

Scientific report for the 2nd period

PART 1 – INFORMATION ON PROGRAM

- 1.1. The title: Next Generation Information and Communication Technologies
- 1.2. The acronym: NexIT
- 1.3. The Web page address - <http://lumii.lv/resource/show/761>
- 1.4. The principal investigator (PI): Dr.sc.comp. Andris Ambainis, +371 67034517, andris.ambainis@lu.lv
- 1.5. Contact person: Ināra Opmane, 67224730, imcs@lumii.lv
- 1.6. The reporting period: 01.01.2015-29.02.2016
- 1.7. The programme aim and objectives:

The aim: to develop scientific capacity in the field of next generation information and communication technologies through creating new and competitive approaches to integrating physical and virtual worlds in cyber-physical systems, developing competitive and innovative intelligent sensing software and hardware platforms for their networks, as well as studying and developing competitive model-based information and communication technologies and their applications in modern web-based environments.

Objectives:

- to conduct a research into quantum technologies and information security, and develop ontology-based technologies;
- to develop large scale data visualization and image-processing technologies and their applications, including for acquiring biometric data and performing qualitative analysis on images of tissues;
- to develop new technologies and software for bioinformatics and biomedicine;
- to conduct a research into big data and knowledge engineering, including processing of medical, satellite and space data;
- to develop methods for mathematical modelling, high performance computing and cyber-physical systems, and to test their application in medicine and smart cities;
- to conduct a research into smart transport systems and develop innovative solutions in the field.

1.8. Executive summary of the programme

(max. two A4 pages. Summary of scientific results achieved during reporting period, their scientific and applicational significance)

The programme covers a wide range of research topics (as requested by Latvian Ministry of Science and Education in the call for proposals) and includes high-quality long-term research (for example, our studies in quantum computing, which have received very high international recognition), applied work with immediate applications for the ICT industry (for example, in the field of information systems) and interdisciplinary research aimed at applying ICT methods in other areas (for example, in medicine).

It is implemented by six universities and research institutions: the University of Latvia, the Institute of Mathematics and Computer Science, Liepaja University, Riga Technical University, the Transport and Communications Institute, and Ventspils University College.

Among our research results, particularly noteworthy are the following:

- two results in the theory of quantum computing by a group of researchers lead by A. Ambainis (the University of Latvia):
 - o new bounds on the maximum possible gap between different types of computation (quantum, probabilistic and deterministic) in the commonly used decision tree/query algorithm model of computation, solving longstanding open problems in this field (including two which have been open since 1986) ;
 - o a result that quantum walks provide quadratic speedup over the classical algorithm for search on almost any graph.

The papers describing these results have been accepted by the ACM Symposium on the Theory of Computing (STOC), one of the two leading theoretical computer science conferences in the world, and Physical Review Letters, a leading physics journal.
- the work on semantic information systems by a group of researchers lead by K. Čerāns (Institute of Mathematics and Computer Science), aimed at enabling users without IT background to formulate queries and access data within a database, including:
 - o development, implementation and initial evaluation of notation and tool for describing aggregate queries over RDF databases in a visual query language,
 - o development and prototype implementation of combined graphical and controlled natural language interface for ontology presentation,
 - o implementation and evaluation of notations and tools for mapping relational databases into OWL ontologies and semantic database browsing,
 - o development of principles for web-based ontology modeling tool implementation.
- the work on multilingual verbalisation of facts stored in a semantic database, if the database can be mapped to Berkeley FrameNet. (FrameNet is a linguistically motivated ontology that follows the theory of frame semantics.) We have developed an extensible library of computational grammars, currently for English and Swedish, that share the same FrameNet-based abstract syntax. Thus, the use of the library does not require any language-specific knowledge. The article describing this study is accepted for publishing in the Journal of Language Resources and Evaluation (Springer), a leading journal in the field of computational linguistics.

Other research areas of the programme are:

- o image processing – with an emphasis on processing biomedical images;
- o use of wireless sensor networks and high performance computing (HPC) for control of urban services (such as water supply and intelligent transport systems);
- o bioinformatics;
- o large-volume data and knowledge infrastructure (e.g., cloud computing);
- o satellite imaging, processing of satellite images and other geospatial data;
- o mathematical modelling using differential equations, for a variety of modelling tasks.

A total of 35 research papers have been submitted or prepared for submission, with 27 of them already published or accepted for publication. A number of presentations on the research results have been given, both at international conferences and local events with students among the target audience.

Several of tasks have been carried out in collaboration with researchers in other countries:

- quantum computing research - together with researchers from University of Paris Diderot and National University of Singapore (bounds on the gap between quantum and other models of computation) and University of Lisbon, Portugal (results on quantum walks).

- computational linguistics research - together with researchers from University of Gothenburg (Sweden).
- bioinformatics research – together with European Bioinformatics Institute, University of Cambridge and King’s College London (UK).
- biomedical imaging research --together with the University of Lorraine, France.

Among researchers of the programme, we have 16 Ph.D. students, 14 M.Sc. students and 16 recent Ph.D.’s (who have received their Ph.D. in the last 10 years). Thirteen M.Sc. thesis based on the research in programme have been defended, and one doctoral dissertation has been accepted for the Ph.D. defense.

1.9. The programme results

Performance indicator	Results	
	Planned	Achieved
Scientific performance indicators		
1. Scientific publications:		
number of original scientific articles Z(SCOPUS)(SNIP>1)	1	6
number of other original scientific articles included in Web of Science or SCOPUS databases	9	13 and 7 in preparation
number of original scientific articles enclosed in magazines of database <i>ERIH(A and B)</i> or in conference proceedings	2	8 and 1 in preparation
number of reviewed scientific monographs		
2. Within the framework of the programme:		
number of <u>defended</u> doctoral thesis	3	1 (accepted the defense)
number of <u>defended</u> master's thesis	8	13
3. Development of the research and education IT centre that provides remote access for regional higher education institutions (Regional Partner Research Facility)		
4. Setting up a strategic research council for processing partner information		
Performance indicators of the promotion of the programme		
1. Interactive events to promote the process and results of the programme. Target groups should include students and the number of:		
conferences	6	20
seminars	2	2
Seminars, organized	9	2
popular-science publications	14	3
exhibitions	1	2
conference abstracts (without posts)		7
Economic performance indicators		
1. Size of the private funding attracted to the scientific institution within the framework of the programme, including:		
1.1. co-funding from the private sector for implementing the projects of the		

programme		
1.2. income from commercializing the intellectual property created within the framework of the programme (alienation of industrial property rights, licensing, conferring exclusive rights, or rights to use fees)		
1.3. income from contractual jobs that are based on the results and experience acquired within the framework of the programme		
2. Number of applied for, registered, and valid patents or plant varieties within the framework of the programme:		
in Latvia		1
abroad		
3. Number of new technologies, methods, prototypes or services that have been elaborated within the framework of the programme and approbated in enterprises	1	1
4. Number of new technologies, methods, prototypes, products or services that have been submitted for implementation (signed contracts on the intellectual property transfer)		
5. Spin-off companies established		

In case of deviation from the plan, justification of the deviation, and the projected activities for mitigating the deviation.

No deviations in the 2nd period.

1.10. List of the programme outputs:
(List of publications, conference thesis, etc.)

Publications

1. Original scientific publications indexed in SCOPUS (SNIP>1)

1. A.Ambainis, K.Balodis, A.Belovs, T.Lee, M.Santha, J.Smotrovs *Separations in Query Complexity Based on Pointer Functions*. STOC 2016, accepted for publication (SNIP 2.418)
2. S.Chakraborty, L.Novo, A.Ambainis, Y.Omar *Spatial search by quantum walk is optimal for almost all graphs*. *Physical Review Letters*, 116:100501, 2016 (SNIP 2.464)
3. S.Aaronson, A.Ambainis, *Forrelation: A Problem that Optimally Separates Quantum from Classical Computing*. Proceedings of the Forty-Seventh Annual ACM on Symposium on Theory of Computing (STOC'2015 (reported in the 1nd report as accepted for publication) (SNIP 2.418)
4. A.Ambainis, A.Belovs, O.Regev, R.de Wolf, *Efficient Quantum Algorithms for (Gapped) Group Testing and Junta Testing*. Proceedings of the Twenty-Seventh

Annual ACM-SIAM Symposium on Discrete Algorithms (SODA'2016). (SNIP 1.644) (reported in the 1nd report as accepted for publication)

5. N.Gruzitis, D.Dannells, *A Multilingual FrameNet-based Grammar and Lexicon for Controlled Natural Language*. Journal of Language Resources and Evaluation, Springer, accepted for publication (SNIP 2.335)
6. G.Korats, S.Le Cam, R.Ranta, V.Louis-Dorr, *A space-time-frequency dictionary for sparse cortical source localization* in Biomedical Engineering, IEEE Transactions on. (SNIP 1.772)

2. Other original scientific publications indexed in SCOPUS or Web of Science

1. A.Ambainis, J.Vihrovs *Size of Sets with Small Sensitivity: A Generalization of Simon's Lemma. Theory and Applications of Models of Computation. Lecture Notes in Computer Science*, 9076:122-133, 2015. (SCOPUS) (reported in the 1nd report as prepared for submission).
2. K.Čerāns, G.Būmans. *RDB2OWL: A Language and Tool for Database to Ontology Mapping* // In: Proc. of CAiSE FORUM 2015, <http://ceur-ws.org/Vol-1367/paper-11.pdf> (SCOPUS). (reported in the 1st report as prepared for submission)
3. K.Čerāns, A.Romāne *OBIS: Ontology-Based Information System Framework*. // In: Proc. of CAiSE FORUM 2015, <http://ceur-ws.org/Vol-1367/paper-09.pdf> (SCOPUS) (included in Year 1 report as a paper prepared for publication).
4. K.Čerāns, J.Ovčiņņikova, M.Zviedris *Towards graphical query notation for semantic databases*. // In: Proc. of BIR 2015, Springer LNBIP 229, pp.273-281 (SCOPUS)
5. K.Čerāns, J.Ovčiņņikova, M.Zviedris *SPARQL Aggregate Queries Made Easy with Diagrammatic Query Language ViziQuer* // In Proc. of Posters and Demos session of International Semantic Web Conference, Bethlehem, USA, Oct 11-15, 2015 (ISWC 2015 PD) http://ceur-ws.org/Vol-1486/paper_68.pdf (SCOPUS)
6. H.Abdelaal, N.Gruzitis, R.Enache, B.Davis *Extracting Semantic Knowledge from Unstructured Text using Embedded Controlled Language*. Proceedings of the 10th International Conference on Semantic Computing (ICSC). IEEE, 2016 (accepted; SCOPUS)
7. A.Spektors, I.Auzina, R.Dargis, N.Gruzitis, P.Paikens, L.Pretkalnina, L.Rituma, B.Saulite *Tezaurus.lv: the largest open lexical database for Latvian*. Proceedings of the 10th International Conference on Language Resources and Evaluation (LREC), 2016 (accepted; Web of Science)
8. A.Brazma, K.Cerans, D.Ruklisa, T.Schlitt, J.Viksna *Modeling and analysis of qualitative behaviour of gene regulatory networks*. Lecture Notes in Computer Science, vol.7699, pp.51-66, 2015 (SCOPUS).
9. A.Patlins, N.Kunicina *Real-Time Data Collection and Easy Passenger Counting Method for Public Transport System*. Transport Means 2015: Proceedings of the 19th International Conference, Lithuania, Kaunas, 22-23 October, 2015. Kaunas: Kaunas University of Technology, 2015, pp.329-332 (SCOPUS).
10. N.Zenina, A.Romanovs, J.Merkurjevs *Modelling based approach for attracted transport readiness trips estimation to the site*. International Journal of Mathematical Models and Methods in Applied Sciences, 2015, 9, pp.410-417 (SCOPUS).
11. I.Kabashkin, A.Mironov, P.Doronkin, A.Prikloksky *Condition Monitoring of Operating Pipelines with Operational Modal Analysis Application*, Transport and Telecommunication, Vol. 16. 2015, pp. 305–319 (to be indexed in SCOPUS) .

12. I.Kabashkin *Modelling of Regional Transit Multimodal Transport Accessibility with Petri Net Simulation*. Procedia Computer Science, Vol. 77. 2015, pp. 151-157. (to be indexed in SCOPUS)
13. J.Merkurjevs, N.Zenina, A.Romanovs *Intelligent Transport Measures as a Component of Cyber-Physical Systems: Case Study for Adazi City*. In: Proceedings of the 17th International Conference on Harbor, Maritime & Multimodal Logistics Modelling and Simulation, Italy, Bergeggi, 21-23 September, 2015. Genova, Italy: DIME Università di Genova, 2015, pp.57-65. (to be indexed in SCOPUS)
14. G. Korats, R. Ranta, S. Le Cam, V. Louis-Dorr *Sparse cortical source localization using spatio-temporal atoms*. Proceedings of Engineering in Medicine and Biology Society (EMBC), 2015 37th Annual International Conference of the IEEE 2015 Aug 25 (pp. 4057-4060). IEEE. (SCOPUS, MEDLINE/PubMED database)
15. R.Aleksejevs, R.Guseinovs, A.N.Medvedev, Sh.E.Guseynov, *Groupage Cargo Transportation Model*. Journal of Transport and Telecommunication (SCOPUS).

Submitted papers:

16. J.Glagolevs, K.Freivalds *A Statistical Method for Object Counting*, submitted papers to International Conference on Image and Signal Processing 2016 (ICISP 2016).
 17. S.Kozlovics *Models and Model Transformations Within Web Applications*. Submitted to Baltic DB&IS 2016 (Proceedings in Springer CCIS Series, SCOPUS).
 18. K.Cerāns, G.Būmans *Database to Ontology Mapping Patterns in RDB2OWL Lite*. Submitted to Baltic DB&IS 2016 (Proceedings in Springer CCIS Series, SCOPUS).
 19. R.Liepins, U.Bojars, N.Gruzitis, K.Cerans, E.Celms *Towards Self-explanatory Ontology Visualizations with Contextual Verbalizations*. Submitted to Baltic DB&IS 2016 (Proceedings in Springer CCIS Series, SCOPUS).
 20. J.J.Camilleri, N.Gruzitis, G.Schneider *Extracting Formal Models from Normative Texts*. Submitted to 21st International Conference on Applications of Natural Language to Information Systems (NLDB), 2016 (Proceedings in Springer LNCS Series, SCOPUS)
3. Other publications
1. M.Krasnovs, Z.Markovičs, *Development of Decision-Making Software for Patient with Kidney Stones*, Scientific Journal of Riga Technical University, Technologies of Computer Control, 2014/15;
 2. K.Mezale, A.Kundzins, Z.Markovics, *Aspects of Foundation of Knowledge Base in Decision-making Tasks for the Needs of Intellectual Robots*. Scientific Journal of Riga Technical University, Technologies of Computer Control, 2015/2016;
 3. A.Sisojevs, R.Starinskis, *An Approach for Fast Statistical Data Extraction from Biomedical Objects*, Technologies of Computer Control 16 (2015): 64-71;
 4. Sh.E.Guseynov, J.V.Aleksejeva *Mathematical Modelling of Aquatic Ecosystem*. Proceedings of the 10th International Scientific and Practical Conference "Environment. Technology. Resources", June 18-20, 2015, Rezekne, Latvia, ISSN: 1691-5402, Vol. 3, p. 92-99. <http://dx.doi.org/10.17770/etr2015vol3.192> (Proceedings is under consideration for inclusion in the SCOPUS);
 5. Sh.E.Guseynov, A.I.Urbah, S.A.Andreyev *On one Approach for Stable Estimate of Technical System Efficiency*. Proceedings of the 10th International Scientific and Practical Conference "Environment. Technology. Resources", June 18-20, 2015,

- Rezekne, Latvia, ISSN: 1691-5402, Vol. 3, p. 100-108. <http://dx.doi.org/10.17770/etr2015vol3.191> (Proceedings is under consideration for inclusion in the SCOPUS);
6. A.Grickus, Sh.E.Guseynov *On one Mathematical Model for Dynamics of Propagation and Retention of Heat over New Fibre Insulation Coating*. Proceedings of the 10th International Scientific and Practical Conference "Environment. Technology. Resources", June 18-20, 2015, Rezekne, Latvia, ISSN: 1691-5402, Vol. 3, p. 82-86. <http://dx.doi.org/10.17770/etr2015vol3.504> (Proceedings is under consideration for inclusion in the SCOPUS);
 7. U.Zaimis, Sh.E.Guseynov *Analytic-Numerical Modelling and Investigation of Nanostructures' Dynamics on Material Surfaces after Laser Irradiation*. Proceedings of the 10th International Scientific and Practical Conference "Environment. Technology. Resources", June 18-20, 2015, Rezekne, Latvia, ISSN: 1691-5402, Vol. 3, p. 212-216. <http://dx.doi.org/10.17770/etr2015vol3.193> (Proceedings is under consideration for inclusion in the SCOPUS);
 8. N.Zenina, A.Romanovs, J.Merkurjevs *Incoming generated traffic flow estimation based on transport access design and level of service*. In: Advances in Environmental Science and Energy Planning: proceedings of the WSEAS 8th International Conference on Urban Planning and Transportation, Spain, Tenerife, Canary Island, 10-12 January, 2015. WSEAS Press: 2015, pp.195-201.
 9. H.Abdelaal, N.Gruzitis, R.Enache, B.Davis *Embedded Controlled Languages to Facilitate Information Extraction from eGov Policies*. Proceedings of the 17th International Conference on Information Integration and Web-based Applications & Services (iiWAS). ACM, 2015.

Ph.D. and M.Sc. theses

1. Ph.D. thesis "*Cortical source imaging: from the laplacian montage to sparse inverse solutions*", G.Korāts, Ventspils University College.
2. M.Sc. thesis "*A study of model creation from natural language text*", S.Apenītis, University of Latvia
3. M.Sc. thesis "*Sensitivity of Boolean functions and related complexity measures*", J.Vihrovs, LU MII
4. M.Sc. thesis "*Development of transport information system, based on the analysis of transport models*", J. Piskunova, RTU ITI acad. master program;
5. M.Sc. thesis "*Simulation Based Approach for Operating Costs Analysis of Freight Trucking*", N.Ozernova, RTU Baltech master programme "Industrial Engineering and Management";
6. M.Sc. thesis "*Transport node simulation model verification and validation*", J.Sergejenko, RTU ITI acad. master program;
7. M.Sc. thesis "*Vehicle weight measurement precision motion increasing use of fiber optic sensor calibration based on genetic algorithms*", A.Pilipovecs, TSI;
8. M.Sc. thesis "*Balancing load of user defined functions in "Cassandra" data base cluster*", I.Kocins, University of Latvia;
9. M.Sc. thesis "*Development and Efficiency Analysis of Channel Coding Methods*", E.Briede, Ventspils University College;
10. M.Sc. thesis "*Design of OFDM signal synthesier and parametric analysis of it's implementations*", J.Šate, Ventspils University College;
11. M.Sc. thesis "*Development of Rician channel simulator*", R.Trops, Ventspils University College.

12. M.Sc. thesis “*Route selection in fuzzy environment*”, P.Sergejs, RTU;
 13. M.Sc. thesis “*Robotic control in fuzzy environment*”, P.Aleksandrs, RTU.

Talks at conferences:

- A.Ambainis. *Cik liela var būt atšķirība starp kvantu un determinētajiem algoritmiem? (How large can be the gap between quantum and deterministic algorithms?)*. Presentation in the 74th conference of University of Latvia, Riga, Latvia, 05.02.2016;
- M.Kokainis. *No polinomiem uz kvantu algoritmiem. (From polynomials to quantum algorithms)*. Presentation in the 74th conference of University of Latvia, Riga, Latvia, 12.02.2016;
- A. Ambainis. *What is the biggest possible gap between quantum and classical computing?* Heilbronn Quantum Algorithms Meeting, Bristol, UK, April 13, 2015.
- A. Ambainis, J. Vihrovs: *Size of Sets with Small Sensitivity: A Generalization of Simon's Lemma*. Theory and Applications of Models of Computation - 12th Annual Conference, TAMC 2015, May 18-20, 2015, Singapore.
- A. Ambainis. *Search by quantum walk and extended hitting time*. Quantum Random Walks and Quantum Algorithms workshop at Lorentz Center, Leiden, Netherlands, Dec 7-11, 2015.
- K.Čerāns, J.Ovčiņņikova, M.Zviedris. *ViziQuer: diagrammatiska vaicājumu notācija un rīks pār semantiskajām datubāzēm (ViziQuer: a diagrammatic query notation and tool over semantic databases)*. Presentation in the 74th conference of University of Latvia, Computer Science Section, Riga, Latvia, 12.02.2016;
- K.Čerāns, G.Būmans, J.Ovčiņņikova, A.Romāne, M.Zviedris *Dinamiskas analīzes rīki medicīnas datiem (Tools for dynamic analysis of Medicine data)*, Presentation in the 74th conference of University of Latvia, Medicine Section, Riga, Latvia, 19.02.2016;
- K.Čerāns, J.Ovčiņņikova, M.Zviedris. *Towards graphical query notation for semantic databases*. 14th International Conference on Perspectives in Business Informatics Research (BIR 2015), 26.-28.August, 2015, Tartu, Estonia.
- K.Čerāns, J.Ovčiņņikova, M.Zviedris. *SPARQL Aggregate Queries Made Easy with Diagrammatic Query Language ViziQuer*. Posters and Demonstrations session of 14th International Semantic Web Conference, (ISWC 2015), Oct 11-15, 2015, Bethlehem, USA;
- Sh.E.Guseynov, A.V.Berezhnoy, J.S.Rimshans, J.V.Aleksejeva *Mathematical modelling of computer networks for optimization of their performance, reliability and efficiency*. Presentation in the Baltic HPC and Cloud Computing Conference, Riga, Latvia; June 02.04.2015;
- A.N.Medvedev, Sh.E.Guseynov *On a model for maritime cargo transportation planning*. The 15th International Conference "Reliability and Statistics in Transportation and Communication" (RelStat'15), Riga, Latvia, October 21-24, 2015;
- Sh.E.Guseynov. *On an analytical approach for finding the temperature diffusivity coefficient of the material*. Riga Technical University 56th International Scientific Conference, Riga, Latvia, October 14-16, 2015;
- Sh.E.Guseynov *On a problem of frequency electromagnetic ionospheric sounding for unambiguous determination of electron concentration distribution*. Riga Technical University 56th International Scientific Conference, Riga, Latvia, October 14-16, 2015;

- Sh.E.Guseynov, J.V.Aleksejeva *On a problem of heat exchanging in 1D-, 2D- and 3D-periodic systems with rectangular fins*. Riga Technical University 56th International Scientific Conference, Riga, Latvia, October 14-16, 2015;
- R.Aleksejevs, R.Guseinovs, Sh.E.Guseynov *On a multicriteria problem of maritime cargo transportation planning with handling operations in intermediate seaports*. Riga Technical University 56th International Scientific Conference, Riga, Latvia, October 14-16, 2015;
- E.Vaviļina, G. Gaigals *Improved LabVIEW Code Generation*. Contribution at the IEEE conference "Advances in Information, Electronic and Electrical Engineering", 13.11.2015;
- E.Vaviļina, G. Gaigals *LabVIEW code generation tool application in development of signal processing algorithms*. Contribution at the Christmas Scientific Conference of Ventspils University College, 17.12.2015;
- L.Truksans, *E-Spiets2 – universal cloud for science*, Latvian Open Technologies Association (LATA) conference, 28.01.2016;
- A.Patlins *Passenger Counting Methodology for Sustainable Intellectual Transport System*, RTU 56th International scientific conference, Riga, Latvia, 14.10.2015;
- N.Zenina, J.Merkurjevs, A.Romanovs *Global modelling parameters and two step clustering algorithm for transport simulation model calibration*. RTU 56th International scientific conference, Riga, Latvia, 14-16 October 2015,;
- A.Patlins, N.Kunicina *Real-Time Data Collection and Easy Passenger Counting Method for Public Transport System*. 19th International Conference "Transport Means", Lithuania, Kaunas, 23.10.2015;
- J.Merkurjevs, N.Zenina, A.Romanovs *Intelligent Transport Measures as a Component of Cyber-Physical Systems: Case Study for Adazi City*. 17th International Conference on Harbor, Maritime & Multimodal Logistics Modelling and Simulation, Bergeggi, Italy 21-23 September, 2015;
- I.Kabashkin *Reliability of Bidirectional V2X Communications*, Advances in Wireless and Optical Communications 2015 (RTUWO'2015) IEEE International Conference, Riga, Latvia, 5-6 November 2015;
- M.Savrasov *Macroscopic Transport Model as a Part of Traffic Management Center: Technical Feasibility Study*. Tenth International Conference on Dependability and Complex Systems DepCoS-RELCOMEX, Brunow, Poland, 29. june-3.july 2015;
- A.Mironov, P.Doronkin, A.Priklonsky, I.Kabashkin *Operational Modal Analysis (OMA) Application for Condition Monitoring of Operating Pipelines*. 15th International Conference "Reliability and Statistics in Transportation and Communication (RelStat'15)", Riga, Latvia, 21–24 October 2015;
- A.Grakovski, A.Pilipovecs *Multi-Purpose Fiber Optic System for Automated Measurement of Vehicle's Parameters*. 15th International Conference „Reliability and Statistics in Transportation and Communication” (RelStat'15), Riga, Latvia, 21–24 October 2015;
- N.Gruzitis, D.Dannells, A.Ranta *Grammatical Framework for implementing multilingual frames and constructions*. Theme session "Computational Semantics with Frames and Constructions" at the 9th International Conference on Construction Grammar (ICCG), 2016 (accepted);
- J.Viksna. *Modelling and analysis of the impact of parameter values on dynamic behaviour of gene regulatory networks*. Joint conference between Genome Informatics Workshop and International Conference in Bioinformatics GIW/InCoB 2015, Odaiba, Japan, September 2015;

- G. Korats, R. Ranta, S. Le Cam, V. Louis-Dorr *Sparse cortical source localization using spatio-temporal atoms*, Proceedings of Engineering in Medicine and Biology Society (EMBC), 2015 37th Annual International Conference of the IEEE 2015 Aug 25 (pp. 4057-4060). IEEE.

Popular science publications:

1. *Vai diagramma var jautāt par datiem? (Can a diagram query the data?)* Published on the project web site <http://syslab.lumii.lv/index.php/projects/valsts-ptjumu-programmas/nexit/1project/papers/365-vaidiagrammasvarvaicatpardatiem>;
2. Sh.E.Guseynov, J.V.Aleksejevs, J.Kaupuzs *Synthesis of Mathematical Modeling and Theory of Differential Equations*;
3. N.Zenina, A.Romanovs, J.Merkurjevs *Transport Simulation Model Calibration with Two-Step Cluster Analysis Procedure*. Accepted for publication Information Technology and Management Science, Vol.18, 2015.

National patent application: Nr.P-15-113 23.10.2015 "Mobile robot battery charger contact"

PART 2: PROGRAMME PROJECT INFORMATION

2.1. Project No. 1

Title	Ontology technologies, semantic web and security	
Project leader's name, surname	Kārlis Čerāns	
Degree	Dr.sc.comp.	
Institution	IMCS UL	
Position	Leading Researcher	
Contacts	<i>Phone number</i>	67213716
	<i>E-mail</i>	Karlis.Cerans@lumii.lv

Project goal and objectives

(Describe the project goals and objectives so that the achievements reported below could be placed in context and evaluated)

The following objectives have been set:

- Develop new methods of computing for quantum computers;
- Analyze security of cryptographic schemes against quantum computers;
- Study mathematical objects related to quantum computing;
- Design, implement and evaluate web-based tools for graphical OWL ontology modeling;
- Develop principles and languages for definition and graphical presentation of data ontologies and management of the corresponding ontology-conformant data;
- Develop, apply and evaluate languages and tools for external data translation into RDF/OWL format;
- Develop, apply and evaluate languages and web-based tools for analysis and management of data in ontology-conformant knowledge bases
- Develop combined graphical and controlled natural language techniques for ontology design, lexicalization and querying.

Description of the acquired scientific results

(Describe scientific results achieved during reporting period, give their scientific importance)

1. We have compared the power of different modes of computation (quantum, randomized, deterministic) in the widely studied model of query algorithms (which encompasses most of the known quantum algorithms). More specifically, we have studied how large can be the gap among the models for computational tasks that are defined for all input data (for total Boolean functions). The main results of our research (performed together with scientists from University Paris Diderot (France) and National University of Singapore) are as follows:
 - a. a computational task which requires T queries for deterministic algorithms and $\tilde{O}(\sqrt{T})$ queries for randomized algorithms;
 - b. a computational task which requires T queries for deterministic algorithms and queries for quantum algorithms;
 - c. a computational task which requires T queries for randomized algorithms that must always output a correct answer and $\tilde{O}(\sqrt{T})$ queries for randomized algorithms that may err with a small probability;

Before our work, the best known results were:

- a. a computational task which requires T queries for deterministic algorithms and $O(T^{0.753})$ queries for randomized algorithms (binary AND-OR tree, Snir, 1985);
- b. a computational task which requires T queries for deterministic algorithms and queries for quantum algorithms (Grover's search, 1996);
- c. examples with a non-negligible gap between randomized algorithms with no error and randomized algorithms with small error were not known.

Thus, our algorithms are a significant improvement over the state-of-the-art, for research problems for which there has been no progress for a very long time (since 1985 and 1996, respectively).

2. We have shown that search by a quantum gives a substantial speedup over classical search for a wide range of structures. The structure on which we are searching can be modelled as a graph with some vertices marked. If a graph has T vertices, it is known that there are graphs that can be searched by an algorithm based on a quantum walk, in $O(\sqrt{T})$ steps. Together with researchers from University of Lisbon (Portugal), we have shown that $O(\sqrt{T})$ steps suffice for almost any graph (in the Erdos-Renyi model of random graphs). This shows that quantum advantage for search on graphs is very generic. Our result also has applications to quantum communication: it can be used to design a protocol for quantum state transfer on a network with the corresponding interconnection graph.
3. In order to prepare the technological basis for web-based graphical OWL ontology modeling tools the basic functionality of universal modeling tool building platform web-TDA 2.0 has been implemented. The prototype of the graph diagramming component has

been implemented, including the transfer of the graph layouting algorithms into the web environment. A manuscript about general use of models and model transformations within web environment has been prepared and submitted to Baltic DB&IS conference.

4. The database to ontology mapping tool RDB2OWL has been extended with new implementations via RDB2OWL notation translations into executable D2RQ and R2RML mapping notations, so providing a practical opportunity of writing executable database to ontology mapping specifications in a high level language such as RDB2OWL that allows, for instance, use of user defined functions for compact specification of repeating mapping patterns. The patterns of database to ontology mapping definition have been considered, as well. The testing and extension of the RDB2OWL mapping language and tool have been performed on the basis of the practical example of semantic re-engineering of Latvian medicine registries.
5. A major extension to the visual/diagrammatic tool ViziQuer for query definition over RDF databases has been designed, implemented and demonstrated. The ViziQuer tool provides means for diagrammatic query formulation over the data structured in the form of a give data ontology; then the diagrammatic queries are translated into SPARQL 1.1. textual notation. The new and extended ViziQuer language and tool version supports both usage of aggregate functions, as well as rich expression language for query condition and selection definition. The ViziQuer tool has been evaluated on the example of semantically re-engineered Latvian medicine registries. It is intended that the tool could be given directly to the end users of the semantical information basis, giving them direct means of query formulation are receiving the corresponding answers without the intermediate involvement of a programmer for query writing.

We note also on the further development and demonstration of the accompanying OBIS framework for automated data-management application generation from the data schema specified as annotated OWL ontology; the OBIS framework has received a refined user interface annotation set, as well as generic data handling features necessary for the framework's practical usability.

The tool suite comprising of RDB2OWL tool for database to ontology mapping definition, OBIS for semantic database browsing and ViziQuer for diagrammatic ad hoc query formulation have been enhanced and tested on concrete practical examples. A server with semantically re-engineered de-personalized Latvian Medicine registries (Cancer Registry, Diabetes Registry, Multiple sclerosis Registry, Trauma Registry, Narkological Registry, Psychic disorder Registry) data has been prepared for prototype use outside the scientific laboratory. The RDB2OWL tool has been used to connect the data ontology, prepared in the OWLGrEd tool, with the real database structure. The RDF data corresponding to the database have been generated via translation of RDB2OWL mapping into executable D2RQ mappings. The data have been loaded into the Virtuoso server that is installed in the server environment. The access to the data is organized via OBIS web application that offers both the structural analysis means for the data, as well as the possibility to process custom queries presented in SPARQL language.

The ViziQuer tool version for diagrammatic query definition has been created, pre-

configured with the Medicine Registries ontology and transferred to the end user. The user instruction for the ViziQuer tool usage, explaining on the examples the formulation possibilities of typical queries, has been created and transferred to the end user, as well.

6. The access to the server, as well as the ViziQuer software together with its usage instructions, has been issued to the Center of Disease Prevention and Control that is the holder of the Medicine Registries data.
7. We have developed a method and the first prototype for self-explanatory ontology visualization by combining the graphical OWLGrEd notation and controlled natural language, a multilingual version of Attempto Controlled English. We submitted an article on these results to the Journal of Web Semantics (Elsevier), and the approach itself was recognized as novel, however, our current case study is too preliminary to justify a journal contribution, and we have to conduct a more mature evaluation (user study) and statistical analysis. Meanwhile, we have submitted a derived paper to the Baltic DB&IS conference.

In collaboration with researchers from University of Gothenburg, we have extended this research activity by developing and evaluating a multilingual method and a library of computational grammars that can be used for verbalizing ontologies that are mapped to Berkeley FrameNet. Based on this research, we have submitted an article to the Journal of Language Resources and Evaluation (Springer), which has been accepted for publication.

We are now extending this method to handle non-compositional multi-word expressions, and an extended abstract on the first experiments has been accepted to the theme session "Computational Semantics with Frames and Constructions" at the 9th International Conference on Construction Grammar.

Another extension to this activity has emerged in collaboration with researchers from NUI Galway and University of Gothenburg. We have proposed a conceptual method for information extraction from normative texts, combining a general-purpose parser with an embedded controlled language. This work has resulted in two accepted papers: at the 10th International Conference on Semantic Computing, and at the 17th International Conference on Information Integration and Web-based Applications & Services.

In parallel, we have conducted an experiment on semi-automatic construction of contract-oriented diagrams (CO-Diagrams) based on deontic norms that are expressed in normative texts (contracts). A paper on these results has been submitted to the 21st International Conference on Applications of Natural Language to Information Systems.

It should be noted that, in the scope of this activity, synergy has emerged with other State Research Programmes, Letonica and SOPHIS, developing a large open machine-readable lexicon of Latvian. The aim is to map this lexicon to widely used lexical ontologies and the Linked Data cloud that would also facilitate the ontology verbalization. This collaboration has resulted in an accepted paper at the 10th International Conference on Language Resources and Evaluation.

Publications (published and/or accepted for publication):

1. A.Ambainis, K.Balodis, A.Belovs, T.Lee, M.Santha, J.Smotrovs. *Separations in Query Complexity Based on Pointer Functions*. STOC 2016, Accepted for publication (SNIP 2.418)
2. Sh.Chakraborty, L.Novo, A.Ambainis, Y.Omar. *Spatial search by quantum walk is optimal for almost all graphs*. Physical Review Letters, Accepted for publication (SNIP 2.464)
3. S.Aaronson, A.Ambainis. *Forrelation: A Problem that Optimally Separates Quantum from Classical Computing*. Proceedings of the Forty-Seventh Annual ACM on Symposium on Theory of Computing (STOC'2015), pp. 307-316. (reported in the 1st report as accepted for publication) (SNIP 2.418)
4. A.Ambainis, A.Belovs, O.Regev, R.de Wolf. *Efficient Quantum Algorithms for (Gapped) Group Testing and Junta Testing*. Proceedings of the Twenty-Seventh Annual ACM-SIAM Symposium on Discrete Algorithms (SODA'2016), pp. 903-922. (SNIP 1.644) (reported in the 1nd report as accepted for publication)
5. N.Gruzitis, D.Dannells. *A Multilingual FrameNet-based Grammar and Lexicon for Controlled Natural Language*. Journal of Language Resources and Evaluation, Springer (accepted; SNIP 2.335)
6. A.Ambainis, J.Vihrovs. *Size of Sets with Small Sensitivity: A Generalization of Simon's Lemma*. *Theory and Applications of Models of Computation*. Lecture Notes in Computer Science, 9076:122-133, 2015. (SCOPUS) (reported in the 1nd report as prepared for submission).
7. K.Čerāns, G.Būmans. *RDB2OWL: A Language and Tool for Database to Ontology Mapping* // In: Proc. of CAiSE FORUM 2015, <http://ceur-ws.org/Vol-1367/paper-11.pdf> (SCOPUS). (reported in the 1nd report as prepared for submission)
8. K.Čerāns, A. Romāne. *OBIS: Ontology-Based Information System Framework*. // In: Proc. of CAiSE FORUM 2015, <http://ceur-ws.org/Vol-1367/paper-09.pdf> (SCOPUS) (included in Year 1 report as a paper prepared for publication).
9. K.Čerāns, J.Ovčiņņikova, M.Zviedris. *Towards graphical query notation for semantic databases*. // In: Proc. of BIR 2015, Springer LNBIP 229, pp.273-281 (SCOPUS)
10. K.Čerāns, J.Ovčiņņikova, M.Zviedris. *SPARQL Aggregate Queries Made Easy with Diagrammatic Query Language ViziQuer* // In Proc. of Posters and Demos session of International Semantic Web Conference, Bethlehem, USA, Oct 11-15, 2015 (ISWC 2015 PD) http://ceur-ws.org/Vol-1486/paper_68.pdf (SCOPUS)
11. N.Gruzitis, D.Dannells. *A Multilingual FrameNet-based Grammar and Lexicon for Controlled Natural Language*. Journal of Language Resources and Evaluation, Springer (accepted; SNIP 2.335)
12. H.Abdelaal, N.Gruzitis, R.Enache, B.Davis. *Embedded Controlled Languages to Facilitate Information Extraction from eGov Policies*. Proceedings of the 17th International Conference on Information Integration and Web-based Applications & Services (iiWAS). ACM, 2015 (accepted; SCOPUS)
13. H.Abdelaal, N.Gruzitis, R.Enache, B.Davis. *Extracting Semantic Knowledge from Unstructured Text using Embedded Controlled Language*. Proceedings of the 10th International Conference on Semantic Computing (ICSC). IEEE, 2016 (accepted; SCOPUS)
14. A.Spektors, I.Auzina, R.Dargis, N.Gruzitis, P.Paikens, L.Pretkalnina, L.Rituma, B.Saulite. *Tezaurs.lv: the largest open lexical database for Latvian*. Proceedings of the 10th

International Conference on Language Resources and Evaluation (LREC), 2016 (accepted; Web of Science)

Submitted papers:

15. S.Kozlovics. *Models and Model Transformations Within Web Applications*. Submitted to Baltic DB&IS 2016 (Proceedings in Springer CCIS Series, SCOPUS).

16.K.Čerāns, G.Būmans. *Database to Ontology Mapping Patterns in RDB2OWL Lite*. Submitted to Baltic DB&IS 2016 (Proceedings in Springer CCIS Series, SCOPUS).

17. R.Liepins, U.Bojars, N.Gruzitis, K.Cerans, E.Celms. *Towards Self-explanatory Ontology Visualizations with Contextual Verbalizations*. Submitted to Baltic DB&IS 2016 (Proceedings in Springer CCIS Series, SCOPUS).

18. John J. Camilleri, N.Gruzitis, G.Schneider. *Extracting Formal Models from Normative Texts*. Submitted to 21st International Conference on Applications of Natural Language to Information Systems (NLDB), 2016 (Proceedings in Springer LNCS Series, SCOPUS)

Further research and practical exploitation of the results

(Describe further research activities that are planned, describe possibilities to practically exploit results)

The following research activities have been projected:

1. We plan to continue our investigation of quantum algorithms with a small number of queries (started in the 1st year). We will study concrete computational tasks, to determine whether our bound of $O(N^{1-1/2k})$ queries for classically simulating a quantum algorithm with k queries is optimal.
2. We will study the power of the Goos-Pitassi-Watson construction which we used to show gaps between quantum/randomized and deterministic algorithms, with the goal of obtaining even more examples which separate different modes of computation.
3. We will study the properties of quantum walks and their power for solving computational tasks, in several directions. In particular, we will analyze the conditions under which a quantum walk stays in a localized state and the conditions under which it disperses over the entire graph quite uniformly. The second case has applications to quantum algorithms which provide a big speedup over conventional algorithms.
4. We will apply quantum walks to provide improvement for classical search algorithms based on backtracking.
5. We will investigate the security of commitment schemes and zero-knowledge proofs against a quantum attacker, in collaboration with Tartu University, Estonia. A query problem related to the security of zero-knowledge proofs has been identified and we are working on showing a lower bound for it.
6. We are going to continue the development of the web-based TDA 2.0 platform and creating the concrete modeling tools on the basis of it. The current challenges for the

web-based modeling tool environment involve the efficiency of the web infrastructure when multiple users are connected simultaneously and developing a server-side resource manager and a solution for synchronizing model data efficiently between the server and the browser.

7. We shall continue re-engineering and development of the diagrammatic OWL ontology editor OWLGrEd, including fine-tuning, evaluating and publishing the ontology import and visualization principles in OWLGrEd, as well as re-arranging its export module into a modular architecture using model-to-text transformations. The re-engineered OWLGrEd editor will be migrated into the web environment, as well as the experiences and achievements from the migration between the conventional and UML-based ontology presentations is to be prepared as a publication.
8. We shall migrate the ViziQuer tool (the one meant for direct end user interaction) from its prototype desktop implementation into web-based environment, allowing for new options in computer-assisted query formulation, as well as for smoother query and result interaction with the database.
9. The OWLGrEd, RDB2OWL, ViziQuer and OBIS tools will be further tested on real life case studies outside the scientific laboratory on the examples from the medical as well as state governance areas. The principal aim is to make the tool suite available to the end user that is not an IT specialist at least on the level of data browsing and custom query formulation. The tools and their usage methodology are to be further fine-tuned to respect the lessons learned from the use cases.
10. We shall continue the development of self-explanatory ontology visualization, conducting a user study and statistical analysis, as well as the development of methods for multilingual ontology lexicalization and for the reuse of such lexicalizations, building on the Linked Data technology and already established lexicon-ontology models (e.g. LEMON) and the development of multilingual computational FrameNet and construction grammars to bridge the gap between controlled and natural language.

In terms of exploitation, quantum computing has the potential of a very substantial impact on ICT in longer-term future (15-20 years). Quantum computers may provide a major advantage for modelling physics and chemistry (quantum simulation) which currently uses about 10% of all supercomputer resources and for tasks related to computer security (both for encryption and codebreaking). High quality elementary operations for quantum computers have been demonstrated in laboratory (with precision over 99.9%) and the experimentalists are working scale up these technologies to a larger number of quantum bits. Given these achievements, it becomes worthwhile to patent discoveries in quantum computing for use when a sufficiently large scale quantum computer is available and we are looking into possibilities of doing that.

Dissemination and outreach activities

(Describe activities that were performed during reporting period to disseminate project results)

18 scientific publications have been prepared, submitted and/or accepted for publication (please see the ‘Scientific results’ section (Section 2.3) for the list of the publications/manuscripts.

Four talks have been given at the University of Latvia conference, to an audience including students:

- A.Ambainis. *Cik liela var būt atšķirība starp kvantu un determinētajiem algoritmiem?* (*How large can be the gap between quantum and deterministic algorithms?*). Presentation in the 74th conference of University of Latvia, Riga, Latvia, 05.02.2016;
- M.Kokainis. *No polinomiem uz kvantu algoritmiem.* (*From polynomials to quantum algorithms*). Presentation in the 74th conference of University of Latvia, Riga, Latvia, 12.02.2016;
- K.Čerāns, J.Ovčiņņikova, M.Zviedris. *ViziQuer: diagrammatiska vaicājumu notācija un rīks pār semantiskajām datubāzēm* (*ViziQuer: a diagrammatic query notation and tool over semantic databases*). Presentation in the 74th conference of University of Latvia, Computer Science Section, Riga, Latvia, 12.02.2016;
- K.Čerāns, G.Būmans, J.Ovčiņņikova, A.Romāne, M.Zviedris *Dinamiskas analīzes rīki medicīnas datiem* (*Tools for dynamic analysis of Medicine data*), Presentation in the 74th conference of University of Latvia, Medicine Section, Riga, Latvia, 19.02.2016;

Technology presentations to their potential users:

- Medicine Faculty of Riga Stradins University, 14.01.2016
- Centre for Disease Prevention and Control (SPKC), 9.02.2016.

General technology presentation seminar:

- ViziQuer: Vizuāla valoda agregātvaicājumu uzdošanai, (ViziQuer: a visual language for aggregate query formulation), 02.10.2015, LU MII room 210.

Conference abstracts (without posts):

N.Gruzitis, D.Dannells, A.Ranta. *Grammatical Framework for implementing multilingual frames and constructions*. Theme session "Computational Semantics with Frames and Constructions" at the 9th International Conference on Construction Grammar (ICCG), 2016 (theses; accepted)

Scientific-popular publication:

“Vai diagramma var jautāt par datiem?” (Can a diagram query the data?) Published on the project web site <http://syslab.lumii.lv/index.php/projects/valsts-ptjumu-programmas/nexit/1project/papers/365-vaidiagrammasvarvaicatpardatiem>

2.1.2. Project No. 2

Title	Biometry, biosignals and non-invasive diagnostic technologies.
Project leader's name, surname	Janis Hofmanis
Degree	PhD, Dr.sc.comp
Institution	Ventspils University College
Position	Lead researcher

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Project goal and objectives

(Describe the project goals and objectives so that the achievements reported below could be placed in context and evaluated)

The projected is implemented with the aim of developing new and modern E-medicine technologies that affect the acquiring and processing of biosignals/bioimages for diagnostics of diseases and pathologies, utilization of computerised decision support system with knowledge bases and artificial intelligence, providing screening and clinical approbation.

Objectives of the project:

- Develop and experimentally approve new imaging and processing technologies and methods in signal and image processing, imaging and non-invasive diagnostics:
 - Segmentation, Co-registration and visualization of multimodal 3D radiological image;
 - Development of new multimodal image processing algorithms and determination/segmentation of the state of different tissues, using medical radiological data (different weighted magnetic resonance images (T1, T2, PD, DWI) and computer tomography imaging)
 - Development of efficient algorithms of automatic/semi-automatic detection of tumour areas (contours) in magnetic resonance images – contouring in MRI images;
 - Development of prototype of imaging tools of radiological 3D images and information added by doctor (marks, contours, texts) on web, using WebGL and other technologies.
 - Processing of EEG data algorithms, localization of epileptic and evoked potential signals with high-resolution head models;
- Development of efficient analytical inverse problem solving methods and algorithms, focusing on the usage of modern data parallel processing technology in the processing of medical signals, including multispectral signal, multi-dimensional signals and images:
 - Development of a prototype of dimensional tissue representation based on complex tissue segmentation prototype (made in the first task) for visualization of the object and solving different problem in bioelectromagnetism.
 - Apply the finite element method (FEM) models to solving the forward problem of bioelectromagnetism, using parallel computing technology.
 - Development of efficient and accurate inverse problem solving methods in bioelectromagnetic source localization and separation problem.
 - Development of efficient inverse algorithms for solving specific problems, finding of the most suitable method of detecting the regularisation parameter, development and approbation of a new method of detecting the regularisation parameter.
- Development of innovative e-medicine technology and expert system for the realisation of non-invasive and non-contact clinical diagnostics and deciding process based on the results of the acquiring and processing of biophotonic and other diagnostic information (biometrics, biosignals, bioimages)
 - realisation of diagnostic screening with a further decision-making procedure;
 - realisation of diagnostics (including differential diagnosis);
 - evaluation of risk factors;

- selection of the strategy of decision process (decision support system);
- providing the monitoring process;
- approbation of developed technology.

Description of acquired scientific results

(Describe scientific results achieved during reporting period, give their scientific importance)

1. EEG signal processing and Cortical source imaging

Cortical source imaging aims at identifying activated cortical areas on the surface of the cortex from the raw EEG data. This problem is ill-posed, the number of channels being very low compared to the number of possible source positions.

In some realistic physiological situations, the active areas are sparse in space and of short time durations, and the amount of spatio-temporal data to carry the inversion is then limited. In this work, we propose an original data driven space-time-frequency (STF) dictionary which takes into account simultaneously both spatial and time-frequency sparseness while preserving smoothness in the time-frequency (i.e. non-stationary smooth time courses in sparse locations). Based on these assumptions, we take benefit of the Matching Pursuit (MP) framework for selecting the most relevant atoms in this highly redundant dictionary.

We apply two recent MP algorithms, Single Best Replacement (SBR) and Source Deflated Matching Pursuit (SDMP), and we compare the results using a spatial dictionary and the proposed STF dictionary to demonstrate the improvements of our multidimensional approach. We also provide comparison using well established inversion methods, FOCUSS and RAP-MUSIC, analysing performances under different degrees of non-stationarity and signal to noise ratio. Our STF dictionary combined with the SBR approach provides robust performances on realistic simulations. From a computational point of view, the algorithm is embedded in the wavelet domain, ensuring high efficiency in term of computation time.

The proposed approach ensures fast and accurate sparse cortical localizations on highly non-stationary and noisy data.

This study also addresses the problem of sparse localization of cortical sources from scalp EEG recordings. Localization algorithms use propagation model under spatial and/or temporal constraints, but their performance highly depends on the data signal-to-noise ratio (SNR). In this study we propose a dictionary based sparse localization method which uses a data driven spatio-temporal dictionary to reconstruct the measurements using Single Best Replacement (SBR) and Continuation Single Best Replacement (CSBR) algorithms. We tested and compared our methods with the well-known MUSIC and RAP-MUSIC algorithms on simulated realistic data. Tests were carried out for different noise levels. The results show that our method has a strong advantage over MUSIC-type methods in case of synchronized sources.

2. Analysis of photographic images used in medical surgical operations.

The statistical data of biomedical object is very important input information for medical diagnostics or/and anatomical pathology research. The approach for this data extraction is photo survey of biomedicine object and next image processing, based on image

segmentation. For image segmentation methods of pattern recognition can be used. In the present research, the authors implement different methods for extracting the statistical data from images.

Some pattern recognition methods (“Template Matching” method and method of “k Nearest-Neighbours”) were implemented in the present research in order to solve the task of image semi-automatic segmentation. After a series of experiments it was concluded that:

- the method of “k Nearest-Neighbours” provided a more precise result than the “Template matching” method;
- the modification of “k Nearest-Neighbours” methods gave a better result by segmentation time.

It could also be noted that the method of “k Nearest-Neighbours” required more time for full segmentation (up to 3 minutes) when compared to “Template Matching” method (up to 0.1 seconds). The segmentation time by modified “k Nearest-Neighbours” methods was approximately equivalent to “Template Matching” method (up to 0.6 seconds).

Articles will be published in EBSCO, ProQuest and VINITI databases.

3. Studies in formalisation of expert knowledge in decision making tasks for a specific application.

We conducted research of decision algorithms during the report period. We found that the algorithm modifications are linked with both specific decision applications and the structure and volume of expert knowledge. The research of the theoretical aspects of decision trees examined the description of trees using production rules and inclusion of subjective data as indications or contraindications for decision making. The theoretical results have been applied in medicine for decision making process when choosing an appropriate therapy.

4. New image processing technologies - natural graph recognition

During this period research about natural graph recognition (such as neuron images, blood vessels) was performed.

In this study we present a new object counting method that is intended for counting similarly sized and mostly round objects. Unlike many other algorithms of the same purpose, the proposed method does not rely on identifying every object, it uses statistical data obtained from the image instead. The method is evaluated on images with human bone cells, oranges and pills achieving good accuracy. Its strengths are ability to deal with touching and partly overlapping objects, ability to work with different kinds of objects without prior configuration and good performance.

5. New web technologies for medical data representation

This study three main technologies WebGL, Leap Motion and Three.js are researched in developing interactive web based radiological data representation together with the intra EEG electrodes.

A browser based 3D environment has been developed using the latest web technologies capable of displaying and manipulating 3D objects. Since the developed environment is operable on a web browser, it can be used from anywhere in the world without the need to install additional software. This environment also supports the Leap Motion controller,

allowing users to interact with the 3D environment using hand movements. Developed environment with aid medical doctors to position intracranial electrodes in 3D patient headspace. Work will be published in year 2016.

Also a technical specification of the set-up for biomedical application - system for early detection of cancer using CRDS (cavity ring down spectrometry) method was created and set up in the Ventspils University laboratory.

Publications

1. G.Korats, R.Ranta, S.Le Cam, V.Louis-Dorr, *Sparse cortical source localization using spatio-temporal atoms*, Proceedings of Engineering in Medicine and Biology Society (EMBC), 2015 37th Annual International Conference of the IEEE 2015 Aug 25 (pp. 4057-4060). IEEE. (SCOPUS, MEDLINE/PubMED database)
2. G. Korats, S.Le Cam, R.Ranta, V.Louis-Dorr, *A space-time-frequency dictionary for sparse cortical source localization*, in *IEEE Transactions on Biomedical Engineering (TBME)*, vol.PP, no.99, pp.1-1 (SCOPUS, IF 2.347, SNIP 1.772)
3. M.Krasnovs, Z.Markovičs, *Development of Decision-Making Software for Patient with Kidney Stones*, Scientific Journal of Riga Technical University, Technologies of Computer Control, 2014/15,
4. K.Mezale, A.Kundzins, Z.Markovics, *Aspects of Foundation of Knowledge Base in Decision-making Tasks for the Needs of Intellectual Robots*. Scientific Journal of Riga Technical University, Technologies of Computer Control, 2015/2016.
5. A.Sisojevs, R.Starinskis, *An Approach for Fast Statistical Data Extraction from Biomedical Objects*, Technologies of Computer Control 16 (2015): 64-71.

Submitted:

6. J. Glagolevs and K. Freivalds "A Statistical Method for Object Counting", International Conference on Image and Signal Processing 2016 (ICISP 2016). (SCOPUS).

PhD and M.Sc Theses:

- Ph.D. thesis (accepted for defence), G. Korāts "Cortical source imaging: from the laplacian montage to sparse inverse solutions (French: Estimation de sources corticales: du montage laplacian aux solutions parcimonieuses)". Place: University of Lorraine, Nancy, France. Date of Defence: February 26, 2016.
- M.Sc thesis: P.Sergejs, "Route selection in fuzzy environment", supervisor Z. Markovics, RTU.
- M.Sc thesis: P.Aleksandrs, "Robotic control in fuzzy environment", supervisor Z. Markovics, RTU.

Further research and practical exploitation of the results

(Describe further research activities that are planned, describe possibilities to practically exploit results)

1. All activities will be continued in further research. We expect 3 PhD thesis being delivered during the year 2016.

2. Further research will be made in WebGL and Leap Motion technologies to provide new and interactive medical data exploration. Additionally, infrared cameras with face recognition and speech analysis will be explored to help develop speech quality monitoring system in rehabilitation.
3. Will start the different research activities with the the promising CRDS for the detection of cancer indicators in human breath. Investigation of Tikhonov regularization used in inverse problems of spectroscopy will be continued. Submission of the Ph.D thesis of Natlaja Zorina is expected during 2016.
4. Graph recognition technology including semi-automatic optical graph recognition will be continued to research application in different image processing field.

Dissemination and outreach activities

(Describe activities that were performed during reporting period to disseminate project results)

Several outreach activities were performed:

1. Second Meeting with Ventspils Hospital medical personnel.
2. Continuing collaboration of developing new project proposal with Riga Stradina University using IT technologies in rehabilitation, signal and video analysis.
3. Continuing talks of developing new IT solution proposal with Heart Surgery Center of Pauls Stradiņš Clinical University Hospital in using image segmentation and statistical analysis.

2.1.3. Project No. 3

Title	Sensor networking and signal processing applications in the economy	
Project leader's name, surname	Nadezhda Kunicina	
Degree	Dr.sc.eng.	
Institution	Riga Technical University, Department of Industrial Electronics and Electrical Technologies	
Position	Professor	
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Project goal and objectives

(Describe the project goals and objectives so that the achievements reported below could be placed in context and evaluated)

The main goal of the project is development and practical implementation of new methods for processing large amount of data, which will allow acquiring, storing and interpreting data about the urban environment as well as modelling its processes using high performance computation and next generation smart sensor infrastructure. This will ensure automatic or semi-automatic high level decision making to minimize losses and damages in case of any critical situation.

The main and detailed objectives:

The first objective is to develop a safety-monitoring and modelling solution for the urban environment via applying high performance data processing technologies.

- to develop methods for mathematical modelling, high performance computing and cyber-physical systems, and to test their application in smart cities;
- to develop sensor data collecting technology from water infrastructure service and extend this approach to other infrastructure services;
- to develop new methods of integrated large-scale sensor processing high-performance computing (HPC) for control of urban environment services (water, electricity, telecommunications, transport systems) in normal and critical conditions.

The second objective is to develop and explore intelligent sensor network technologies and applications of intelligent transportation systems.

- development and modification of sensors, upgrading of existing technological solutions; adopting of data remote reading solutions;
- developing control sensing technologies to collect data on the traffic flows on system level (such as average speed, structure of traffic flow, etc.);
- to model the processes of ensuring a high level of automatic control and to monitor the alternatives for decisions in the urban environment, using high-performance computing and the next generation of intelligent sensor infrastructure.
- to conduct a research into smart transport systems and develop innovative solutions in the field.

Description of acquired scientific results

(Describe scientific results achieved during reporting period, give their scientific importance)

We have developed a novel data transmitting technology and prepared for testing it in a water laboratory. In the reporting period, the physical prototype was developed. The sensor reading technology will be tested and adapted if necessary during this experimental testing in water research laboratory in the next period.

As a separate research topic, we developed power supply solution for remote readers and wireless nodes. This is important for all infrastructure services. National patent application: Nr.P-15-113 23.10.2015 "Mobile robot battery charger contact" has been submitted.

The research and development of intelligent sensor network technologies and applications of intelligent transportation systems was significantly developed in the frame of second objective. The sensor solutions its integration in transport intelligent system and supporting transport flow modelling questions were detailed in seven scientific publications listed below:

The original scientific publications included in the SCOPUS database (7):

1. A.Patlins, N.Kunicina *Real-Time Data Collection and Easy Passenger Counting Method for Public Transport System*. Transport Means 2015: Proceedings of the 19th International Conference, Lithuania, Kaunas, 22-23 October, 2015. Kaunas: Kaunas University of Technology, 2015, pp.329-332.
2. N.Zenina, A.Romanovs, J.Merkurjevs *Modelling based approach for attracted transport readiness trips estimation to the site*. International Journal of Mathematical Models and Methods in Applied Sciences, 2015, 9, pp.410-417.

3. I.Kabashkin, A.Mironov, P.Doronkin, A.Priklonsky *Condition Monitoring of Operating Pipelines with Operational Modal Analysis Application*, Transport and Telecommunication, Vol. 16. 2015, pp. 305–319.
4. I.Kabashkin *Modelling of Regional Transit Multimodal Transport Accessibility with Petri Net Simulation*. Procedia Computer Science, Vol. 77. 2015, pp. 151-157. (submitted for indexing in SCOPUS)
5. A.Patlins *Passenger Counting Methodology for Sustainable Intellectual Transport System*. In: 2015 56th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTU CON), Latvia, Riga, 14 October, 2015. Riga: 2015, pp.299-302. (submitted for indexing in SCOPUS)
6. N.Zenina, A.Romanovs, J.Merkurjevs *Incoming generated traffic flow estimation based on transport access design and level of service*. In: Advances in Environmental Science and Energy Planning: proceedings of the WSEAS 8th International Conference on Urban Planning and Transportation, Spain, Tenerife, Canary Island, 10-12 January, 2015. WSEAS Press: 2015, pp.195-201.
7. J.Merkurjevs, N.Zenina, A.Romanovs *Intelligent Transport Measures as a Component of Cyber-Physical Systems: Case Study for Adazi City*. In: Proceedings of the 17th International Conference on Harbor, Maritime & Multimodal Logistics Modelling and Simulation, Italy, Bergeggi, 21-23 September, 2015. Genova, Italy: DIME Università di Genova, 2015, pp.57-65. (proceedings submitted for indexing in SCOPUS)

Apart of conferences such results were obtained in the referred period:

Conferences:

1. A.Patlins *Passenger Counting Methodology for Sustainable Intellectual Transport System*, RTU 56th International scientific conference. 14 October 2015, Riga, Latvia;
2. N.Zenina, J.Merkurjevs, A.Romanovs *Global modelling parameters and two step clustering algorithm for transport simulation model calibration*. RTU 56th International scientific conference. 14-16 October 2015, Riga, Latvia;
3. A.Patlins, N.Kunicina *Real-Time Data Collection and Easy Passenger Counting Method for Public Transport System*. 19th International Conference "Transport Means", Lithuania, Kaunas, 23. October 2015;
4. J.Merkurjevs, N.Zenina, A.Romanovs *Intelligent Transport Measures as a Component of Cyber-Physical Systems: Case Study for Adazi City*. 17th International Conference on Harbor, Maritime & Multimodal Logistics Modelling and Simulation. 21-23 September, 2015. Bergeggi, Italy;
5. I.Kabashkin *Reliability of Bidirectional V2X Communications*, Advances in Wireless and Optical Communications 2015 (RTUWO'2015) IEEE International Conference, 5-6 November 2015, Riga, Latvia;
6. M.Savrasov *Macroscopic Transport Model as a Part of Traffic Management Center: Technical Feasibility Study*. Tenth International Conference on Dependability and Complex Systems DepCoS-RELCOMEX;
7. S.Kamenchenko, A.Grakovski *Increased Safety of Data Transmission for "Smart" Applications in the Intelligent Transport Systems*. Tenth International Conference on Dependability and Complex Systems DepCoS-RELCOMEX;
8. A.Mironov, P.Doronkin, A.Priklonsky, I.Kabashkin *Operational Modal Analysis (OMA) Application for Condition Monitoring of Operating Pipelines*. 15th International Conference "Reliability and Statistics in Transportation and Communication (RelStat'15)", 21–24 October 2015, Riga, Latvia;

9. A.Grakovski, A.Pilipovacs *Multi-Purpose Fiber Optic System for Automated Measurement of Vehicle's Parameters*. 15th International Conference „Reliability and Statistics in Transportation and Communication” (RelStat'15).

National patent application: Nr.P-15-113 23.10.2015 "Mobile robot battery charger contact"

Participation in industrial events 2:

ICT 2015 Innovate, Connect, Transform" <https://ec.europa.eu/digital-agenda/en/ict2015-innovate-connect-transform-lisbon-20-22-october-2015>

ARTEMIS 2015 Brokerage Event 21-22 Jan 2015 <https://artemis-ia.eu/calendar>

Popular-science publications (1)

N.Zenina, A.Romanovs, J.Merkurjevs *Transport Simulation Model Calibration with Two-Step Cluster Analysis Procedure*. Accepted for publication Information Technology and Management Science, Vol.18, 2015.

Number of defended master's thesis (4):

1. M.Sc. thesis "*Development of transport information system, based on the analysis of transport models*", J.Piskunova, RTU ITI acad. master program;
2. M.Sc. thesis "*Simulation Based Approach for Operating Costs Analysis of Freight Trucking*", N.Ozernova, RTU Baltech master programme "Industrial Engineering and Management";
3. M.Sc. thesis "*Transport node simulation model verification and validation*", J.Sergejenko, RTU ITI acad. master program;
4. M.Sc. thesis "*Vehicle weight measurement precision motion increasing use of fiber optic sensor calibration based on genetic algorithms*", A.Pilipovacs, TSI.

Further research and practical exploitation of the results

(Describe further research activities that are planned, describe possibilities to practically exploit results)

Descriptions of activities are structured according to the above-mentioned tasks:

The developed data transition technology, and its practical exploitation after testing of it in water research laboratory will be deployed for large infrastructure objects control, it will allow to control one of regional segment with the several optimisation aspects. The data raiding solution allows to control different remote infrastructure objects using the same approach: e.g. the same data format is collected from all element. It regular conditions it will allow to achieve energy efficient region paradigm, infrastructure services supply on demand as well as synchronised infrastructure maintenance process. In critical situations it will allow to reduce possible negative impact as automatically will take in account possible impacts and immediately will provide control on best possible scenario. The study will be continued in such main directions:

- to integrate and elaborate new unified methods for consolidating, interpreting and modelling data acquired from different sensors;
- to use the same methodology not only for water supply services, but also for all city infrastructure systems including power, water heat supply;
- to develop novel methods applicable in high performance computing environment.

- to test and improve developed data transmitting process;
- to integrate developed data transmitting with HPC (High performance computing) capacity
- to integrate addressed integration problems used GPU (Graphical Processing Units);
- the prototype of future data transmitting technology is developed and will be tested in water research laboratory;
- the data transmitting prototype of water infrastructure is created, and data transmitting experiments will be started. The same technology will be extended on infrastructure services intelligent sensor network technologies and applications of intelligent transportation systems.
- the sensors and modelling technologies will be developed for transport and other infrastructure services e.g. weight sensor design and development (WiM - weight in motion);
- the traffic counting and classification solution, as well as data transmission module (responsible for the transmission of data from the sensor to the data centre). Will be tested and connected with monitoring tools, using new data transmitting paradigm.

Dissemination and outreach activities

(Describe activities that were performed during reporting period to disseminate project results)

<http://www.tsi.lv/lv/content/nakamas-paaudzes-informacijas-un-komunikaciju-tehnologiju-ikt-petniecibas-valsts-programma>

<http://www.itbaltic.com/en/news/nexit-programmas-apsriesanas-seminars-24-novembri>

2.1.4. Project No. 4

Title	New generation large volume data processing systems	
Project leader's name, surname	Juris Viksna	
Degree	Dr.sc.comp.	
Institution	Institute of Mathematics and Computer Science, University of Latvia	
Position	Leading researcher	
Contacts	<i>Phone number</i>	+371-67213716
	<i>E-mail</i>	juris.viksna@lumii.lv

Project No. 4.1. Bioinformatics and biomedicine

Project goal and objectives

(Describe the project goals and objectives so that the achievements reported below could be placed in context and evaluated)

- Develop new methods and supporting software tools for laboratory information systems (LIMS) for collecting and integrating phenotype and experimental sources of biomedical data.
- Develop methods for analysing and visualizing large sets of bioinformatics data.
- Develop methods and supporting software tools for integrating local biomedical databases and other data sources with centralized European and other international data repositories (EGA, ICGC and others), in accordance with the set standards for

data formats, and in line with the security requirements for data storage and data transfer procedures.

- Develop further cooperation between Latvian research institutions and institutions of other European Union countries in the fields of bioinformatics and biomedicine; to ensure a sufficiently high research capacity of Latvian research institutions to make them attractive for participating in European research projects; to facilitate integration of Latvian research institutions into the existing collaborative research projects and networks, in particular inclusion of Latvian institutions in ELIXIR consortium.

Description of the acquired scientific results

(Describe scientific results achieved during reporting period, give their scientific importance)

We have continued development and maintenance of laboratory information management system KIDREP (Kidney cancer Data REPository) intended for storing annotation, analysis and import and export from other laboratory information management systems of phenotype and digital microscopy imaging data for renal cell adenocarcinoma patients after the end of EU 7th framework research project CAGEKID during which the initial KIDREP prototype has been created. Continuous access to the data repository was provided for the partners of the initial project consortium and during these continuing collaborations the repository was supplemented with a number of new data sets. The work has continued towards the development of the open source version of the software as well as to the preparation of publication about the software.

We have tested the methods of graph visualisation and analysis on bioinformatics data sets. The methods were successfully used for analysis of state spaces of gene regulatory networks. A scientific paper has been prepared and has been published (the paper is indexed in Scopus database):

A.Brazma, K.Cerans, D.Ruklisa, T.Schlitt, J.Viksna. *Modeling and analysis of qualitative behaviour of gene regulatory networks*. Lecture Notes in Computer Science, vol.7699, pp.51-66, 2015.

We have continued working on integration of local biomedical data bases and other data resources with centralised European and other international data repositories. This included the preparation of RNA and DNA sequencing data according to ICGC specifications and submission of these data sets to ICGC Data Portal.

We have prepared and submitted a number of proposals to Ministry of Education and Science in response to the call of proposals for development of ESFRI roadmap, these propositions emphasising and justifying the need of integration of Latvian research institutions within pan-European ELIXIR research infrastructure.

Further research and practical exploitation of the results

(Describe further research activities that are planned, describe possibilities to practically exploit results)

1. Development of methods for analysing and visualizing large sets of bioinformatics data:
2. Development of methods and supporting software tools for integrating locally hosted databases and services with the centralized European and other international repositories (EGA, ICGC etc.), according to the required standards and specification on data formats, and data privacy protection requirements during data storage and transmission:

Dissemination and outreach activities

(Describe activities that were performed during reporting period to disseminate project results)

Published papers:

A.Brazma, K.Cerans, D.Ruklisa, T.Schlitt, J.Viksna. *Modeling and analysis of qualitative behaviour of gene regulatory networks*. Lecture Notes in Computer Science, vol.7699, pp.51-66, 2015.

Conference presentations:

J.Viksna. *Modelling and analysis of the impact of parameter values on dynamic behaviour of gene regulatory networks*. Joint conference between Genome Informatics Workshop and International Conference in Bioinformatics GIW/InCoB 2015, Odaiba, Japan, September 2015.

Project No. 4.2. Large-volume data and knowledge infrastructure

Project goal and objectives

(Describe the project goals and objectives so that the achievements reported below could be placed in context and evaluated)

- Approbation of the solution for visualization of Big Data analyses on geographical images and interactive map platforms.
- Approbation of the new Scientific cloud computing platform according to its conceptual planning that includes Big Data and other platform services.
- Improvement of the effective Web-harvesting technology to significantly increase its self learning rate.
- Deployment of a technical solution for using specific device components (like GPU accelerators) in a cloud infrastructure.

Description of acquired scientific results

(Describe scientific results achieved during reporting period, give their scientific importance)

The new Scientific cloud computing platform is deployed and being used by first users. The infrastructure as a service (IaaS) is in operation. It allows users to self service provisioning of virtual discs, networks and virtual machines. The new cloud platform serves as highly automated infrastructure provisioning system for the Latvian scientific community. Since the previous, 1st generation cloud has been very successful in supporting scientific calculations and already congested for years, the new cloud is highly anticipated and welcome by multiple research groups eager to start using it.

Three other service types are in deployment phase in the new cloud infrastructure: Big Data analyses, high throughput computing (HTC), databases as a service.

The existing Big Data platform is still supported and in use on the cluster of 32 servers. A new user is testing ways to use it for transferring and processing large volumes of data.

Technical solution is deployed for using GPU accelerators in the cloud infrastructure. It allows the provision of such computing services on demand.

The new and effective web harvesting technology has been improved. It is able to identify which Web URLs, potentially, contain the already seen content and avoids requesting those. Thus the effectiveness of harvesting original content is significantly better, and the resources are freed from mining and processing duplicate content. The technology is improved with more intensive self learning algorithm that even more increases the effectiveness of

predicting duplicate content. The new technology will serve as a reliable tool for harvesting vast volumes of Web content for research and training the artificial intelligence language tools.

Dissemination and outreach activities

(Describe activities that were performed during reporting period to disseminate project results)

Conference presentations:

L.Truksans, *E-Spiets2 – universal cloud for science*, Latvian Open Technologies Association (LATA) conference, 28.01.2016.

M.Sc. theses:

- I.Kocins., “*Balancing load of user defined functions in “Cassandra” data base cluster*”.
- M. Balodis, “*Web harvesting technologies*”.

Project No. 4.3. Cyber-physical systems’ platform

Project goal and objectives

(Describe the project goals and objectives so that the achievements reported below could be placed in context and evaluated)

- Develop algorithms for recognizing specific sites and urban areas (for example, green areas, industrial regions, etc.) in high-resolution satellite images. In addition to improve the results by using multiple data sources of information.
- Carry out the computational complexity assessments of specified in Project tasks algorithms (GMEM, CLEAN and others). Their adaption to the possibilities of parallel computing facilities by using of high-performance computing clusters in order to automate the processing of data in information systems.
- Development of programmable directional antenna array field antenna signal generation model for simulating radio astronomy signal source. Develop antenna array directional beamforming algorithm using high performance cluster. Performing antenna array beamforming simulations. Study of beamforming algorithm realization methods and the necessary computing power for realization.
- Develop solutions for establishment of large-scale sensor fields, their operation, data acquisition and processing.

Description of acquired scientific results

(Describe scientific results achieved during reporting period, give their scientific importance)

1. During the reporting period, emphasis was put on the processing of high spatial resolution remote sensing data. Processing of Latvian Geospatial Information Agency orthophotomaps enables preparation of detailed thematic maps of green vegetation and buildings in vast areas. Automated preparation of the thematic maps would promote studies of the development of the urban areas and would allow quick information updating of the current situation.

Main scientific results during the reporting period:

- Literature studies on building detection using high spatial resolution satellite images and aerial photos
 - Mapping of green vegetation in the area of Salaspils using orthophotomaps and methodology based on vegetation index NDVI and colour information in the images. As a result, thematic map was produced.
 - Comparison between orthophoto and satellite images based green vegetation maps was performed.
 - First version of the building detection methodology was developed.
 - Initial tests on building detection were performed using orthophotomaps.
2. We have prepared for testing image processing algorithms using the Irbene 32 m radio telescope. The diagram pattern of the VIRAC RT-32 radio telescope was revealed on the base of 3.2 cm observations of large isolated sunspots. The technique makes use of the minimum intensity of a set of images and the stable relative position with time of the diagram side lobes.
 3. We have developed a toolbox for improved LabVIEW code generation. LabVIEW provides highly convenient environment for simulation development and tools for generation of simulation environment that can include simulation itself and collection of simulation data. However, it is not easy to understand the principles of code generation and effectively develop simulation generators. With our toolbox, we aim to solve this problem. The toolbox is based on standard LabVIEW code generation functions by maximally simplifying the application and minimizing the necessary amount of tools for code generation. These toolbox functions can be used for generation of antennae signal processing code; where there are many repetitive code parts to be implemented in signal processing hardware. Part of the results are included in 3 Mg.Sc. theses (publications 1 – 3).
 4. We are working to adapt the complex of spatially remoted (up to thousands km) antennae in order to convert it in the large-scale sensor field based on use of VLBI technologies. We developed and tested algorithms and software solutions for antenna elements mutual synchronization and long-term synchronization control. Created algorithms and software solutions were tested in the number of real experiments. Two 32 and 16 m diameter radio telescopes (Irbene VSRC RT-32 and RT-16) were used as test platform. Experiments have shown that the antennae as a united system can provide tracking of GLONASS and GPS satellites with different speeds and motion paths, as well as perform a solar or other radio objects scanning with synchronization accuracy and stability, which would be sufficient for VLBI observations. From September 2015, several VLBI observation sessions together with the European VLBI Network radio observatories, RadioAstron space observatory and the Radiophysical Research Institute (NIRFI), Nizhniy Novgorod.

Further research and practical exploitation of the results

(Describe further research activities that are planned, describe possibilities to practically exploit results)

The practical exploitation of the achieved results may be as follows:

1. Methodologies, developed during the reporting periods, could be exploited to prepare maps of green vegetation and buildings automatically, based on up-to-date orthophotos. Comparison between the results of orthophotos and satellite images will help to improve understanding of the results of satellite image classification.
2. Solar radio imaging is plays of great importance for prediction of geomagnetic situation (magnetic storms). More precise definition of the antenna beam pattern is much more cheaper than the refinement of the radiotelescope itself.

3. The developed code generation tools will be used in developing beam forming algorithm for two dimensional directional antenna field. The application range of these generation tools is very wide since they can be used in other projects, where MIMO (Multiple-Input Multiple-Output) type of signal processing and other complex algorithms are to be implemented.
4. The research results may be used in order to establish various similar size antenna systems designed for satellite signal transmitting and reception with VLBI techniques as well as for space debris, near the Earth asteroids and solar observations.

Further research activities are planned as follows:

1. Identification of the error sources and misidentification problems in building detection methodology. Improvements of the methodology are planned based on the knowledge about critical points in the methods. Methodology will be tested for Salaspils city. Similar to the case of green vegetation maps, comparison will be made for mapping of the impervious surfaces using orthophotomaps and satellite images. Results of the research will be presented in the part of scientific article.
2. At the next stage of the project, the yielded diagram pattern will serve for the cleaning of the radio images taken with the RT-32 radio telescope. Thereby image-processing algorithms, established during the project, will be tested.
3. The next stage is development of programmable two dimensional directional antenna array field simulation and carrying out the antenna array beamforming simulations.
4. Further research activities will be focused on testing the established algorithms for large array sensor field by integration of VIRAC radio telescope RT-16 to the VLBI observations including long and short baseline interferometric experiments on radio sources as well as GLONASS and GPS satellites observations. Particularly data processing algorithms will be tuned for short baseline interferometer RT-32 – RT16 with baseline 1 km.

Dissemination and outreach activities

(Describe activities that were performed during reporting period to disseminate project results)

1. E.Vaviļina, G. Gaigals *Improved LabVIEW Code Generation*. The 3rd IEEE Workshop on "Advances in Information, Electronic and Electrical Engineering". Riga, 13th November, 2015.
2. E.Vaviļina, G. Gaigals *LabVIEW code generation tool application in development of signal processing algorithms*. Christmas Scientific Conference of Ventspils University College, Ventspils 17th December, 2015.

Publications

Mg. Sci Theses:

1. E.Briede, *Development and Efficiency Analysis of Channel Coding Methods*, Ventspils University College, 2015;
2. J.Šate, *Design of OFDM signal synthesier and parametric analysis of it's implementations*, Ventspils University College, 2015;
3. R.Trops, *Development of Rician channel simulator*, Ventspils University College, 2015.

Project No. 4.4. Mathematical modelling, methods and algorithms for analytically solving inverse problems, oriented to data processing technologies

Project goal and objectives

(Describe the project goals and objectives so that the achievements reported below could be placed in context and evaluated)

Aims of the Project 4.4

1. Development of mathematical models as well as analytical and numerical methods for stable solving of multi-dimensional problems including inverse problems, which occur in technical technological processes, economic planning, and optimal ecosystems management, for identification, diagnostics and prediction
2. Development of complex software for correct realization of the constructed models, analytical and numerical methods for modern highly productive computing systems.

Objectives of the Project 4.4

1. Develop the mathematical models by using the language of the inverse problems theory. The constructed mathematical models will adequately describe real technical technological processes and objects while identified, diagnosed, and/or managed.
2. Develop the analytical methods for finding the stable solutions of 1D-3D linear and nonlinear inverse problems arising in processing, recognition and identification of multi-structured images (radar, medical, economic, technical and technological, etc. digital images and/or numerical data).
3. Develop the analytico-numerical and numerical algorithms for finding the stable solutions of control inverse problems of dynamic systems, and realize these algorithms by using multiprocessor computer systems.
4. Participation in the international conferences; organize the workshop; prepare the popular science article.

Description of acquired scientific results

(Describe scientific results achieved during reporting period, give their scientific importance)

1. We have investigated a specific problem of optimal planning of maritime transportation of multiproduct cargo by ships of one (corporate strategy) or several (partially corporate strategy) companies: the core of the problem consists of the existence of the network of intermediate seaports (i.e. transitional seaports), where for every ship arrived the cargo handling is done, and which are situated between the starting and the finishing seaports. In this work, there are mathematical models built from scratch in the form of multicriteria optimization problem; according to the properties of the criteria and structure of the feasible solution set; are formulated different optimality conditions; are analyzed different approaches for finding effective solutions (i.t. Pareto optimal solutions) and for check of the given solutions' effectiveness. In addition, in this work, there are considered and analyzed three well-known methods of contraction of the Pareto boundary (weighted sum method; epsilon-constraint method; goal attainment method of Gembicki), one of which, then, is used for reducing the built models to a one-criterion problem of linear programming. The obtained results can be used in planning of multinomenclature goods transportation on roads and railways.
2. We have we constructed and investigated three mathematical models, which are written in the language of differential equations, and belong to the kind of initial-boundary value problems. These models describe various problems arising in the study of aquatic ecosystems of Latvia. All three models are evolutionary models: they are non-stationary

and continuous qualitative models with dynamic parameters, and all they are designed for the analysis, evaluation and forecast of aquatic systems (reservoirs, lakes and seas). In the construction and study of all these three mathematical models as a tool it was used the classic theory of differential equations (ODE un PDE) as well as the apparatus of mathematical physics.

3. We have investigated the problem of efficiency evaluation of technical system by measurable structural design parameters. To accomplish the purpose of considered problem it is constructed the mathematical model in the form of a finite-dimensional operator equation, where desired elements are both influence weights of the calculated structural design parameters and technical effectiveness indicator of the system. First, the constructed model is reduced to the normal system, and then the apparatus of the ill-posed inverse problem theory is used for the reduced problem: a regularizing operator is constructed and an algorithm for finding the regularization parameter is developed.
4. As it is known, in the capacity of fibre material could be used wide range of materials, both organic and inorganic, for instance, cellulose, fabrics, wool, cotton, glass, rockwool, basalt fibre, etc. As the insulator could be used chopped polystyrene, polyurethane, cork, peat, bark, etc. Binding together of the insulation particles, forming self-supporting layer of insulation material, useful both for thermal and for acoustic insulation. Remarkable positive property among others is ability of the material to accept and release water vapour – "breathe" like most of the natural materials. Other – it is stable against setting – opposite to pure cellulose wool insulation. New insulation has been developed by the Liepaja University scientists. It is based on mix of insulation material particles enclosed in fibrous mass, having insulation properties (as it contains trapped air micro pockets) in the same time it. We have proposed the mathematical model describing the dynamics of propagation and retention of heat over fibre insulation coating by taking "inner" specificities (graininess and porosity of layered structure of the considered fibre insulation) of heat insulator into account. It should be noted that the proposed model has its limitations: it describes only "internal" physical processes includes: (a) heat propagation in the insulation material; (b) mechanical process, related to tensions in material structure and differences in elasticity of said material under the influence of uneven heat spreading in the insulation material, which has been regarded as non-homogeneous layered structure.
5. We have considered the problem of formation and behavior of solid nano-sized particles on the surface of materials. In the simulation, it is assumed that the main processing technology of surface nanostructures is laser irradiation, which causes the Brownian motion of nanoparticles, due mainly to thermal fluctuations: if the temperature around the nanoparticles is uniformly distributed, the time average of the Brownian fluctuations is zero; however, if there is a temperature gradient around the nanoparticles, the thermal fluctuations affect the nanoparticle in different ways from different sides, and there is a force like the thermophoretic force, biasing the average position of the nanoparticle. When building a 1D model of the formation and flow behavior of nanoparticles, three important assumptions are introduced: the impact of nanoparticles on the process of irradiation is negligible; the impact of nanoparticles on each other as compared to the effect of laser irradiation on them is also negligible; and nanoparticles after laser irradiation can move both forward and backward and at every fixed period of time, moving the nanoparticles does not impose any steric constraints. Under the above assumptions, a 1D continuous model is built, implicit and explicit finite difference schemes to solve it are developed; their convergence and order of convergence are studied; an output condition ensuring the stability of the explicit difference scheme is obtained, the unconditional stability of implicit difference scheme is proven, and software for computer implementation of some of the obtained analytical and numerical results developed.

6. Network reliability to a large extent is determined by the topological type of network, from what efficiency of the network stream management depends as well as opportunity for performing alternative routing with the purpose of provision reliability and security to data transmission resisting to informational threats. Synthesis of topology should be performed with consideration of the future development of network. In that context, development of the methods of structural projecting and modeling for networks of data transmission (more concretely – solution of problems of construction of optimal topology of network by the criterion of resistance towards breaks, reliability and low cost) is actual. We have proposed the parametric non-linear optimization model for analysis of the structural reliability of the networks as well as for synthesis of the optimal topologies of these networks in order to boost their reliability and resistance.
7. We have suggested and substantiated an analytical method for solving a wide class of linear coefficient inverse problems. The suggested method is applied to the inverse initial-boundary value problems (with boundary conditions of all four kinds: Dirichlet, Neumann, Robben-Newton and mixed types) for finding coefficient of the temperature resistance of the homogeneous material. The performed plentiful computing experiments point that the proposed analytical method is self-regularizing and it finds stable solutions of the initially ill-posed inverse problems.
8. We have studied one of the problems of frequency electromagnetic ionospheric sounding for unambiguous determination of electron concentration distribution. An analytical method is suggested, so it is possible to find solution in the closed form of the considered problem. The suggested method initially reduces the original problem to the problem of integral geometrics. Further, the integral geometrics problem is reduced to the first kind matrix integral equation of the Volterra type with a weak singularity, and the obtained integral equation is solved by the Tikhonov's regularization method, so the solution is found in the space of continuous functions.
9. Systems with fins play very important role in various branches of engineering, including aircraft and aerospace: from domestic radiators and refrigerators trough motor and aircraft vehicle engines to PC and cosmic apparatus. Cooling and heating systems with fins are widely exploited in various technical facilities. Therefore the modelling of heat transfer in these systems is very actual problem. Traditionally such problems are solved in 1D approximation. We have continued our early investigation of systems with fins that have been realized by us in 2003-2005. We have suggested an analytical method for finding the exact solution as well as an analytico-numerical method for finding the stable approximate solution of 2D model for periodic systems with fins.

Publications:

1. R.Aleksejevs, R.Guseinovs, A.N.Medvedev, Sh.E.Guseynov. *Groupage Cargo Transportation Model*. Journal of Transport and Telecommunication, Vol. 17, Issue 1, pp. 60-72, <http://www.degruyter.com/view/j/ttj.2016.17.issue-1/issue-files/ttj.2016.17.issue-1.xml>.
2. Sh.E.Guseynov, J.V.Aleksejeva. *Mathematical Modelling of Aquatic Ecosystem*. Proceedings of the 10th International Scientific and Practical Conference "Environment. Technology. Resources", June 18-20, 2015, Rezekne, Latvia, ISSN: 1691-5402, Vol. 3, p. 92-99. <http://dx.doi.org/10.17770/etr2015vol3.192>
3. Sh.E.Guseynov, A.I.Urbah, S.A.Andreyev. *On one Approach for Stable Estimate of Technical System Efficiency*. Proceedings of the 10th International Scientific and Practical Conference "Environment. Technology. Resources", June 18-20, 2015, Rezekne, Latvia, ISSN: 1691-5402, Vol. 3, p. 100-108. <http://dx.doi.org/10.17770/etr2015vol3.191>
4. A.Grickus, Sh.E.Guseynov (2015). *On one Mathematical Model for Dynamics of Propagation and Retention of Heat over New Fibre Insulation Coating*. Proceedings of the 10th International Scientific and Practical Conference "Environment. Technology.

- Resources", June 18-20, 2015, Rezekne, Latvia, ISSN: 1691-5402, Vol. 3, p. 82-86. <http://dx.doi.org/10.17770/etr2015vol3.504>
5. U.Zaimis, Sh.E.Guseynov. *Analytic-Numerical Modelling and Investigation of Nanostructures' Dynamics on Material Surfaces after Laser Irradiation*. Proceedings of the 10th International Scientific and Practical Conference "Environment. Technology. Resources", June 18-20, 2015, Rezekne, Latvia, ISSN: 1691-5402, Vol. 3, p. 212-216. <http://dx.doi.org/10.17770/etr2015vol3.193>
 6. Sh.E.Guseynov, A.V.Berezhnoy, J.S.Rimshans, J.V.Aleksejeva. *Mathematical modelling of computer networks for optimization of their performance, reliability and efficiency*. Presentation in the Baltic HPC and Cloud Computing Conference, June 02-04, 2015, Riga, Latvia, 7 pages. <http://www.hpc.rtu.lv/en/content/preliminary-program>
 7. A.N.Medvedev, Sh.E.Guseynov. *On a model for maritime cargo transportation planning*. The 15th International Conference "Reliability and Statistics in Transportation and Communication" (RelStat'15), October 21-24, 2015, Riga, Latvia, p. 47. <http://relstat.tsi.lv>
 8. Sh.E.Guseynov. *On an analytical approach for finding the temperature diffusivity coefficient of the material*. Riga Technical University 56th International Scientific Conference, October 14-16, 2015, Riga, Latvia, p. 72, 160. http://www.rtu.lv/en/component/option,com_docman/task,doc_download/gid,4193/rtu-56.-scientific-conference-programme.pdf
 9. Sh.E.Guseynov. *On a problem of frequency electromagnetic ionospheric sounding for unambiguous determination of electron concentration distribution*. Riga Technical University 56th International Scientific Conference, October 14-16, 2015, Riga, Latvia, p. 72, 160. http://www.rtu.lv/en/component/option,com_docman/task,doc_download/gid,4193/rtu-56.-scientific-conference-programme.pdf
 10. Sh.E.Guseynov, J.V.Aleksejeva. *On a problem of heat exchanging in 1D-, 2D- and 3D-periodic systems with rectangular fins*. Riga Technical University 56th International Scientific Conference, October 14-16, 2015, Riga, Latvia, p. 72, 160. http://www.rtu.lv/en/component/option,com_docman/task,doc_download/gid,4193/rtu-56.-scientific-conference-programme.pdf
 11. R.Aleksejevs, R.Guseinovs, Sh.E.Guseynov. *On a multicriteria problem of maritime cargo transportation planning with handling operations in intermediate seaports*. Riga Technical University 56th International Scientific Conference, October 14-16, 2015, Riga, Latvia, p. 73, 160. http://www.rtu.lv/en/component/option,com_docman/task,doc_download/gid,4193/rtu-56.-scientific-conference-programme.pdf

Further research and practical exploitation of the results

(Describe further research activities that are planned, describe possibilities to practically exploit results)

The following research activities have been projected:

1. We will develop stable approximation algorithms for solving irregular problems with application to multi-dimensional integral equations.
2. We will develop stable analytico-numerical algorithms for processing of structured and unstructured data arising in medicine and molecular biology.
3. We will develop mathematical models and stable analytical methods for investigation of comparative degree of coherence of key indicators for some post-socialist countries of Central and Eastern Europe to determine the potential of export banking and certain other luxury services.
4. We will develop physico-mathematical models and the corresponding analytical and numerical methods for controlled formation of periodic nanostructures at solid surfaces irradiated by femtosecond laser pulses.

5. We will continue the development of multi-criteria models and stable analytical-numerical algorithms for optimization of intermodal transportation of multiproduct cargo.
6. We will continue the development of analytical and analytico-numerical methods for solving linear and nonlinear coefficient inverse problems that appear in various technical systems and devices of different complexity.
7. We will continue to investigate different problems on application of frequency electromagnetic sounding of artificial Earth satellites as well as near-Earth atmosphere.
8. We will continue to investigate the formation and behavior of solid nano-sized particles on the surface of semiconductors.
9. We plan to prepare and publish two mathematical textbooks.

Dissemination and outreach activities

(Describe activities that were performed during reporting period to disseminate project results)

1. The Workshop entitled "The Week of Science and Education for Economics and Business", organized by the Institute of Mathematical Sciences and Information Technologies in collaboration with the Higher School of Information Systems Management, June 08-12, 2015, Riga, Latvia. In the framework of this Workshop the following contribution was held:
 - Sh.E.Guseynov, J.V.Aleksejeva. *Problems facing the decision-maker in the process of choosing the optimal strategy: subjectivity and ambiguity against the reasonableness*, 112 pages.
2. The following popular science article was prepared and published on the Liepaja University site <https://www.liepu.lv/lv/1040/valsts-petijumu-programmas> as well as on the site <https://sites.google.com/site/sharifguseynov/popular-science>:
 - Sh.E.Guseynov, J.V.Aleksejevs, J.Kaupuzs. *Synthesis of Mathematical Modeling and Theory of Differential Equations*, 4 pages.

PART 3: INFORMATION ABOUT PROGRAM FINANCE

Short information about the use of program finances

		Year 1	Year 2	Year 3	Year 4
1000–9000	EXPENSES - IN TOTAL	131 575	220 430		
1000	Remuneration	102 858	193 571		
2000	Goods and services	22 539	26 089		
2100	Study, work and official missions, official and work trips	4 620	7 611		
2200	Services	15 250	14 952		
2300	Stock, materials, energy resources, goods, office supplies and inventory	1 758	2 598		
2400	Expenses for the purchase of periodicals	911	928		
5000	Establishment of core capital	6 178	770		