15.09.-19.09.2014.
6. Gunnar Piho: osalemine ettekandega „Archetypes based Meta-modeling towards Evolutionary, Dependable and Interoperable Healthcare Information Systems“ konverentsil „The 4th International Conference on Current and Future Trends of Information and Communication Technologies in Healthcare (ICTH 2014)“, Halifax, Canada, 20.09.-27.09.2014.
7. Pirjo Elbrecht: osalemine ettekandega „Precision of 3D Body scanners“ konverentsil „18th International Conference on Intelligent Engineering Systems (INES 2014)“, Tihany, Ungari, 02.07.-07.07.2014.

8. Alexander Norta: 2 töötoa juhatamine („1st Workshop on Resource Management in Service-Oriented Computing (RMSOC)“ ja „Intelligent Service Clouds Workshop (ISC 2014)“) konverentsil „12th International Conference on Service Oriented Computing (ICSOC 2014)“, Paris, Prantsusmaa, 02.11.-07.11.2014.
9. Eduard Ševtšenko: osalemine ettekandega konverentsil „25th International DAAAM Symposium "Intelligent Manufacturing & Automation"“, Viin, Austria, 26.11.-30.11.2014.
10. Jaak Henno: osalemine plenaaristungil kutsutud ettekandega „Information and Information Security“ konverentsil „3rd Workshop on Software Quality Analysis, Monitoring, Improvement, and Applications co-sponsorship of IEEE“, Lovran, Horvaatia, 17.09.-22.09.2014.
11. Ahti Lohk: osalemine ettekandega „New Test Patterns to Check the Hierarchical Structure of Wordnets“ konverentsil „20th International Conference on Information and Software Technologies (ICIST)“, Druskininkai, Leedu, 08.10.-11.10.2014.
12. Erki Eessaar: osalemine ettekandega „Searching Orthogonality Problems in Software Languages in the Example of a Data Model“ virtuaalkonverentsil „International Conference on Systems, Computing Sciences and Software Engineering (SCSS 14)“, 12.12.-14.12.2014.
13. Deniss Kumlander: osalemine ettekandega „Unexplored Opportunities to Motivating Personnel Seamlessly by Involving them into Agile Software Development“ virtuaalkonverentsil „International Conference on Systems, Computing Sciences and Software Engineering (SCSS 14)“, 12.12.-14.12.2014.
14. Gunnar Piho: osalemine ettekandega „Archetypes Based Approach towards Interoperable, Dependable and Evolutionary E-Health Software Systems“ konverentsil „BIT's 5th World Gene Convention-2014 (WGC-2014)“, Haikou, Hiina, 11.11.-17.11.2014.
15. Eduard Ševtšenko: osalemine kutsutud ettekandega „Collaborative Project Management Framework for Partner Network Initiation“ virtuaalkonverentsil „2014 Online Conference on Soft-Computing in Industrial Applications“, 01.12.-12.12.2014.
16. Pirjo Elbrecht: osalemine konverentsil "5th International Conference and Exhibition on 3D Body Scanning Technologies", Lugano, Šveits, 19.-23.10.2014
17. Erki Eessaar: osalemine ettekandega „Specifying Business Architecture as a Step Towards Achieving Normalized Systems“ konverentsil „11th International Baltic Conference on DB and IS“, Tallinn, Eesti, 08.06.-11.06.2014.
18. Eduard Ševtšenko: osalemine ettekandega „Partner Selection Criteria for Virtual Organization Forming“ konverentsil „9th International DAAAM Baltic Conference "INDUSTRIAL ENGINEERING““, Tallinn, Eesti, 24.04.-26.04. 2014.

Hinnang

- 1) Instituudi nõukogu koondhinnang aruandlusperioodi teadus- ja arendustööle on „väga hea“ (4). Sama hinnang anti informaatikainstituudi kesksele uurimisrühmale – sotsiotehniliste süsteemide ja e-riigi uurimisrühmale – ka hiljutisel IKT-alase teadustöö sihtvalveerimisel TTÜ-s. Püstitatud ülesanded on valdavalt täidetud, lõpetati sihtfinantseeritav teadusprojekt ja koos automaatikainstituudiga jätkub osalemine EL-i 7. raamprogrammi projektis „Kriisihalduse modelleerimine tegevuste ja valmisoleku parandamiseks“ (CRISMA).
- 2) Võrreldes eelmise aruandlusperioodiga on teadusaktiivsus ja tulemused temaatiliselt edasi arenenud, tõsist analüüsi ja arendamist leidis sihtfinantseeritav teadusteema „Evolutsioneeruvate infosüsteemide mudelipõhine loomine ja haldamine“ (T013). Finantseerimise maht on kasvanud, seda eelkõige välislepingute ja õppearendusprojektide kasvu arvelt. Samas ei kajasta käesolev aruanne täielikult meie töötajate teadus-arendustegevust, sest et nad osalevad ka välistes teadusprojektides (näiteks Prof Ahto Buldas osaleb Küberneetika instituudi grantides ja AS Cybernetica projektides, mis pole registreeritud meie teadusteemadena, mitmed meie töötajad ja doktorandid on osalenud MEKTORY projektides (E. Õunapuu, I. Liiv, J. Ivask, N. Järv, A. Sulakatko jt).

Rahalises väljenduses on viimase kuue aasta dünaamika järgmine:

	2009 (EEK)	2010 (EEK/EUR)	2011	2012	2013	2014
Põhiteema	-	1 508 900/96400	92700	82400	82400	82400
Baasfinantseerimine	1 425 600	-	-	-	-	-
ETF grantid	168 000	-	-	-	-	-
Välisprojektid	-	-	-	21576	40000	57000
Lepingud	300 800	347 400/22203	14345	9000	5300	16000
Individaalsed toetused	Andmed puuduvad	Andmed puuduvad	9921	11383	50200	20000
Õppearendustegevuse projektid	35 000	63 000/4026	50600	40500	34000	125000
Kokku	1929400	1919300/122165	162866	164859	211900	300400

- 3) Publitseerimise seisukohalt tuleb aastat lugeda heaks – 32 rahvusvahelist kõrgtaseme (kategooria 1.1 kuni 3.1) artiklit olukorras, kus neid lisaks põhikohaga teaduritele toodavad regulaarselt ka teaduskohustuslikud õppejõud, on hea tulemus (keskmiselt 1,3 artiklit iga teaduskohustusliku õppejõu ja teaduri kohta). Artiklite tootmise protsess on stabiliseerunud ja arvestades suurt õppetöö koormust on raske paremat nõuda. Samas on olemas veel kasutamata reserve suurema rühma kaasautorite ühisartiklite ja doktorantide aktiivsema tegutsemise näol.
- 4) Kaitsiti kaks doktoritööd (Jaan Übi, Ingrid Pappel). Kaitsmistite arv on küll ühe võrra väiksem planeeritust, aga 2015. aastal on oodata 5 kaitsmist (Kairit Sirts, Ahti Lohk, Inna Shvartsman, Tanel Tenso, Msury Mahunnah).
- 5) Instituudi juurde kuuluva mitteformaalse struktuurina töötab „Tööstusliku andmekaeve labor“ (juht dots. Innar Liiv), mille raames alustati teist MEKTORY projekti Mitsubishi korporatsiooniga. Lisaks teeb labor koostööd Georgia Ülikooliga ja Salisbury Ülikooliga USA-s ning Università degli Studi di Veronaga Itaalias.
- 6) Instituudi juurde kuuluva mitteformaalse struktuurina töötab „Sotsiotehniliste süsteemide labor“ (juht Prof Kuldar Taveter), mille raames jätkati edukalt EL-i 7. raamprogrammi projekti „Kriisihalduse modelleerimine tegevuste ja valmisoleku parandamiseks“ (CRISMA). Lisaks teeb labor koostööd Swinburne Tehnikaülikooliga Austraalias, Lõuna Carolina Ülikooliga USA-s ning Lääne-Sveitsi Rakendusteaduste Ülikooliga Sierres (HES-SO).
- 7) Vastavalt sihtfinantseeritava teadusteema projektiplaanile jätkati 2014. aastal infosüsteemide evolutsioonilise arendamise ühtse metodoloogia põhjal mudelitest tarkvara genereeriva süsteemi arendamisega. Seda käsitleb rida teaduspublikatsioone. Sihtfinantseeritav projekti raames jätkus samuti mooduli realiseerimine, mis toob ärireeglid äriprotsessi mudelist välja. Loodavas prototüübis võtab protsessi mudel reeglitega ühendust läbi veebiteenuse. Niisugune lahendus toetab hästi evolutsioneeruvust, sest võimaldab otsustuste aluseks olevate ärireeglite muutmist sõltumata vastavast äriprotsessist. Sihtfinantseeritav teadusteema lõppes 2014. aastaga. Informaatikainstituut taotles Eesti Teadusagentuurilt institutsionaalset uurimistoetust e-valitsemise ja e-riigi alase uurimistöö jaoks aga ei saanud, kuigi TTÜ näitas antud taotlust prioriteetsena ning tegemist on ka Eesti riigi jaoks väga olulise uurimissuunaga. Õnneks saime ülikoolilt ja teaduskonnalt baasfinantseerimise raha, mida plaanime kasutada e-riigi interdistsiplinaarse uurimiskeskuse sisuliseks käivitamiseks instituudis. Selle keskuse üheks oluliseks komponendiks on kavandatud e-riigi simulatsioonide ja prototüüpide loomise platvorm, mille kavandamise ja realiseerimisega teeme baasfinantseerimise toel algust. Samuti plaanime saata uuendatud taotluse 2015. aasta institutsionaalsete uurimistoetuste taotlusvoorule. Teadus- ja arendustegevuse põhieesmärgiks instituudis aga on saanud uute projektitaotluste ettevalmistamine EL-i „Horizon 2020“ taotlusvoorudeks.
- 8) Aastal 2014 toimusid jätkuvalt sihtfinantseeritava teadusprojekti ning e-valitsemise ja e-riigi teemalised regulaarsed töögruppide aruandeseminarid ja samuti iganädalased instituudi siseseminarid. Arvestades neile juurde 2 iganädalast doktoriseminari, toimub instituudis pea igal nädalal 4 teadusseminari. Stabiilseks peab muutuma nelja doktoritöö kaitsmine aastas, ka ootaks juba kaitsnud doktorite läbimurret rahvusvahelisele tuntusele oma teadustöös (Ermo Täks, Jaan Übi).