Scientific report for the 3nd 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: 01.01.2016-31.12.2016
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:
- We have shown an equivalence between quantum algorithms and polynomials: every quantum algorithm of a certain type (1-query algorithm in the quantum black box model) can be described by a polynomial of a certain form and vica versa. This is the first time when the power of quantum algorithms has been exactly characterized in terms of a mathematical notion that does not involve quantum physics.
- In synergy with the State research programme on Latvian studies, we have contributed to the development of a large open lexical database for Latvian which will be further linked to the Linked Open Data Cloud (LOD) cloud in a separate industry-oriented research project. This will facilitate the ontology lexicalization in Latvian.
- We have developed a new method for segmentation of biological images which allows to decrease the segmentation time while preserving quality of segmentation. The method is being tested on actual images from pathological anatomy.
- We have created a high performance computing (HPC) platform, creating a research and education IT centre for regional colleges with the possibility of remote work.

Other research areas of the programme are:
- o tools for modelling and semantic data bases;
- 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 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 40 research papers have been submitted. 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 a researcher from MIT.
- 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.
- satellite image processing research – together with the European VLBI network, Nizhny Novgorod Radiophysical Research Institute and others.

Among researchers of the programme, we have 18 Ph.D. students, 11 M.Sc. students and 25 recent Ph.D.'s (who have received their Ph.D. in the last 10 years). Five 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)	6	2 and 1 submitted

number of other original scientific articles included in Web of Science or SCOPUS databases	9	27
number of original scientific articles enclosed in magazines of database *ERIH(A and B)* or in conference proceedings	4	8 and 2 submitted
number of reviewed scientific monographs	1	
2. Within the framework of the programme:		
number of <u>defended</u> doctoral thesis	4	1
number of <u>defended</u> master's thesis	11	6
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	1	1
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	7	20
seminars	3	1
Seminars, organized	7	4
popular-science publications	3	8
exhibitions	1	2
conference abstracts (without posts)		3
the investigator's brochure		1
Economic performance indicators		
1. Size of the private funding attracted to the scientific institution within the framework of the programme, including:		
2. Number of applied for, registered, and valid patents or plant varieties within the framework of the programme:		
in Latvia	2	
abroad		
3. Number of new technologies, methods, prototypes or services that have been elaborated within the framework of the programme and approbated in enterprises	2	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. Research and education IT centre's development with remote access in regional higher educational establishments (Regional Partner Research Facility)	1	1

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

No deviations in the 3nd period.

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

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

1. L.Koessler, S.Colnat-Coulbois, T.Cecchin, J.Hofmanis, J.P.Dmochowski, A.M.Norcia & L.G.Maillard (2016). In-vivo measurements of human brain tissue conductivity using focal electrical current injection through intracerebral multicontact electrodes. Human Brain Mapping (IF - 5.9) Accepted SCOPUS (SNIP: 1,728).

2. Sh.E.Guseynov, R.Aleksejevs, R.Guseinovs, J.V.Aleksejeva, A.V.Berezhnoy, A.N.Medvedev (2016). *On a multicriteria problem of planning maritime cargo transportation with handling operations in intermediate seaports.* – Annals of Operations Research, ISSN: 0254-5330, 25 p. Accepted SCOPUS (SNIP: 1.123).

Other original scientific publications indexed in SCOPUS or Web of Science

1. K.Prūsis, J.Vihrovs, and Thomas G. Wong. Doubling the Success of Quantum Walk Search Using Internal-State Measurements. Journal of Physics A 49, 455301 (2016) (SCOPUS).
2. K.Prūsis, J.Vihrovs, and Thomas G. Wong. Stationary States in Quantum Walk Search. Physical Review A 94, 032334 (2016) (SCOPUS).
3. S.Aaronson, A.Ambainis, J.Iraids, M.Kokainis, J.Smotrovs. Polynomials, Quantum Query Complexity, and Grothendieck's Inequality. Conference on Computational Complexity 2016: 25:1-25:19 (SCOPUS).
4. A.Ambainis, M.Kokainis, R.Kothari. Nearly Optimal Separations Between Communication (or Query) Complexity and Partitions. Conference on Computational Complexity 2016: 4:1-4:14 (SCOPUS).
5. A.Ambainis, K.Prūsis, J.Vihrovs. Sensitivity Versus Certificate Complexity of Boolean Functions. Computer Science in Russia (CSR) 2016: 16-28 (SCOPUS).
6. U.Bojārs, R.Liepiņš, N.Grūzītis, K.Čerāns, E.Celms. Extending OWL Ontology Visualizations with Interactive Contextual Verbalization. In Proc. of the Second International Workshop on Visualization and Interaction for Ontologies and Linked Data (VOILA '16), Kobe, Japan. CEUR Workshop Proceedings, vol. 1704, CEUR-WS.org, 2016, pp.5-16. (Expected to be indexed by SCOPUS).
7. J.Ovčiņņikova, K.Čerāns. Advanced UML Style Visualization of OWL Ontologies. In Proc. of the Second International Workshop on Visualization and Interaction for Ontologies and Linked Data (VOILA '16), Kobe, Japan. CEUR Workshop Proceedings, vol. 1704, CEUR-WS.org, 2016, pp.136-142. (Expected to be indexed by SCOPUS).
8. K.Čerāns, J.Ovčiņņikova. ViziQuer: Notation and Tool for Data Analysis SPARQL Queries. In Proc. of the Second International Workshop on Visualization and Interaction for Ontologies and Linked Data (VOILA '16), Kobe, Japan. CEUR Workshop Proceedings, vol. 1704, CEUR-WS.org, 2016, pp.151-159. (Expected to be indexed by SCOPUS).

9. R.Liepiņš, N.Grūzītis, K.Čerāns, J.Ovčiņņikova, U.Bojārs and E.Celms. Adding Verbalization to Graphical Ontology Editor OWLGrEd. In, Databases and Information Systems IX, Selected Papers from the Twelfth International Baltic Conference, DB&IS 2016, Frontiers in Artificial Intelligence and Applications, Vol 291, IOS Press, pp.17-30, 2016 (Expected to be indexed by SCOPUS).

10. G.Būmans and K.Čerāns. Database to Ontology Mappings in RDB2OWL: Notation and Implementation. In, Databases and Information Systems IX, Selected Papers from the Twelfth International Baltic Conference, DB&IS 2016, Frontiers in Artificial Intelligence and Applications, Vol 291, IOS Press, pp.31-42, 2016. (Expected to be indexed by SCOPUS).

11. S.Kozlovics. A Model-Driven Approach to Web Applications. In, Databases and Information Systems IX, Selected Papers from the Twelfth International Baltic Conference, DB&IS 2016, Frontiers in Artificial Intelligence and Applications, Vol 291, IOS Press, pp.31-42, 2016. (Expected to be indexed by SCOPUS).

12. N.Grūzītis and G.Bārzdiņš. The role of CNL and AMR in scalable abstractive summarization for multilingual media monitoring. Controlled Natural Language, LNCS 9767, Springer, 2016, pp. 127-130 (SCOPUS).

13. H.Altakroury, L.Koessler, J.Hofmanis & V.Louis-Dorr. (2016). In vivo estimation of head conductivities frequency response with IES and SEEG-EEG. Neurophysiologie Clinique/Clinical Neurophysiology, 46(2), 77-79.

14. V.Louis-Dorr, H.Altakroury, J.Hofmanis, V.Caune, R.Ranta, S.Le Cam, ... & L.Koessler. (2016). Résolution de problèmes direct et inverse à partir de mesures SEEG et de la stimulation électrique intracérébrale. Neurophysiologie Clinique/Clinical Neurophysiology, 46(2), 88.

15. A.Laurs, J.Priekulis, Z.Markovics. Aboltins A. Research in farm management Technologies using the expert method. Agronomy Research, Volume 14, Number 3, Tartu, Estonia, 2016, pp.811-820.

16. M.Ekmanis, A. Nikitenko. Mobile Robot Camera Extrinsic Parameters Auto Calibration by Spiral Motion. No: 15th International Scientific Conference "Engineering for Rural Development": Proceedings. Vol.15, Latvija, Jelgava, 25.¬27. May, 2016. Jelgava: 2016, 558.¬565.p. ISSN 1691¬5976.

17. E.Sultanovs, A.Romanovs and A.Skorobogatjko. Centralized Healthcare Cyber-Physical System's Architecture Development 2016 57th International Scientific Conference on Power and Electrical Engineering of Riga Technical University, Latvia, Riga, October 13-14, 2016. Riga: RTU Press, 2016, ISBN 978-1-5090-3731-5. e-ISBN 978-1-5090-3730-8. 5 p. (in press).

18. A.Zabasta, K.Kondratijevs, N.Kunicina, J.Peksa, L.Ribickis, J.Caiko. Smart Municipal Systems and Services Platform Development. 17th International Conference Mechatronika 2016, Prague, Czech Republic, December 7 – 9, 2016 7 p (in press)

19. N.Zenina, A.Romanovs, Y.Merkuryev. Trip-based transport travel demand model for intelligent transport system measure evaluation based on micro simulation. International Journal "Int. J. of Simulation and Process Modelling".

20. I.Kabashkin. Heuristic Based Decision Support System for Choice of Alternative Routes in the Large-Scale Transportation Transit System on the Base of Petri Net Model. Procedia Engineering, Volume 134, Elsevier, 2016, Pages 359-364, ISSN 1877-7058. DOI:10.1016/j.proeng.2016.01.020.

21. K.Kondratjevs, N.Kuņicina, A.Patļins, A.Zabašta, A.Galkina. Vehicle Weight Detection Approach Development for Data Collecting in Sustainable City Transport System. 57th International Scientific Conference on Power and Electrical Engineering of Riga Technical University, Riga, Latvia, October 13-13, 2016. Riga: RTU Press, 2016, ISBN 978-1-5090-3731-5. e-ISBN 978-1-5090-3730-8, 5 p. (in press)

22. I.Kabashkin. Effectiveness of Redundancy in Communication Network of Air Traffic Management System. In the book "Dependability Engineering and Complex Systems". Volume 470 of the series "Advances in Intelligent Systems and Computing". Springer, Switzerland, 2016, pp. 257-265. Print ISBN 978-3-319-39638-5, Online ISBN 978-3-319-39639-2. DOI 10.1007/978-3-319-39639-2_22. http://link.springer.com/chapter/10.1007/978-3-319-39639-2_22.

23. I.Kabashkin. Analysing of the Voice Communication Channels for Ground Segment of Air Traffic Management System Based on Embedded Cloud Technology. In the book "Information and Software Technologies". Volume 639 of the series "Communications in Computer and Information Science". Springer, Switzerland, 2016, pp. 639-649. Print ISBN 978-3-319-46253-0, Online ISBN 978-3-319-46254-7. 10.1007/978-3-319-46254-7_52. http://link.springer.com/chapter/10.1007/978-3-319-46254-7_52

24. I.Kabashkin. Design of Embedded Architecture for Integrated Diagnostics in Avionics Domain. Procedia Engineering (Elsevier), in publishing process.

25. M.Savrasov and I.Pticina. Methodology of OD Matrix Estimation Based on Video Recordings and Traffic Counts, Procedia Engineering (Elsevier), in publishing process.

26. V.Gaidash, A.Grakovski. "Mass centre" vectorization algorithm for vehicle's counting portable videosystem, Transport and Telecommunication Journal, in publishing process.

27. J.Viksna, D.Gilbert. Gene duplication models and reconstruction of gene regulatory network evolution from network structure. Baltic Journal of Modern Computing, vol. 4:5, 2016.

28. R.Aleksejevs, R.Guseinovs, A.N.Medvedev, Sh.E.Guseynov (2016). *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 SCOPUS

29. R.Aleksejevs, Sh.E.Guseynov, R.Guseinovs (2016). *On a multicriteria problem of planning maritime cargo transportation with handling operations in intermediate seaports.* – International Journal of Applied and Computational Mathematics, 31 p. (Submitted) SCOPUS

Other publications

1. A.Sisojevs, R.Starinskis. An Approach for Fast Statistical Data Extraction from Biomedical Objects. Datorvadības tehnoloģijas. Nr.16, 2016, 64.-71.lpp.

2. A.Sisojevs, K.Boločko. Vector-Based Approach to Skeleton Extraction from the Human Hand's 3D Model. No: 13th International Conference on Applied Computing 2016 Processing (IADIS)

3. A.Sisojevs, R.Starinskis, P.Stradiņš. An Semi-Automatic Approach for Fast Statistical Data Extraction from Aortic Valve. No: Multi Conference on Computer Science and Information Systems, Computer Graphics, Visualization, Computer Vision and Image Processing (IADIS): Proceedings, Portugale, Funšala, July 1-4, 2016. Lisbon: IADIS, 2016, 293.-297.lpp.

4. G.Revalde, J.Alnis, E.Nitišs, K.Blušs, K.Grundšteins, "CRDS measurements of Acetone concentration", Abstract in the book " 23rd International Conference on

Spectral Line Shapes", ICSLS, 19-24 Jun, 2016, Torun, Poland, printed by Wydawnictwo Naukowe UMK, editor Piotr Ablewski, pp.137.

5. G.Revalde, N.Zorina, A.Skudra, Multicomponent line profile restoring by means of illposed inverse task solution, Abstract in the book "23rd International Conference on Spectral Line Shapes", ICSLS, 19-24 Jun, 2016, Torun, Poland, printed by Wydawnictwo Naukowe UMK, editor Piotr Ablewski, pp.180.

6. A.Laurs, Z.Markovičs. Calculation of Threshold Value by Expert Methods. *Scientific Journal of Riga Technical University. Technologies of Computer Control*. Vol.16, Riga, Latvia, 2015, pp.18-23. ISSN 2256-0343. e-ISSN 2256-0351. Available from: doi:10.7250/tcc.2015.003

7. K.Mezale, A.Kundziņš, Z.Markovičs. 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*. Vol.16, Riga, Latvia, 2015, pp.36-44. ISSN 2256-0343. e-ISSN 2256-0351. Available from: doi:10.7250/tcc.2015.005

8. E.Vavilina, G.Gaigals. Improved LabVIEW Code Generation, Baltic J. Modern Computing, Vol. 4, No. 1, 89-97, 2016. (http://www.bjmc.lu.lv/fileadmin/user_upload/lu_portal/projekti/bjmc/Contents/4_1_9_Vavilina.pdf)

9. 2. E.Vavilina, G.Gaigals. Improved LabVIEW Code Generation, 2015 IEEE 3rd Workshop on Advances in Information, Electronic and Electrical Engineering (AIEEE 2015) conference proceedings, ISBN-978-1-5090-1202-2, 2016. (http://ieeexplore.ieee.org/abstract/document/7367304/?reload=true)

10. M.P.Kaliuzhnyi, F.I.Bushuev, Ye.S.Sibiriakova, O.V.Shulga, L.S.Shakun, V. Bezrukovs, V.F.Kulishenko, S.S.Moskalenko, Ye.V.Malynovskyi, O.A.Balagura. Monitoring of the orbital position of a geostationary satellite by the spatially separated reception of signals of digital satellite television. Submitted to "Science and Innovation" http://scinn-eng.org.ua/. (accepted)

11. G.Revalde, N.Zorina, A.Skudra „Multicomponent line profile restoring by means of ill-posed inverse task solution" proceedings of 23ICSLS(23 International Conference on Spectral Line Shapes), Torun,Poland, June 19-24, 2016

12. G.Revalde, J.Alnis, K.Grundšteins. "CRDS measurements of Acetone concentration", Abstract in the book " 23rd International Conference on Spectral Line Shapes", proceedings of ICSLS, 19-24 June ,2016, Torun, Poland

13. G.Revalde, J.Alnis, K.Grundšteins, A.Skudra. Cavity Ring-Down Spectroscopy technique for detecting biomarkers, konference New Technologies of Early Cancer Screening And Diagnosis of Few Other Diseases on the base of exhaled air analysis, 8-9, 11, 2016, Mikkeli, Finland.

14. A.Skudra, G.Revalde, J.Alnis. Cavity Ring-Down Spectroscopy set-up for non-invasive diagnosticēs, konference New Technologies of Early Cancer Screening And Diagnosis of Few Other Diseases on the base of exhaled air analysis, 8-9, 11, 2016, Mikkeli, Finland

15. A.Laurs, J.Priekulis, Z.Markovics. Aboltins A. Research in farm animal breeding technological parameters. 15-th International Scientific Conference Engineering for Rural Development, Latvia, Jelgava, May 25-27, 2016. pp.1054-1058. http://www.tf.llu.lv/conference/proceedings2016/

16. K.Mezale, A.Kundzins, Z.Markovics. Decision tabele synthesis in fuzzy Environment for industrial robot-telpher. 15-th International Scientific Conference Engineering for Rural Development, Latvia, Jelgava, May 25-27, 2016. pp.1054-1058. http://www.tf.llu.lv/conference/proceedings2016/

17. Sh.E.Guseynov, U.Zaimis, J.V.Aleksejeva, J.Kaupuzs, A.Jansone, A.Grickus (2016). *On a mathematical model describing the motion of solid particles of micro- and nano-*

size in gas flow. – Proceedings of the XIII International Scientific Congress "Machines. Technologies. Materials", September 14-17, 2016, Varna, Bulgaria, Issue 23 (209), Volume 1: Technologies, ISSN: 1310-3946, pp. 53-62. http://mtmcongress.com/summer/sbornik/2016-1.pdf

18. Sh.E.Guseynov, U.Zaimis (2016). *On a physico-mathematical model for controlled formation of periodic nanostructures at solid surfaces irradiated by femtosecond laser pulses.* – Proceedings of the 4th International Scientific Conference "Engineering. Technologies. Education. Security", June 01-03, 2016, Veliko Tarnovo, Bulgaria, Issue 9 (195), Volume 1: Information Technologies, Natural and Mathematical Sciences, ISSN: 1310-3946, pp. 54-57.

19. A.Natrins, K.Lesinskis, Sh.E.Guseynov (2016). *Evaluating country attractiveness by using index approach for strategic decision making process related to expansion of financial service markets.* – The 9th Annual Scientific Baltic Business Management Conference "Challenges of Business Sustainability in the Digital Age" (ASBBMS'16), April 21-23, 2016, Riga, Latvia, Presentation 27 p. http://asbbmc.eu/

20. Sh.E.Guseynov, J.S.Rimshans (2016). *On the Ginzburg-Feinberg problem of frequency electromagnetic sounding for unambiguous determination of the electron density in the ionosphere.* – Book of Abstracts of the 11th Latvian Mathematical Conference, April 15-16, 2016, Daugavpils, Latvia, pp. 32-33. http://www.mathematics.lv/lv/11lmb/Abstracts.pdf

21. Sh.E.Guseynov, R.Guseinovs, J.V.Aleksejeva, R.Aleksejevs (2016). *On two approaches for determining countries potential on purpose of export of non-expensive and luxury services.* – Book of Abstracts of the 11th Latvian Mathematical Conference, April 15-16, 2016, Daugavpils, Latvia, pp. 30-31. http://www.mathematics.lv/lv/11lmb/Abstracts.pdf

22. A.Natrins, I.Drikis, Sh.Guseynovs, K.Lesinskis, A.Sarnovics (2016). *The basic principles of formation attractiveness indices of Central and Eastern Europe countries to assess the potential of the financial services and the affluent customers segment.* – Riga: Business and Financial Research Center of the BA School of Business and Finance, 107 pages. (In Latvian: A.Nātriņš, I.Driķis, Š.Guseinovs, K.Lešinskis, A.Sarnovičs (2016). *Centrāleiropas un Austrumeiropas valstu pievilcīguma indeksu izveidošanas pamatprincipi turīgo klientu segmenta un finanšu pakalpojumu potenciāla novērtēšanai.* – Rīga: Banku Augstskolas Biznesa un finanšu pētniecības centrs, 107 lappuses).

23. A.Natrins, K.Lesinskis, Sh.E.Guseynov (2016). *Evaluating country attractiveness by using index approach for strategic decision making process related to expansion of financial service markets.* – Journal of Business Management, ISSN: 1691-5348, 13 p. (Submitted)

24. Sh.E.Guseynov, U.Zaimis (2016). *On a physico-mathematical model for controlled formation of periodic nanostructures at solid surfaces irradiated by femtosecond laser pulses.* – Scientific Technical Journal of Material Science, Issue 3/2016: "Nonequilibrium Phase Transformations", ISSN: 2367-749X, pp. 17-20.

25. Sh.E.Guseynov, U.Zaimis (2016). *On a physico-mathematical model for controlled formation of periodic nanostructures at solid surfaces irradiated by femtosecond laser pulses.* – International Journal for Science, Technics and Innovations for the

Industry "Machines, Technologies, Materials", Issue 7/2016, ISSN: 1313-0226, Publisher: Scientific Technical Union of Mechanical Engineering, pp. 23-26.

26. Sh.E.Guseynov, U.Zaimis, J.V.Aleksejeva, J.Kaupuzs, A.Jansone, A.Grickus (2016). *On a mathematical model describing the motion of solid particles of micro- and nano-size in gas flow.* – International Scientific Journal "Machines. Technologies. Materials", Issue 11/2016, ISSN: 1313-0226, 1314-507X, pp. 23-32. http://www.stumejournals.com/mtm/Archive/2016/11-2016.pdf

27. Sh.E.Guseynov, U.Zaimis, J.V.Aleksejeva (2016). *Thermodynamic analysis of two-temperature model describing the dynamics of the temperature field on the material surface under the influence of femtosecond laser pulses.* – International Scientific Journal "Machines. Technologies. Materials", 6 p. (Accepted)

M.Sc. theses

1. M.Sc. thesis *"CAPTCHA and Its Alternatives for Implementing Turing Test on Web-Pages"* I. Ivanāne, LU MII (supervisor S.Kozlovičs).

2. M.Sc. thesis *"Development of mathematical models, analytico-numerical methods, and appropriate information system for controlled formation of periodic nanostructures at solid surfaces irradiated by femtosecond laser pulses"*, U.Žaimis, Liepaja University (supervisor Sh.E.Guseynov).

3. M.Sc. thesis *"Creation of physical problems and their using in a school course of physics"* V.Priedols, Liepaja University (supervisor J.Rimšāns, A.Grickus).

4. M.Sc. thesis *"Two-phases Stefan problem for semiconductors under laser irradiation – exponential ADI difference scheme and parallel computing approach"* M.Ķemere, Liepaja University (supervisor J.Rimšāns, J.Kaupužs).

5. M.Sc. thesis *"High availability OpenStack solution,"*, T.Dreiže, University of Latvia (supervisor L.Trukšāns).

6. M.Sc. thesis *"Development of VLBI data processing and monitoring system for VIRAC"*, M. Koloda, Ventspils University College (supervisor Vl. Bezrukovs).

Talks at conferences:

1. 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;

2. 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;

3. 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;

4. 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;

5. N.Grūzītis, A.Spektors. *Tēzaurs.lv – lielākā atvērtā latviešu valodas leksikas datubāze (Tezaurs.lv: the largest open lexical database for Latvian)*, Presentation at the 74th conference of University of Latvia, Computational Linguistics Section, Riga, Latvia, 18.02.2016.

6. K.Kondratjevs, N.Kunicina, A.Patlins, A.Zabasta, A.Galkina. Vehicle Weight Detection Approach Development for Data Collecting in Sustainable City Transport System. 2016 57th International Scientific Conference on Power and Electrical Engineering of Riga Technical University Latvia, Riga, 13.-14. October, 2016.

7. I.Kabashkin. Design of Embedded Architecture for Integrated Diagnostics in Avionics Domain. Proceedings of the 16th International Conference "Reliability and Statistics in Transportation and Communication (RelStat'16)", 19–22 October 2016, Riga, Latvia. Riga, 2016. 368–374 pp.. ISBN 978-9984-818-83-2.

8. I.Kabashkin. Analysing of the Voice Communication Channels for Ground Segment of Air Traffic Management System Based on Embedded Cloud Technology. Proceedings of the 22nd International Conference, ICIST 2016, Druskininkai, Lithuania, October 13-15, 2016. Communications in Computer and Information Science, Volume 639. Information and Software Technologies. Springer International Publishing Switzerland. 2016, , 639-649 pp. ISBN: 978-3-319-46253-0 (Print) 978-3-319-46254-7 (Online). DOI 10.1007/978-3-319-46254-7_52

9. A.Grakovski, A.Pilipovecs. The problem of Tyre Footprint Width Estimation by Fibre Optic WIM Sensors in Condition of Geometric Complexity.// Dependability Engineering and Complex Systems, 11th International Conference, DepCoS-RELCOMEX, June 27 – July 1, 2016, Brunow, Poland, Revised Selected Papers, Series: Advances in Intelligent Systems and Computing. W.Zamojski, J.Mazurkiewicz, J.Sugier, T.Walkowiak and J.Kacprzyk eds. 2016, vol.470, pp. 219-227. (ISSN 2194-5357, DOI: 10.1007/978-3-319-39639-2).

10. A.Grakovski, A.Pilipovecs. Dynamics of interaction between the road surface and vehicle's wheel in fibre-optic system for automatic weighing in motion of transport. // Proc. of the 16th International Conference "Reliability and Statistics in Transportation and Communication" (RelStat'16), 19–22 October 2016, Riga, Latvia, p. 318–324. (ISBN 978-9984-818-83-2).

11. M.Savrasov and I.Pticina. "Methodology of OD Matrix Estimation Based on Video Recordings and Traffic Counts". Proceedings of the 16th International Conference "RELIABILITY and STATISTICS in TRANSPORTATION and COMMUNICATION" (RelStat'16). I. Kabashkin and I. Yatskiv eds. 2016. pp. 325-333.

12. M.Ekmanis, A.Ņikitenko. Mobile Robot Camera Extrinsic Parameters Auto Calibration by Spiral Motion. No: 15th International Scientific Conference "Engineering for Rural Development": Latvija, Jelgava, 25.¬27. MAy, 2016. Jelgava: 2016.

13. E.Sultanovs, A.Romanovs and A.Skorobogatjko. Centralized Healthcare Cyber-Physical System's Architecture Development 2016 57th International Scientific Conference on Power and Electrical Engineering of Riga Technical University, Latvia, Riga, October 13-14, 2016.

14. A.Zabasta, K.Kondratijevs, N.Kunicina, J.Peksa, L.Ribickis, J.Caiko. Smart Municipal Systems and Services Platform Development. 17th International Conference Mechatronika 2016, Prag, Chech Republic, 7 – 9 of December, 2016.

15. Sh.E.Guseynov, U.Zaimis (2016). *High-precision lapping of spherical surface of titanium alloy by laser irradiation in order to receive high quality and wear-resistant implants of the human hip joint* (10 pages), Presentation in the Scientific Workshop "Application of mathematical modelling and information technologies in solving

scientific-technical, industrial-engineering, economic, financial, environmental and social-humanitarian problems", December 15-16, 2016, Liepaja, Latvia.

16. Sh.E.Guseynov, A.Grickus (2016). *Mathematical modelling of the processing mechanism of dispersed granular materials in gravitational flow with horizontal or inclined vibrating sieve classifying screens* (12 pages), Presentation in the Scientific Workshop "Application of mathematical modelling and information technologies in solving scientific-technical, industrial-engineering, economic, financial, environmental and social-humanitarian problems", December 15-16, 2016, Liepaja, Latvia.

17. Sh.E.Guseynov, J.V.Aleksejeva (2016). *Investigation of comparative degree of coherence of key socioeconomic indicators for the post-socialist countries of Central and Eastern Europe to determine the potential of export banking and certain other luxury services* (32 pages), Presentation in the Scientific Workshop "Application of mathematical modelling and information technologies in solving scientific-technical, industrial-engineering, economic, financial, environmental and social-humanitarian problems", December 15-16, 2016, Liepaja, Latvia.

18. Sh.E.Guseynov, J.V.Aleksejeva (2016). *On a multi-criteria model for planning maritime cargo transportation with handling operations in intermediate seaports*, 17 pages, Presentation in the Scientific Workshop "Application of mathematical modelling and information technologies in solving scientific-technical, industrial-engineering, economic, financial, environmental and social-humanitarian problems", December 15-16, 2016, Liepaja, Latvia,.

19. Sh.E.Guseynov, U.Zaimis, J.V.Aleksejeva, J.Kaupuzs, A.Jansone, A.Grickus (2016). *On a mathematical model describing the motion of solid particles of micro- and nano-size in gas flow* (23 pages), Presentation in the Scientific Workshop "Application of mathematical modelling and information technologies in solving scientific-technical, industrial-engineering, economic, financial, environmental and social-humanitarian problems", December 15-16, 2016, Liepaja, Latvia.

20. V.A.Ravichandran, Sh.Iqbal, Sh.E.Guseynov (2016). *Methods of propositional algebra in solving convoluted verbal problems arising in the social-humanitarian fields* (8 pages), Presentation in the Scientific Workshop "Application of mathematical modelling and information technologies in solving scientific-technical, industrial-engineering, economic, financial, environmental and social-humanitarian problems", December 15-16, 2016, Liepaja, Latvia.

21. U.Untulis, J.Gegeris, Sh.E.Guseynov (2016). *Mathematical modelling of problem of optimal sowing agricultural crops* (15 pages), Presentation in the Scientific Workshop "Application of mathematical modelling and information technologies in solving scientific-technical, industrial-engineering, economic, financial, environmental and social-humanitarian problems", December 15-16, 2016, Liepaja, Latvia.

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.

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	Phone number	67213716
	E-mail	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 investigated quantum walks as a tool for constructing quantum search algorithms. We have improved one of main quantum walk search algorithms by doubling its success probability (1.). We also investigated stationary states of quantum walks (the states which are left unchanged by performing a walking step) (2.). Such states are important because they correspond to cases when quantum search algorithm fails to find the required object.
2. We have shown a new connection between quantum algorithms (in the black box or query model of computation) and polynomials: quantum algorithms making 1 query about input data are equivalent to approximations by polynomials of degree 2 (3.). This is the first result of this type which shows equivalence between the two notions. (Previous results only showed a transformation from quantum algorithms to polynomials but not in the other direction.)
3. We have shown two results about complexity measures of Boolean functions related to quantum algorithms:
   a. A new gap between the number of queries required to compute a function (both for classical and quantum algorithms) and unambiguous certificate complexity (4.);

12

b. A new relation between certificate complexity/block sensivity of Boolean functions and sensitivity of Boolean functions (5.).

4. We have published several papers that were reported as manuscripts or accepted for publication in the previous reports (6., 7., 8.).

5. A prototype of web-based Transformation Driven Architecture platform (TDA/web) has been developed. It allows model transformations running at the server-side to communicate with graphical presentation engines at the client-side. The results have been published as (9., 17.).

   The process of development of the two web-based engines - Graph Diagram Engine and Dialog Engine – has been started. These engines are being attached to the TDA/web platform.

6. The ontology modeling tool OWLGrEd has been enriched by tools for guided graphical ontology visualization and local transformations between different representation variants of the same semantic construct; the results are used in creation of the visual presentation of the Latvian Medicine Registries ontology and are reported in (13.). A renewed prototype of the OWLGrEd ontology visualizer and editor has been prepared. The ViziQuer tool for creating visual queries over semantic databases has been tested on example queries over Latvian Medicine registry ontology data; further aggregate query definition options have been added to the tool; the results have been reported as (14.) Within the context of Latvian Medicine registry data representation infrastructure the principles for ontology data representation infrastructure have been elaborated, as well as the implementation of the RDB2OWL database to ontology mapping language has been enriched by offering the full RDB2OWL expression translation into R2RML. The results have been reported as (10., 16.).

7. The research on principles of co-use of ontology graphical and lexical forms in ontology preparation and presentation, as well as their implementation on the basis of OWLGrEd ontology editor, has been published in (11., 12., 15.). This research direction has been additionally explored in a feasibility study on multilingual text generation from Abstract Meaning Representation (18.), which will be further developed in a separate industry-oriented research project.

   In synergy with the State research programme on Latvian studies, we have contributed to the development of a large open lexical database for Latvian (19.), which will be further linked to the LOD cloud in a separate industry-oriented research project. This will facilitate the ontology lexicalization in Latvian.

   Additionally, we have continued the collaboration with researchers from University of Gothenburg (Sweden), publishing a paper on semi-automatic construction of CO-diagrams from deontic norms expressed in contracts (20.).

1. K.Prūsis, J.Vihrovs, and Thomas G. Wong. Doubling the Success of Quantum Walk Search Using Internal-State Measurements. Journal of Physics A 49, 455301 (2016).

2. K.Prūsis, J.Vihrovs, and Thomas G. Wong. Stationary States in Quantum Walk Search. Physical Review A 94, 032334 (2016).

3. S.Aaronson, A.Ambainis, J.Iraids, M.Kokainis, J.Smotrovs. Polynomials, Quantum Query Complexity, and Grothendieck's Inequality. Conference on Computational Complexity 2016: 25:1-25:19.

4. A.Ambainis, M.Kokainis, R.Kothari. Nearly Optimal Separations Between Communication (or Query) Complexity and Partitions. Conference on Computational Complexity 2016: 4:1-4:14.

5. A.Ambainis, K.Prūsis, J.Vihrovs. Sensitivity Versus Certificate Complexity of Boolean Functions. Computer Science in Russia (CSR) 2016: 16-28.

6. A.Ambainis, A.Belovs, O.Regev, Ronald de Wolf. Efficient Quantum Algorithms for (Gapped) Group Testing and Junta Testing. SIAM Symposium on Discrete Algorithms (SODA) 2016: 903-922 (previously reported as manuscript).

7. A.Ambainis, K.Balodis, A.Belovs, T.Lee, M.Santha, J.Smotrovs. Separations in query complexity based on pointer functions. ACM Symposium on Theory of Computing (STOC) 2016: 800-813 (previously reported as accepted).

8. S.Chakraborty, L.Novo, A.Ambainis and Y.Omar. Spatial Search by Quantum Walk is Optimal for Almost all Graphs. Physical Review Letters 116, 100501, 2016 (previously reported as accepted).

9. S.Kozlovics. Models and Model Transformations With in Web Applications. In Proc. of Baltic DB&IS 2016, Springer CCIS Series 615, pp. 53-67 (SCOPUS) (Previously reported as accepted).

10. K.Cerāns, G.Būmans. Database to Ontology Mapping Patterns in RDB2OWL Lite. In Proc. of Baltic DB&IS 2016, Springer CCIS Series 615, pp. 35-49 (SCOPUS) (Previously reported as accepted).

11. R.Liepins, U.Bojars, N.Gruzitis, K.Cerans, E.Celms. Towards Self-explanatory Ontology Visualizations with Contextual Verbalizations. In Proc. of Baltic DB&IS 2016, Springer CCIS Series 615, pp. 3-17 (SCOPUS) (Previously reported as accepted).

12. U.Bojārs, R.Liepiņš, N.Grūzītis, K.Cerāns, E.Celms. Extending OWL Ontology Visualizations with Interactive Contextual Verbalization. In Proc. of the Second International Workshop on Visualization and Interaction for Ontologies and Linked Data (VOILA '16), Kobe, Japan. CEUR Workshop Proceedings, vol. 1704, CEUR-WS.org, 2016, pp.5-16. (Expected to be indexed by SCOPUS).

13. J.Ovčiņņikova, K.Cerāns. Advanced UML Style Visualization of OWL Ontologies. In Proc. of the Second International Workshop on Visualization and Interaction for Ontologies and Linked Data (VOILA '16), Kobe, Japan. CEUR Workshop Proceedings, vol. 1704, CEUR-WS.org, 2016, pp.136-142. (Expected to be indexed by SCOPUS).

14. K.Cerāns, J.Ovčiņņikova. ViziQuer: Notation and Tool for Data Analysis SPARQL Queries. In Proc. of the Second International Workshop on Visualization and Interaction for Ontologies and Linked Data (VOILA '16), Kobe, Japan. CEUR Workshop Proceedings, vol. 1704, CEUR-WS.org, 2016, pp.151-159. (Expected to be indexed by SCOPUS).

15. R.Liepiņš, N.Grūzītis, K.Cerāns, J.Ovčiņņikova, U.Bojārs and E.Celms. Adding Verbalization to Graphical Ontology Editor OWLGrEd. In, Databases and Information Systems IX, Selected Papers from the Twelfth International Baltic Conference, DB&IS 2016, Frontiers in Artificial Intelligence and Applications, Vol 291, IOS Press, pp.17-30, 2016 (Expected to be indexed by SCOPUS).

16. G.Būmans and K.Cerāns. Database to Ontology Mappings in RDB2OWL: Notation and Implementation. In, Databases and Information Systems IX, Selected Papers from the Twelfth International Baltic Conference, DB&IS 2016, Frontiers in Artificial Intelligence and Applications, Vol 291, IOS Press, pp.31-42, 2016. (Expected to be indexed by SCOPUS).

17. S.Kozlovics. A Model-Driven Approach to Web Applications. In, Databases and Information Systems IX, Selected Papers from the Twelfth International Baltic Conference, DB&IS 2016, Frontiers in Artificial Intelligence and Applications, Vol 291, IOS Press, pp.31-42, 2016. (Expected to be indexed by SCOPUS).

18. N.Grūzītis and G.Bārzdiņš. The role of CNL and AMR in scalable abstractive summarization for multilingual media monitoring. Controlled Natural Language, LNCS 9767, Springer, 2016, pp. 127-130 (SCOPUS).

19. A.Spektors, I.Auziņa, R.Darģis, N.Grūzītis, P.Paikens, L.Pretkalniņa, L.Rituma and B.Saulīte. Tezaurs.lv: the largest open lexical database for Latvian. Proceedings of the 10th International Conference on Language Resources and Evaluation (LREC), 2016, pp. 2568-2571 (Expected to be indexed by Web of Science) (previously reported as accepted).

20. John J. Camilleri, N.Gruzitis and G.Schneider. Extracting formal models from normative texts. Natural Language Processing and Information Systems, LNCS 9612, Springer, 2016, pp. 403-408 (SCOPUS) (Previously reported as submitted).

Further research and practical exploitation of the results
(Describe further research activities that are planned, describe possibilities to practically exploit results)
1. We will continue the study of stationary states of quantum walks, with the goal of obtaining a general characterizations for the conditions when they occur.
2. We will work on new quantum search algorithms based on quantum walks, with a particular emphasis on combinatorial optimization problems (for example, NP-complete problems).
3. We will investigate the connections between the two types of polynomials that appear in our equivalence between quantum algorithms and polynomials and attempt to generalize our result to quantum algorithms making more than 1 query to input data.
4. We will complete the creation of the prototype of web-based ontology visualization and modeling tool.
5. We will propose methods of defining schema assertions relating properties to classes within an ontology modeling framework and shall define a visual notation for the schema assertions within ontologies.
6. We will test the semantic technology tools on practical data analysis use cases from public sector domain.
7. We will develop a controlled natural language extension to the web-based prototype of ontology visualization, modeling and lexicalization tool.

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

Andris Ambainis has given several popular lectures on quantum computing:
- For high school students at Rīgas Purvciema vidusskola school, 19.01.2016;
- Natural sciences student conference "Open Readings" in Vilnius, Lithuania (approx. 200 students from different countries), 18.03.2016;
- At Latvian office of "Accenture" IT company, 19.05.2016;
- Baltic conference "Data bases and Information Systems", 06.07.2016;
- IT security conference "Cyberchess" (approx. 700 computer security professionals, mainly from Latvia), 06.10.2016.

Five 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;

- N.Grūzītis, A.Spektors. *Tēzaurs.lv – lielākā atvērtā latviešu valodas leksikas datubāze (Tezaurs.lv: the largest open lexical database for Latvian)*, Presentation at the 74th conference of University of Latvia, Computational Linguistics Section, Riga, Latvia, 18.02.2016.

General technology presentation seminars:
- Daži semantisko tehnoloģiju jautājumi, (Some Semantic Technology issues), 11.11.2016, IMCS UL, room 210.
- Jaunākie rezultāti mākslīgā intelekta jomā (Recent results in Artificial Intelligence), 16.09.2016, IMCS UL, room 210.

2.1.2. Project No. 2

Title	Biomertry, 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

Contacts	Phone number	+371 22078375
	E-mail	janis.hofmanis@gmail.com

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

Goal of the project: develop new and modern E-medicine technologies that affect the acquisition and processing of biosignals/bioimages for diagnostics of diseases and pathologies, utilization of computerised decision support systems with knowledge bases and artificial intelligence.
Objectives of the project:
- Develop and experimentally test 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;

- o 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.
  - o 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:
  - o 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.
  - o Applications of the finite element method (FEM) models to solving the forward problem of bioelectromagnetism, using parallel computing technology.
  - o Development of efficient and accurate inverse problem solving methods in bioelectromagnetic source localization and separation problem.
  - o 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)
  - o realisation of diagnostic screening with a further decision-making procedure;
  - o realisation of diagnostics (including differential diagnosis);
  - o evaluation of risk factors;
  - o selection of the strategy of decision process (decision support system);
  - o providing the monitoring process;
  - o approbation of developed technology.

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

Nr 1. Research of radiological image processing and additional information visualization.
This research direction is based on the need for modern and state-of-the-art analysis methods of image and signal processing in medical applications. In particular, we have developed methods which help to investigate statistical properties of a dissected biological structures.
To obtain statistical data about the object, it is necessary to carry out the presegmentation of the image of the tissue. The standard segmentation method does not make it possible to carry out successful data extraction from abnormal tissues. Thus, there is a need to develop a more effective method. In the reference period, we developed such a method. It is based on the use of image recognition algorithms and their adaptation to the segmentation tasks (segmentation task is transformed to the classification task). Our modified segmentation method allows to significantly reduce the segmentation time and maintain appropriate segmentation accuracy. A method is being tested on eal pathological anatomy object images.

Nr. 2. Inverse problems in biomedicine.

During the report period research on non-invasive technologies based on CRDS for desease detection was continued. Such technologies can be used in order to detect the diabetes or cancer by analyzing the gases from the expiration of patients. During the previous period CDRS system was made, calibrated and tested using acetone which for the diabetic patiens exhale is around 1-3ppm.

Additional measurements were made for patients after physical exercise, after different diets, and for smoking and non-smoking patients. First measurements were made also in order to detect the benzol in patients expiration, therefore collaboration were established with scientists from University of Latvia, Faculty of Medicine and Riga Technical University in order to develop sensors.

Nr 3. Research of bioelectromagnetism in the human brain

Research of bioelectromagnetism in biological tissues is motivated by the need to understand the properties of complex anatomical structures and their electromagnetic conductance. These properties allow to develop detailed brain models also called forward or direct models. In this project, we analyse human head tissue properties using Electroencephalogram (EEG) and intracranial EEG (SEEG).

In this context, the direct problem relies on models of propagation media (tissues constituting the head) consisting of biophysical equations that connect the sources to the generated potentials (EEG / SEEG measurements). These models have two main components: cerebral structures that are considered and parameters of the sources. Thanks to the clinical routine use of intracerebral electrical stimulations, which are perfectly deterministic (place, amplitude, frequency, ...), the parameters of intracerebral "sources" can be determined and controlled. The direct problem is then the modeling of the cerebral structures and their conductivity. Under certain assumptions, we perform a sensitivity analysis of the parameters of the propagation model based on realistic FEM constructs with 5 compartments extracted from the CT and MRI images of the patients explored in intracerebral. We will discuss the performance of different models of propagation media (FEM, BEM and spherical) and justify their limits according to the location of the stimulation: deep, median or lateral. We also compare the results obtained when we take into account the simultaneous measurements of surface and depth EEG (SEEG). Thus, here we are addresing the inverse problem of locating sources from the intracerebral SEEG data according to the biophysical model and the number of sources. This source location study based on the weighting of SEEG measurements in the vicinity of sources has been applied to several simultaneous activities on data in the presence of intracerebral electrical simulations and more broadly on clinical data.

Nr 4. Variations of decision trees in medical applications.

In medicine, a doctor must choose the treatment for each diagnosis. The choice of medication is defined by its indications and efficiency and limited by counterindications according to European guidelines for the respective illness. Decision making can be illustrated using a decision tree (DT).

Constructions of DTs have different shape and content. It is possible that the DT is not able to make a decision and forwards the problem to another DT. Also, there can be a situation where decision procedure is forwarded back again to the original DT which makes infinite loop which must be interrupted. Interruption is implemented with condition that such infinite loop is cycled through only once. The positive aspect of DT is its visual clarity and perceptibility.

The most appropriate method for describing connections among all events are the decision-making tables (Decision Table), where each cell in the table corresponds to a partial decision and Decision Table contains all possible events.

Decision can be used to distinguish areas where the decision is obvious, or at least more easily formulated and areas with difficult formulated decisions, which should be decided together with expert advice.

Nr 5. Theoretical aspects of graphs in biological structures
We have worked on recognition of networks from their images. We consider biological networks such as skeleton of leaves and blood vessels and obtain their combinatorial structure consisting of straight line segments and their connections. In particular,
(1) We developed a detector of branching of biological networks based on parallel multi-resolution processing of circular profiles.
(2) We extended methods for edge-centric biological network recognition, continuing recognizer improvements in usability and reduction of duplicated edges. We implemented parametrized graph drawing generator that prepares test sets of recognizable graph drawings. We started research of arbitrary dashed edge recognizer, firstly, evaluating limitations of the previous approach and secondly advancing a new approach based on new findings in relevant literature.
(3) We developed a detector of structure of biological network of complex structure -- parallel multi-resolution processing of biological leaf skeleton.
(4) As a typical biological network is three-dimensional, it is natural to enclose three-dimensionality into recognition of corresponding graphs. The first approach that we tried is recognition of stereo pairs of three-dimensional networks, including their generators.
(5) We worked on modelling of recognition of three-dimensional biological networks by 3D combinatorial analysis of epipolar structures of stereo pairs of corresponding straight line graphs. We carried out recognition of stereo pairs of spatial configurations of straight line segments: generators, depth calculators, brute force method of finding stereo correspondences. We investigated requirements for stereo recognizer. We started development of teaching material "Recognition of straight line segment network from a stereo pair".

Publications and conferences:
1. A.Sisojevs, K.Boločko. Vector-Based Approach to Skeleton Extraction from the Human Hand's 3D Model. Multi Conference on Computer Science and Information Systems, Computer Graphics, Visualization, Computer Vision and Image Processing (IADIS): Proceedings, Funchal, Portugale, July 1-4, 2016. Lisbon: IADIS
2. A.Sisojevs, R.Starinskis, P.Stradiņš. An Semi-Automatic Approach for Fast Statistical Data Extraction from Aortic Valve. Multi Conference on Computer Science and Information Systems, Computer Graphics, Visualization, Computer Vision and Image Processing (IADIS): Proceedings, Funchal, Portugale, July 1-4, 2016. Lisbon: IADIS, 2016, pp. 293-297.
3. A.Sisojevs, R.Starinskis. An Approach for Fast Statistical Data Extraction from Biomedical Objects. Datorvadības tehnoloģijas. Nr.16, 2016, 64.-71.lpp.
4. G.Revalde, J.Alnis, E.Nitišs, K.Blušs, K.Grundšteins, "CRDS measurements of Acetone concentration", Abstract in the book "23rd International Conference on Spectral Line Shapes". ICSLS, 19-24 June, 2016, Torun, Poland, printed by Wydawnictwo Naukowe UMK, editor Piotr Ablewski, pp.137.
5. G.Revalde, N.Zorina, A.Skudra, Multicomponent line profile restoring by means of illposed inverse task solution, Abstract in the book "23rd International Conference on Spectral Line Shapes", ICSLS, 19-24 June, 2016, Torun, Poland, printed by Wydawnictwo Naukowe UMK, editor Piotr Ablewski, pp.180.
6. G.Revalde, N.Zorina, A.Skudra „Multicomponent line profile restoring by means of ill-posed inverse task solution" Abstract in the book "23rd International Conference on Spectral Line Shapes", ICSLS, 19-24 June, 2016, Torun, Poland, printed by Wydawnictwo Naukowe UMK, editor Piotr Ablewski.

7. G.Revalde, J.Alnis, K.Grundšteins. "CRDS measurements of Acetone concentration", Abstract in the book " 23rd International Conference on Spectral Line Shapes", proceedings of ICSLS, 19-24 June ,2016, Torun, Poland

8. G.Revalde, J.Alnis, K.Grundšteins, A.Skudra. Cavity Ring-Down Spectroscopy technique for detecting biomarkers, konference New Technologies of Early Cancer Screening And Diagnosis of Few Other Diseases on the base of exhaled air analysis, 8-9, 11, 2016, Mikkeli, Finland.

9. A.Skudra, G.Revalde, J.Alnis. Cavity Ring-Down Spectroscopy set-up for non-invasive diagnosticēs, konference New Technologies of Early Cancer Screening And Diagnosis of Few Other Diseases on the base of exhaled air analysis, 8-9, 11, 2016, Mikkeli, Finland.

10. L.Koessler, S.Colnat-Coulbois, T.Cecchin, J.Hofmanis, J.P.Dmochowski, A.M.Norcia & L.G.Maillard (2016). In-vivo measurements of human brain tissue conductivity using focal electrical current injection through intracerebral multicontact electrodes. Human Brain Mapping (IF - 5.9) (SCOPUS, SNIP: 1,728), https://www.journalguide.com/journals/human-brain-mapping*

11. H.Altakroury, L.Koessler, J.Hofmanis & V.Louis-Dorr. (2016). In vivo estimation of head conductivities frequency response with IES and SEEG-EEG. Neurophysiologie Clinique/Clinical Neurophysiology, 46(2), 77-79.*

12. V.Louis-Dorr, H.Altakroury, J.Hofmanis, V.Caune, R.Ranta, S.Le Cam, ... & L.Koessler. (2016). Résolution de problèmes direct et inverse à partir de mesures SEEG et de la stimulation électrique intracérébrale. Neurophysiologie Clinique/Clinical Neurophysiology, 46(2), 88.*

13. A.Laurs, Z.Markovičs. Calculation of Threshold Value by Expert Methods. *Scientific Journal of Riga Technical University. Technologies of Computer Control.* Vol.16, Riga, Latvia, 2015, pp.18-23. ISSN 2256-0343. e-ISSN 2256-0351. Available from: doi:10.7250/tcc.2015.003

14. K.Mezale, A.Kundziņš, Z.Markovičs. 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.* Vol.16, Riga, Latvia, 2015, pp.36-44. ISSN 2256-0343. e-ISSN 2256-0351. Available from: doi:10.7250/tcc.2015.005

15. O.Minejeva, Z.Markovičs. Choice of Interpolation Method for an Arbitrary Arc Welding Curve. *Scientific Journal of Riga Technical University. Technologies of Computer Control.* Vol.16, Riga, Latvia, 2015, pp.24-35. ISSN 2256-0343. e-ISSN 2256-0351. Available from: doi:10.7250/tcc.2015.004.

16. A.Laurs, J.Priekulis, Z.Markovics. Aboltins A. Research in farm management Technologies using the expert method. Agronomy Research, Volume 14, Number 3, Tartu, Estonia, 2016, pp.811-820.

17. A.Laurs, J.Priekulis, Z.Markovics. Aboltins A. Research in farm animal breeding technological parameters. 15-th International Scientific Conference Engineering for Rural Development, Latvia, Jelgava, May 25-27, 2016. pp.1054-1058. http://www.tf.llu.lv/conference/proceedings2016/

18. K.Mezale, A.Kundzins, Z.Markovics. Decision tabele synthesis in fuzzy Environment for industrial robot-telpher. 15-th International Scientific Conference Engineering for Rural Development, Latvia, Jelgava, May 25-27, 2016. pp.1054-1058. http://www.tf.llu.lv/conference/proceedings2016/

Further research and practical exploitation of the results
(Describe further research activities that are planned, describe possibilities to practically exploit results)

During this activity period we developed and submitted project proposal for the Latvian "Industry-Driven Research" programme about radiological image processing and visualizing technologies, and their approbation in hospitals (together with SIA Arbor and SIA Diamed).

The proposed project aims to develop technology prototype – the module for radiology and hospital information systems that use new data-processing techniques and algorithms for multimodal imaging (MRI, CT, PET) biomedical signal and image acquisition, processing and visualization to improve accuracy and efficiency of diagnosis of various diseases and pathologies in the clinical environment.

During the project, research in biomedicine, medical technology, information and communication technologies will be carried out to develop at least one new technology and one new diagnostic method, results of the work will be submitted to at least two scientific papers and project will be represented in at least one scientific conference, thus directly contributing to the economic transformation laid out in the Smart specialization strategy of Latvia and to the development of human capital, contributing to the objective of the National development strategy – to develop innovative and internationally competitive products with high added value.

Further development of inverse regularization methods. Work on N.Zorina disertation and regularization methods for inverse problems in spectroscopical diagnostics will be continued. Dissertation is submitted on 22.11.2016 and will be defended in 2017.

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

Contacts	Phone number	26162662
	E-mail	Nadezda.Kunicina@rtu.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 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 test of data transmittion model in laboratory conditions.

Objectives:

- Develop a safety-monitoring and modelling solution for the urban environment via applying high performance data processing technologies.
- Develop and explore intelligent sensor network technologies and applications of intelligent transportation systems.

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

1. Development of a safety-monitoring and modelling solution for the urban environment via applying high performance data processing technologies.
Currently, the urban environment monitoring in Latvia is based on the efforts of human-operator, who monitors the current situation and makes decisions when and where necessary. The goal of this task is to develop new methods of consolidation and interpreatation of data, in order to provide means for making high quality decisions about the processes in the urban environment. Within the project, our intension is to integrate data streams form different types of sensors including surveillance cameras, which will provide very intensive real time data streams.
Our research activities are currently concentrated on testing the data transmittion model in laboratory conditions. This technology is common for city infrastructure control based on the new principes of Internet of Things (IoT). We have checked the power supply and water supply infrastructure control paradigms in laboratory conditions. We have also continued research on application of cyber physical sytems in health care.

2. Development and exploration of intelligent sensor network technologies and applications of intelligent transportation systems.
We are developing and analyzing a macroscopic model for traffic flows, using the same methods for data transmitting and HPC based data processing. We have carried out a traffic density impact case study of a transport demand simulation model and its calibration procedure for two steps parameter calibration (using the central part of the Adazi city). We are also performing work on development and testing new types of sensors, including the application of DATEXII standard.
Moreover, we have proposed a methodology for local OD (origin-destination) matrix estimation in traffic flows based on video recordings, which could be actual for evaluation of the "local" OD matrixes for special cases or for the update of the existing matrix. Also it was

proposed the methodology of OD matrix update or re-evaluation based on e-ticket system of the Riga city. The proposed methodology defines the approach how to get the OD matrix for public transport based on existing data in e-ticketing system of Riga, mixing validation data and GPS records of public transport.

During the development and establishment of intelligent transport systems (ITS), one of the most basic challenges is vehicle counting. Some of these systems use a network of static traffic cameras, expensive for establish and maintain, or mobile units, fast for redeployment, but fewer in diversity.We have designeda concept of a low-cost mobile vehicle counting system is which uses a method for object detection based on calculating "mass centre" of detected features of possible object.

Scientific monograph is ready to be submitting in printing house of Riga Technical University

Participation in industry exhibitions: 2

Invention and innovation exhibition MINOX 2016
http://www.connectlatvia.lv/izstade-minox-2016/

The international mechanical engineering, metalworking, automation, electronics, electrical engineering, production of materials, tools and new technologies exhibition "Tech Industry 2016"
http://www.techindustry.lv/index.php/lv/pasakumi/11-lapu-sadalas?start=8

The original scientific publications included in the SCOPUS database – 11

1. M.Ekmanis, A. Nikitenko. Mobile Robot Camera Extrinsic Parameters Auto Calibration by Spiral Motion. 15th International Scientific Conference "Engineering for Rural Development": Proceedings. Jelgava, Latvia, May 25-27, 2016, pp. 558-565, ISSN 1691-5976.
2. E.Sultanovs, A.Romanovs and A.Skorobogatjko. Centralized Healthcare Cyber-Physical System's Architecture Development. 57th International Scientific Conference on Power and Electrical Engineering of Riga Technical University, Latvia, Riga, October 13-14, 2016. Riga: RTU Press, 2016, ISBN 978-1-5090-3731-5. 9, 5 p. (in press)
3. A.Zabasta, K.Kondratijevs, N.Kunicina, J.Peksa, L.Ribickis, J.Caiko. Smart Municipal Systems and Services Platform Development. 17th International Conference Mechatronika 2016, Prague, Czech Republic, December 7 – 9, 2016 7 p. (in press)
4. N.Zenina, A.Romanovs, Y.Merkuryev. Trip-based transport travel demand model for intelligent transport system measure evaluation based on micro simulation. International Journal of Simulation and Process Modelling (in press).
5. I.Kabashkin. Heuristic Based Decision Support System for Choice of Alternative Routes in the Large-Scale Transportation Transit System on the Base of Petri Net Model. Procedia Engineering, Volume 134, Elsevier, 2016, Pages 359-364, ISSN 1877-7058. DOI:10.1016/j.proeng.2016.01.020.
6. K.Kondratjevs, N.Kuņicina, A.Patļins, A.Zabašta, A.Galkina. Vehicle Weight Detection Approach Development for Data Collecting in Sustainable City Transport System. 57th International Scientific Conference on Power and Electrical Engineering of Riga Technical University, Latvia, Riga, October 13-14, 2016. Riga: RTU Press, 2016, ISBN 978-1-5090-3731-5. 9, 5 p. (in press)
7. I.Kabashkin. Effectiveness of Redundancy in Communication Network of Air Traffic Management System. In the book "Dependability Engineering and Complex Systems". Volume 470 of the series "Advances in Intelligent Systems and Computing". Springer,

Switzerland, 2016, pp. 257-265. Print ISBN 978-3-319-39638-5, Online ISBN 978-3-319-39639-2. DOI 10.1007/978-3-319-39639-2_22. http://link.springer.com/chapter/10.1007/978-3-319-39639-2_22.

8. I.Kabashkin. Analysing of the Voice Communication Channels for Ground Segment of Air Traffic Management System Based on Embedded Cloud Technology. In the book "Information and Software Technologies". Volume 639 of the series "Communications in Computer and Information Science". Springer, Switzerland, 2016, pp. 639-649. Print ISBN 978-3-319-46253-0, Online ISBN 978-3-319-46254-7. 10.1007/978-3-319-46254-7_52. http://link.springer.com/chapter/10.1007/978-3-319-46254-7_52

9. I.Kabashkin. Design of Embedded Architecture for Integrated Diagnostics in Avionics Domain. Procedia Engineering (Elsevier), in publishing process.

10. M.Savrasov and I.Pticina. Methodology of OD Matrix Estimation Based on Video Recordings and Traffic Counts, Procedia Engineering (Elsevier), in publishing process.

11. V.Gaidash, A.Grakovski. "Mass centre" vectorization algorithm for vehicle's counting portable video system, Transport and Telecommunication Journal in publishing process.

Conferences: 9

1. K.Kondratjevs, N.Kunicina, A.Patlins, A.Zabasta, A.Galkina. Vehicle Weight Detection Approach Development for Data Collecting in Sustainable City Transport System. 2016 57th International Scientific Conference on Power and Electrical Engineering of Riga Technical University Latvia, Riga, 13.-14. October, 2016.

2. I.Kabashkin. Design of Embedded Architecture for Integrated Diagnostics in Avionics Domain. Proceedings of the 16th International Conference "Reliability and Statistics in Transportation and Communication (RelStat'16)", 19–22 October 2016, Riga, Latvia. Riga, 2016. 368–374 pp.. ISBN 978-9984-818-83-2.

3. I.Kabashkin. Analysing of the Voice Communication Channels for Ground Segment of Air Traffic Management System Based on Embedded Cloud Technology. Proceedings of the 22nd International Conference, ICIST 2016, Druskininkai, Lithuania, October 13-15, 2016. Communications in Computer and Information Science, Volume 639. Information and Software Technologies. Springer International Publishing Switzerland. 2016, , 639-649 pp. ISBN: 978-3-319-46253-0 (Print) 978-3-319-46254-7 (Online). DOI 10.1007/978-3-319-46254-7_52

4. A.Grakovski, A.Pilipovecs. The problem of Tyre Footprint Width Estimation by Fibre Optic WIM Sensors in Condition of Geometric Complexity.// Dependability Engineering and Complex Systems, 11th International Conference, DepCoS-RELCOMEX, June 27 – July 1, 2016, Brunow, Poland, Revised Selected Papers, Series: Advances in Intelligent Systems and Computing. W.Zamojski, J.Mazurkiewicz, J.Sugier, T.Walkowiak and J.Kacprzyk eds. 2016, vol.470, pp. 219-227. (ISSN 2194-5357, DOI: 10.1007/978-3-319-39639-2).

5. A.Grakovski, A.Pilipovecs. Dynamics of interaction between the road surface and vehicle's wheel in fibre-optic system for automatic weighing in motion of transport. // Proc. of the 16th International Conference "Reliability and Statistics in Transportation and Communication" (RelStat'16), 19–22 October 2016, Riga, Latvia, p. 318–324. (ISBN 978-9984-818-83-2).

6. M.Savrasov and I.Pticina. "Methodology of OD Matrix Estimation Based on Video Recordings and Traffic Counts". Proceedings of the 16th International Conference "RELIABILITY and STATISTICS in TRANSPORTATION and COMMUNICATION" (RelStat'16). I. Kabashkin and I. Yatskiv eds. 2016. pp. 325-333.

7. M.Ekmanis, A.Ņikitenko. Mobile Robot Camera Extrinsic Parameters Auto Calibration by Spiral Motion. No: 15th International Scientific Conference "Engineering for Rural Development": Latvija, Jelgava, 25.¬27. MAy, 2016. Jelgava: 2016.

8. E.Sultanovs, A.Romanovs and A.Skorobogatjko. Centralized Healthcare Cyber-Physical System's Architecture Development, 57th International Scientific Conference on Power and Electrical Engineering of Riga Technical University, Riga, Latvia, Riga, October 13-14, 2016.

9. A.Zabasta, K.Kondratijevs, N.Kunicina, J.Peksa, L.Ribickis, J.Caiko. Smart Municipal Systems and Services Platform Development. 17th International Conference Mechatronika 2016, Prag, Chech Republic, 7 – 9 of December, 2016.

- The program to develop new technologies, methods, prototypes or the number of services that enterprises validated 1

A confirmation letter from "Adazi water" is attached to this report.

Further research and practical exploitation of the results
(Describe further research activities that are planned, describe possibilities to practically exploit results)

1. Development of a safety-monitoring and modelling solution for the urban environment via applying high performance data processing technologies.
We plan to integrate the common data transmittion system and to develop the interconnections between legacy infrastructure and smart automatic metering approach. The testing in the frame of real infrastructure systems is planned. We have successfully started discussions with municipally water supply companny in Adazi city, they are interested to test our novel approach in real infrastructure conditions.

2. Development and exploration of intelligent sensor network technologies and applications of intelligent transportation systems.
We expect to continue theoretical research on sensor technologies. We plan to perform a series of laboratory tests to confirm the possibility of practical application of the theoretical results. A special attention will be paid to issues of accuracy, validity and resiliency of sensor networks for different applications. We plan to develop a models of sensor networks reliability with different parameters of sensor nodes.

Regarding the Traffic on-line forecasting tool, we have the following directions for future work:

- economical feasibility study of the solution;
- approbation of the on-line forecasting tool;
- update of the proposed methodologies to insure the continuous update of the data in macromodel;

Also, it is necessary to establish a legal partnership with data providers in order to insure continuous update of the data in the macroscopic model.

Further research and practical implementation of low-cost mobile vehicle counting system and software would include the expansion of the tasks on the automatic classification of counted vehicles as well as the trial operation of it during traffic researches in urban environment.

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

The results of the project execution are disseminated through scientific publication activity and through participation in conferences. This dissemination channel mainly targets the research community in Latvian and abroad.

Dissemination to general audience has been carried out through popular science articles and interviews at Riga Technical University and participation in activies organized by Transport and Telecommunication Institute (such as day of the science, Night of the science, Open doors day, workshops etc).

We also note that participation in the project was positively evaluated by EC evaluators making decision about approval of a Horizon 2020 project for Transport and Telecommunication Institute (TTI) in the beginning of year 2016. This approval confirms the expertise of the partner from Latvia.

Popular scientific publications/reports: 4

1. An article was published in the popular science magazine "Ilustrētā Zinātne" ("Illustrated Science", May 2016);

2. An interview took place in the Latvian Radio 1 program "Zināmais nezināmajā" ("Known in the unknown", producer Paula Gulbinskis, May 25, 2016, 10:30 to 11:00).

3.-4. We participated in the Minox 2016 exhibition and our participation was reported in the media:
http://www.connectlatvia.lv/izstade-minox-2016/
http://ru.sputniknewslv.com/Latvia/20161009/2936685/vystavka-innovacij-riga.html.

Information was also disseminated using the websites of RTU and TTI:
https://www.rtu.lv/lv/universitate/masu-medijiem/zinas/atvert/ipasa-sistema-palidzes-atri-noteikt-un-noverst-zudumus-udens-un-siltuma-apgades-tiklos-12959.
http://www.tsi.lv/lv/content/nakamas-paaudzes-informacijas-un-komunikaciju-tehnologiju-ikt-petniecibas-valsts-programma

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	Phone number	+371-67213716
	E-mail	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)
1. To develop new methods and supporting software tools for laboratory information systems (LIMS) for collecting and integrating phenotype and experimental sources of biomedical data.

2. To develop methods for analysing and visualizing large sets of bioinformatics data.

3. To 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.

4. To further develop 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)

Development and maintenance of KIDREP and AIMS biomedicine databases hosted at IMCS has continued after the end of the 7th Framework EC project during which these databases have been developed. Continuous access of the data repositories was provided for the partners of the respective 7th Framework EC project. The work towards the development and release of open source version of the software is close to completion.

The research was continued in the area of using graph visualisation and analysis methods for analysis of bioinformatics data sets. The methods were successfully used for the study of two bioinformatics problems: the analysis of evolution of gene regulatory networks (both on simulated and experimentally obtained data sets), and the analysis of state spaces of gene regulatory networks. A scientific paper has been prepared and has been accepted for publication (indexed in Scopus database):

J.Viksna, D.Gilbert. Gene duplication models and reconstruction of gene regulatory network evolution from network structure. Baltic Journal of Modern Computing, vol. 4:5, 2016.

Another scientific paper is prepared for submission to PLoS ONE (indexed in SCOPUS database, SNIP > 1).

There have been ongoing work aimed at integration of local biomedical data bases and other data resources with centralised European and other international data repositories. The submission of KIDREP repository data to ICGC Data Portal has been largely completed.

An invitation has been received for participation in H2020 programme COST action CA15120 Open Multiscale Systems Medicine (OpenMultiMed) and the application has been submitted for participation in the management committee of the action.

The development of master level study program in bioinformatics has been started. It is planned to offer this study program as an inter-faculty program by the Faculty of Computing and the Faculty of Biology of University of Latvia.

Further research and practical exploitation of the results
(Describe further research activities that are planned, describe possibilities to practically exploit results)

1. We will continue development of KIDREP biomedical database and plan to develop and release an open source version of the database and the software tools.
2. We will continue to contribute to data submission to ICGC Data Portal according to needs that might arise due to changes and updates in ICGC metadata dictionaries or other data submission formats.

3. We will continue development of methods for analysing and visualizing large sets of bioinformatics data, in particular next generation sequencing data and datasets describing gene regulatory and other biomolecular networks.
4. We will further develop cooperation between Latvian research institutions and institutions of other European Union countries in the fields of bioinformatics and biomedicine, in particular within the framework of H2020 programme COST action CA15120 Open Multiscale Systems Medicine.
5. We plan to develop a master studies level program in Bioinformatics as an inter-faculty program by the Faculty of Computing and the Faculty of Biology of University of Latvia.

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

Published papers:

J.Viksna, D.Gilbert. *Gene duplication models and reconstruction of gene regulatory network evolution from network structure*. Baltic Journal of Modern Computing, vol. 4:5, 2016.

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 it's conceptual planning that includes Big Data and other platform services.

Improvement of the effective Web-harvesting technology to significantly increase it's 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)

We completed and implemented the operation of large-scale data processing platform in the new cloud "Spiets". It can be integrated with other cloud services. Infrastructure of virtual machines with access to big data and calculation results has been deployed in the platform.

High-performance computing (HPC) platform as part of a multi-purpose complex cloud is completed and introduced into service. HPC platform uses dedicated servers (their number can be adjusted following the demand for HPC calculations). Existing cloud services (including big data platform, shared data storage) are used for the calculation of HPC applications for both input data and results. HPC programs are available for high-performance, low-latency, redundant 20GB / s Ethernet core network and 1PB SAN system.
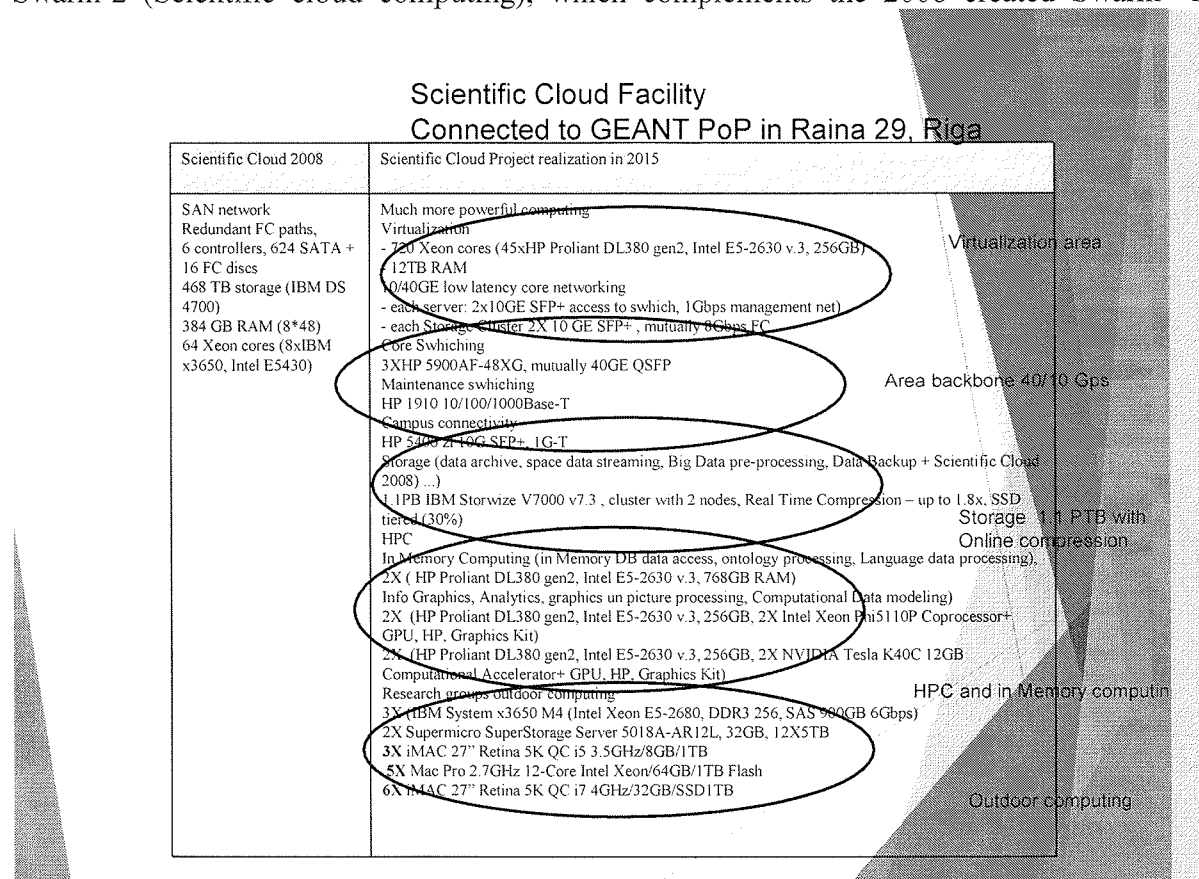
We established research e-infrastructure for the IT doctoral school.
Technical specifications:

- 3× (IBM System x3650 M4 (Intel Xeon E5-2680, 256 DDR3, 900GB SAS 6Gbps)
- 2× SuperStorage Supermicro Server 5018-AR12L, 32GB, 12X5TB
- 3× iMAC 27 "Retina 5K QC i5 3.5GHz / 8GB / 1TB
- 5× 2.7GHz Mac Pro 12-core Intel Xeon / 64GB / 1TB Flash
- 6× iMAC 27 "Retina 5K QC 4GHz i7 / 32GB / SSD1TB

This hardware is connected to the Swarm-2 (see technical specifications in the figure below) with 10/1 GE optical network. Thus, the students' research works can be used for the whole IMCS cloud-computing environment. Result: Establishing IT doctoral school research base (1) IMCS create Internet Video available in the calculation of the environmental complex Swarm-2 (Scientific cloud computing), which complements the 2008 created Swarm -1.

Scientific Cloud Facility
Connected to GEANT PoP in Raina 29, Riga

Scientific Cloud 2008	Scientific Cloud Project realization in 2015
SAN network Redundant FC paths, 6 controllers, 624 SATA + 16 FC discs 468 TB storage (IBM DS 4700) 384 GB RAM (8*48) 64 Xeon cores (8xIBM x3650, Intel E5430)	Much more powerful computing Virtualization - 720 Xeon cores (45xHP Proliant DL380 gen2, Intel E5-2630 v.3, 256GB) 12TB RAM 10/40GE low latency core networking - each server: 2x10GE SFP+ access to swhich, 1Gbps management net) - each Storage Cluster 2X 10 GE SFP+, mutually 8Gbps FC Core Swhiching 3XHP 5900AF-48XG, mutually 40GE QSFP Maintenance swhiching HP 1910 10/100/1000Base-T Campus connectivity HP 5412 zl 10G SFP+, 1G-T Storage (data archive, space data streaming, Big Data pre-processing, Data Backup + Scientific Cloud 2008) ...) 1 1PB IBM Storwize V7000 v7.3 , cluster with 2 nodes, Real Time Compression – up to 1.8x. SSD tiered (30%) HPC In Memory Computing (in Memory DB data access, ontology processing, Language data processing), 2X (HP Proliant DL380 gen2, Intel E5-2630 v.3, 768GB RAM) Info Graphics, Analytics, graphics un picture processing, Computational Data modeling) 2X (HP Proliant DL380 gen2, Intel E5-2630 v.3, 256GB, 2X Intel Xeon Phi5110P Coprocessor+ GPU, HP, Graphics Kit) 2X (HP Proliant DL380 gen2, Intel E5-2630 v.3, 256GB, 2X NVIDIA Tesla K40C 12GB Computational Accelerator+ GPU, HP, Graphics Kit) Research groups outdoor computing 3X (IBM System x3650 M4 (Intel Xeon E5-2680, DDR3 256, SAS 900GB 6Gbps) 2X Supermicro SuperStorage Server 5018A-AR12L, 32GB, 12X5TB 3X iMAC 27" Retina 5K QC i5 3.5GHz/8GB/1TB 5X Mac Pro 2.7GHz 12-Core Intel Xeon/64GB/1TB Flash 6X iMAC 27" Retina 5K QC i7 4GHz/32GB/SSD1TB

Result: Created Research and Education IT center of Regional Universities with remote job opportunities (Regional Partner Research Facility) (1) Completed and implemented the operation of large-scale data processing platform in the new cloud "Spiets".

Further research and practical exploitation of the results

GPU and BigRAM services are part of the E-spiets2 (LU MII cloud) portfolio and already used for scientific calcuations. However, those resources are available on specific compute nodes and provisioned with manual assistance. Further research will be focused on methods to integrate such localised resources into fully automated provisioning system as node properties or partitions. The goal is to allow cloud users self service provisioning of those specific resources as well as

the traditional IaaS cloud resources in the existing E-spiets2 cloud system.

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

Publication in preparation:

(SCOPUS) (0.5): L.Trukšāns, Ģ.Strazdiņš, "Usage of cloud platforms in studies."

M.Sc. theses:
Prepared and defended the Master's thesis (1): T.Dreiže "High availability OpenStack solutions," in 2016, supervisor - L.Trukšāns.

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)

1. Development of programmable directional antenna array field antenna signal generation model for simulating radio astronomy signal source. Performing antenna array beamforming simulations.

2. Improving of building detection methodology for checking and correcting shape of the building to reduce identification and delineation errors.

3. Carrying out the computational complexity assessments of specified in Project tasks algorithms (GMEM, CLEAN and others). Adaption of these assesments in order to automate the processing of data in information systems.

4. Development of solutions for establishment of large-scale sensor fields, their operation, data acquisition and processing. In particular, development of solutions for clarification of positions of VLBI data recording points (antennas) (interferometer-based detection) using satellite signals.

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

1. Continuing the work in the first period of the Project, we developed a simulation of programmable two-dimensional directional antenna array field and beamforming for it (because beamforming is most commonly applied for two-dimensional antenna array field). This simulation demonstrates the functionality of beamforming in two-dimensional antenna array field in a more realistic case. It allows to choose antenna array type (regular or irregular), set the size of antenna array field (defining the location of each antenna in the irregular case and the constant distance between antennae in regular case), and to change the direction of beam by changing the location of observation radio astronomy signal source visually indicating the phases in simulation. After ascertaining that this beamforming algorithm is fully and correctly functional, it will be adjusted and implemented in high performance hardware, which is the final step for this Project.

2. During the reporting period, we continued research on high spatial resolution orthophoto maps. We improved building detection methodology by using sub methods for checking and correcting shape of the building to reduce identification and delineation errors. The complexity of building delineation is determined by the variety in building and their roof shapes, spectral similarity with other objects and sensor view angle. Therefore, algorithms based on straight lines often produce wrong answers corresponding to sharpest changes in grey levels not the actual roof contour. Additional checking increases building delineation accuracy and practical application possibilities for map preparation and update.

Main scientific results during the reporting period:

- Building delineation method was improved by adding decision based sub methods for checking and correcting shape of the building.
- Study on raster descriptors for JSEG segmentation regions to investigate reparability between roofs of buildings and other impervious surfaces.
- Result validation using OpenStreetMap (OSM) building polygons. Task included a lot manual work since OSM polygons often describes only rough shape of the building.
- Evaluation of feature extraction methods for further improving of delineation methodology.

3. We have performed restoration of low quality digital images. As example microwave images of the Sun taken with the radio telescope RT-32 at 16 cm wavelengths were used. Due attention was paid to the large-scale low brightness temperature regions (LTRs).

To reduce the noise in the intensity distribution and the effect of the varying in time background fluctuations we made use of non-orthogonal "à trous" wavelet transform. The B-spline of degree 3 was used as the scaling function (Interactive Data Language procedure STAR2D.pro). Since the only one spatial-scale decomposition was performed, the first wavelet level with the lowest signal-to-noise ratio is removed. As a result, boundaries of the radio image and the large-scale internal features turned to be more sharply defined.

After noise reduction, the total intensity maps were recovered by means of the maximum entropy method (MEM). Doing this, the corrected position of the point spread function of the instrument, i.e. radio telescope RT-32, was taken. We find that besides the LTRs, which coincide with solar coronal holes and dark Hα filaments, some microwave LTRs coincide with the open-magnetic-field regions generating low level of soft X-ray emission. The coincidence of these LTRs with the open-field regions was on the base of the magnetic field line computations with the potential-field-source-surface (PFSS) model proves the relevance of the adapted GMEM and CLEAN algorithms for Project tasks.

The additional result of this laying in the field of astrophysics is the microwave indication of the open-field regions. Such extended regions with reduced soft X-ray brightness are usually termed as the coronal partings and suspected to be the location of the nascent slow solar wind.

4. We completed several technical and scientific experiments, whose aim was to work out algorithms and software that allows using a large parabolic antennas combined into one virtual telescope for large baseline interferometric experiments. The developed solutions were implemented on two radio telescopes with a diameter of 32 and 16 m (VIRAC RT-32 and RT-16) and successfully tested in the following experiments:

- GLONASS and GPS satellite tracking and data registration in VLBI mode, together with the Nizhny Novgorod Radiophysical Research Institute (NIRFI). In the experiment took part two VIRAC antennas RT-16 and RT-32 and two NIRFI test antennas. Data flow synchronization accuracy and stability made it possible to process the data obtained with VLBI techniques with the aim of clarifying the position of the antennas, determine satellite orbits and ionosphere parameters. Data flow synchronization accuracy and stability made it possible to process the data

obtained with VLBI techniques with the aim of clarifying the position of the antennas, determine satellite orbits and ionosphere parameters.

- Since October 2015 VIRAC radio telescope RT-32 is actively involved in the VLBI observation sessions, together with the European VLBI Network radio observatories and RADIOASTRON Space Telescope. different types of VLBI observations were performed: (i) observations with registered data flow rate from one antenna element from 2 up to 2000 Mbps with recording to dedicated "disk pack" of Mark5C equipment, (ii) recording on a standard server equipped with 8 HDD. (iii), two scientific experiments were performed, where the RT-32 registered VLBI data was transmitted to the VLBI correlation data centre (JIVE, The Netherlands) and processed in real-time. During the 24 hours experiments the transfer rate was up to 2 Gbps.

- In order to ensure effective registration of VLBI data management (storage, transfer to correlation centres, logging) specialized tools that allow to manage large volumes of data (per month from a single antenna are generated around 40 TB VLBI data) were developed.

- Cooperation with the Ukrainian Research Institute of "Nikolaev Astronomical Observatory" was started. Cooperation aim is development of method that allows use of small-scale distributed antennas for estimation of orbital parameters of geostationary satellites . Based on the five satellite signal registration stations, four of which are located in Ukraine and one organized in VIRAC was executed continuous (starts in August 2015 and continue throughout the year 2016) geostationary satellite Eutelsat-13B position monitoring.

Further research and practical exploitation of the results
(Describe further research activities that are planned, describe possibilities to practically exploit results)

1. After this Project, we plan to combine the beam forming algorithm (developed and implemented in high performance hardware) with a mobile module of antenna field developed within another project. We plan to use these two developments in future projects, leading to a two dimensional field of antennas with electronically controlled directivity.

2. Building delineation methods can be applied to prepare detailed and up-to-date maps over vast urban areas. Such maps are geometrically compatible with orthophotomaps and therefore further analysis is available without manual work for ensuring compatibility. This method is used for buildings for automated determination of urban areas and building card creation, providing a detailed time and date information. The methodology can be further commercialized by
1) providing maps, drafting services, or
2) the development of a software prototype maps.
Further tasks within a project are as follows. We will summarize the results in scientific article. Building delineation results will be compared with conclusions and results from other studies. Delineation methodology will be further improved by including additional checking sub methods.

3. During the last stage of the Project, we will combine the performed research activities ("à trous" wavelet transform, CLEAN, and GMEM) into one joint procedure to perform the restoration of both the local sources and the large-scale structures in microwave images of the Sun. The developed system of the automated data processing (scanning of the Sun, observational data reduction and restoration) will operate firstly in the Ventspils International Radio Astronomy Centre for scanning of the Sun, observational data reduction and

restoration. It will be made widely available for restoration of dirty digital images, obtained by sensors with directivity far of ideal.

4. During the last Project period, we will continue the testing the network of distributed VLBI stations, including collaboration including collaboration with international VLBI network in Europe, geostationary satellite positioning and GNSS satellites tracking. The algorithms and software developed during the Project as well as "know how" will be available after the end of Project for interferometric research of ionosphere, near-the – Earth objects and astrophysical research.

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

1. E.Vavilina, G.Gaigals. Improved LabVIEW Code Generation, Baltic J. Modern Computing, Vol. 4, No. 1, 89-97, 2016.
(http://www.bjmc.lu.lv/fileadmin/user_upload/lu_portal/projekti/bjmc/Contents/4_1_9_Vavilina.pdf)

2. E.Vavilina, G.Gaigals. Improved LabVIEW Code Generation, 2015 IEEE 3rd Workshop on Advances in Information, Electronic and Electrical Engineering (AIEEE 2015) conference proceedings, ISBN-978-1-5090-1202-2, 2016.
(http://ieeexplore.ieee.org/abstract/document/7367304/?reload=true)

3. L. Gulbe. Building and delineations identification using visible light orthophotomaps ed), Elsevier journal International Journal of Applied Earth Observation and Geoinformation, in preparation (50%).

4. B.I.Ryabov, D.A.Bezrukov, J.Kallunki. Microwave regions on the sun with low brightness temperature as observed by the radio telescope RT-32, Latvian Journal of Physics and Technical Sciences, in preparation (80%).

5. M.Kaliuzhnyi, F.Bushuev, O.Shulga, Y.Sybiryakova, L.Shakun, V.Bezrukovs, S.Moskalenko, V.Kulishenko, Y.Malynovskyi. International network of passive correlation ranging for orbit determination of a geostationary satellite, Odessa Astronomical Publications, submitted (90%).

6. M.P.Kaliuzhnyi, F.I.Bushuev, Ye.S.Sibiriakova, O.V.Shulga, L.S.Shakun, V. Bezrukovs, V.F.Kulishenko, S.S.Moskalenko, Ye.V.Malynovskyi, O.A.Balagura. Monitoring of the orbital position of a geostationary satellite by the spatially separated reception of signals of digital satellite television. Submitted to "Science and Innovation" http://scinn-eng.org.ua/. (accepted)

Master thesis: M. Koloda. Development of VLBI data processing and monitoring system for VIRAC (supervisor Vl. Bezrukovs).

Popular articles: I.Šmelds. Jaunumi Saules pētniecībā, Tematiskā avīze "Astronomija un astroloģija", 2016.g. lpp 48 – 50.

Conferences: VeA ziemassvētku konference, 2016. gada decembrī.

Project No. 4.4. Mathematical modelling, invers problems' analytical solving methods and algorithms, 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)

<u>Aims of the Project 4.4</u>

1. Development of mathematical models as well as analytical and numerical methods for stable solving of multi-dimensional problems including inverse and ill-posed problems, which occur in technical and 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.

<u>Objectives of the Project 4.4</u>

1. To develop discrete 1D and 2D mathematical models for determination of dynamics of solid particles of micro- and nano-size in the 1D and 2D gaseous medium, respectively; to find conditions permitting to carry out passages to the limit in the constructed discrete models to obtain the corresponding 1D and 2D continuous models; to find conditions implementation of which ensures the correctness (by Tikhonov) of the constructed continuous models.

2. To develop physico-mathematical parameterized 3D model for detection of basic features of the interaction between radiation and solid materials (metals, semiconductors, insulators) under influence of femtosecond laser pulses that excitant nano-surface electromagnetic waves with periodic interference.

3. To develop two-temperature mathematical model for describing the evolution of the temperature field on materials surface under the influence of femtosecond laser pulses; to develop thermodynamic approach for both analysis of state of material during its heating and expansion under influence of femtosecond laser pulses and for analysis of mechanism of radiation absorption of material's electron subsystem under assumption that electrons have time to be thermalized.

4. To develop multi-criteria optimization model for transportation of multi-nomenclature cargo; to develop analytico-numerical method which combines the goal attainment method of Gembicki and the Tikhonov's regularization method and which permits to find stable solution of the sated multi-criteria optimization problem.

5. To develop mathematical models and methods for determination of economic attractiveness and investment climate of a group of EU countries for the purpose of exporting inexpensive and exclusive financial services.

6. To develop stable method for determination of the electron density in the ionosphere on the basis of the Ginzburg-Feinberg non-linear problem of frequency electromagnetic sounding of ionosphere.

7. 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 developed the discrete 1D and 2D mathematical models that describe the motion of solid particles of micro- and nano-size in the 1D and 2D gas flow, respectively. Constructed discrete 1D mathematical model is based on the following assumptions: the

influence of the gas on the micro- and nanoparticles is negligible; the influence of the micro- and nanoparticles on each other is negligibly small as compared to the influence of gas on the particles; micro- and nanoparticles can move in the gas flow in different directions. At each time step a particle moves by certain distance, not necessarily to the next position. These assumptions are quite natural if, for instance, the concentration of solid particles is sufficiently small, and if external forces are absent. This situation is typical in many important applications dealing with dilute particle flows. In the following, we have laid down some conditions under implementation of which it is possible to carry out limiting process in the built discrete 1D mathematical model: as a result we obtain a continuous 1D mathematical model in the form of an initial-value boundary problem for the special kind of integro-differential equation. A probabilistic interpretation of the obtained 1D model is provided, and its solvability is studied. We have found certain sufficient condition under implementation of which a unique solution exists. It is shown that the Fokker-Planck equation can be obtained from our deduced special kind of integro-differential equation. Finally, a generalization to the 2D case of the investigated problem is realized.

2. We have developed physico-mathematical parameterized 3D model that describes (under certain assumptions) the evolution of the temperature and electromagnetic fields on materials surface (taking as an example the copper surface) under the influence of femtosecond laser pulses. The developed 3D model is a two-temperature non-linear model, which permits to study some of the basic features of the interaction of radiation with solid materials (metals, semiconductors, insulators) under influence of femtosecond laser pulses. Our 3D model is a parameterized model, which takes into account, in particular, the dependence of the physical and chemical characteristics of the periodic nano-surface structures on controllable parameters: polarization effect; incidence angle; energy density; wavelength; etc. During the derivation of our 3D mathematical model we have taken into account the excitation of nano-surface electromagnetic waves, which in the course of laser ablation are periodically becoming stronger or weaker, i.e. the periodic interference occurs.

3. We have developed an efficient (from the standpoint of simplicity, feasibility and usability) thermodynamic approach for analysing the constructed two-temperature non-linear 3D mathematical model (i.e. system of equations describing the evolution of the temperature and electromagnetic fields on materials surface under the influence of femtosecond laser pulses), to which are appended two more systems of equations: the equations that describe the dynamics of condensed phase; the equations that describe the expansion of vapour phase; and finally, the generalized Van der Waals equation, which is one of the most expanded wording of equilibrium conditions between phases, and which permits to establish an interconnection between variations of temperature, pressure and composition of existing liquid and vapour. All these three systems of equations are solved in different time scales under various conditions of laser irradiation. Finally, it is important to note that our developed thermodynamic approach can be applied for both analysis of state of material during its heating and expansion under influence of femtosecond laser pulses and for analysis of mechanism of radiation absorption of material's electron subsystem in assumption that electrons have time to be thermalized.

4. We investigated a specific problem of optimal planning of maritime transportation of multi-nomenclature divisible cargo by ships of one (in the case of corporate strategy) or several (in the case of partially corporate strategy) companies: the core of the problem consists in 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: (a) mathematical models are built from scratch in the form of multicriteria optimization problem; (b) according to the properties of the criteria and structure of the feasible solution set, different optimality

conditions are formulated; (c) are analyzed different approaches for finding effective solutions (so-called "Pareto optimal" solution) and for checking the prespecified solutions' effectiveness; (d) is developed an analytico-numerical method, which combines the goal attainment method of Gembicki and the Tikhonov's regularization method, and which permits to find stable solution of the considered multicriteria optimization problem if possible errors are present in all source data. 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). The obtained results can be used in planning of multinomenclature goods transportation on roads and railways.

5. We developed two mathematical models on the basis of which we propose two different approaches for investigation of economic attractiveness of some of the post-socialist countries of Central and Eastern Europe: the first approach to determine the best strategies of exportation of inexpensive services, and the second approach to determine the potential of export banking and certain other luxury services. The essence of the first approach is the following: by the theory and methods of inverse and ill-posed problems, the system

$$E[i;t] = C_1 \cdot \sum_{j=1}^{n} w_{i,j} \cdot \hat{x}_{i,j}(t) + C_2, \quad t \in [T_{start}, T_{end}], \quad \forall i = \overline{1,m},$$ which is our first developed model,

leads us to the widely known problem of finding stable solution for finite-dimensional operator equation of the first kind, which then is solved by the Tikhonov regularization method. The basis of the second approach is a rather untraditional idea: initially, the concepts "Degree of favourability of the year", "Degree of succession of the year", "Degree of influence of years' favourability", "Sensitivity switch" are set, so that their meanings are a priori unknown and must be defined, and then we address the question of construction of such mathematical model, which would: (a) range the studied countries by the set of indices of economic attractiveness by years; (b) define "Degree of favourability of the year" for each year both in terms of each indicator and totally; (c) range the years themselves by "Degree of favourability of the year" and "Degree of succession of the year"; (d) define impacts of "Degree of succession of the year" on the indices of economic attractiveness of the studied countries. As the result, we are able to construct "from scratch" the following second mathematical model, and besides, we investigated the solvability of the second constructed mathematical model as well as the uniqueness of its solution. Moreover, we investigated the question of stability of the second model to small changes of the initial data, and we developed an iteration algorithm for finding stable solution of the second model. Finally, we conducted two computing experiments with real statistics – one for each of the described approaches.

6. We investigated one inverse problem of frequency electromagnetic sounding for unambiguous determination of the electron density in the ionosphere. Direct statement of this problem is known as the Ginzburg-Feinberg problem that has, in general case, an essential nonlinearity. We proved the existence and uniqueness of the solution of the stated inverse problem as well as we proposed the analytical method permitting: firstly, to reduce it to the problem of integral geometry, and thereupon, having applied the modificated\adjusted variant of the Lavrentiev's theorem, to reduce the obtained problem of integral geometry to the first kind matrix integral equation of Volterra type with a weak singularity. The considered inverse problem arises, generally, at study of the following problems: propagation of various low-frequency electromagnetic waves in the ionosphere, exosphere and adjacent to its regions of interplanetary space; propagation of radio waves in the ionosphere (i.e. in the upper layers of the Earth's atmosphere); propagation of radio waves of cosmic origin in the solar atmosphere, in the nebulae as well as in the interstellar and interplanetary spaces; propagation of radio waves at laser ranging of the Sun, the Moon and some planets as well as in the case of communication with the distant artificial Earth satellites and space rockets; propagation of low-frequency magneto-hydrodynamic

and acoustic waves in space environment; propagation of plasma waves both on the ionosphere and the solar corona; propagation of various types of electromagnetic waves in plasma created in vitro (i.e. in the laboratory conditions) in study of gaseous discharge as well as in installations meant for study of controlled thermonuclear reactions; etc.

Publications:

1. Sh.E.Guseynov, R.Aleksejevs, R.Guseinovs, J.V.Aleksejeva, A.V.Berezhnoy, A.N.Medvedev (2016). *On a multicriteria problem of planning maritime cargo transportation with handling operations in intermediate seaports.* – Annals of Operations Research, ISSN: 0254-5330, 25 p. Accepted SCOPUS (SNIP: 1.123). http://www.springer.com/business+%26+management/operations+research/journal/10479/PSE

2. Sh.E.Guseynov, U.Zaimis, J.V.Aleksejeva, J.Kaupuzs, A.Jansone, A.Grickus (2016). *On a mathematical model describing the motion of solid particles of micro- and nano-size in gas flow.* – International Scientific Journal "Machines. Technologies. Materials", Issue 11/2016, ISSN: 1313-0226, 1314-507X, pp. 23-32. http://www.stumejournals.com/mtm/Archive/2016/11-2016.pdf

3. Sh.E.Guseynov, U.Zaimis, J.V.Aleksejeva (2016). *Thermodynamic analysis of two-temperature model describing the dynamics of the temperature field on the material surface under the influence of femtosecond laser pulses.* – International Scientific Journal "Machines. Technologies. Materials", 6 p. (Accepted)

4. R.Aleksejevs, R.Guseinovs, A.N.Medvedev, Sh.E.Guseynov (2016). *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 SCOPUS

5. Sh.E.Guseynov, U.Zaimis (2016). *On a physico-mathematical model for controlled formation of periodic nanostructures at solid surfaces irradiated by femtosecond laser pulses.* – Scientific Technical Journal of Material Science, Issue 3/2016: "Nonequilibrium Phase Transformations", ISSN: 2367-749X, pp. 17-20.

6. Sh.E.Guseynov, U.Zaimis (2016). *On a physico-mathematical model for controlled formation of periodic nanostructures at solid surfaces irradiated by femtosecond laser pulses.* – International Journal for Science, Technics and Innovations for the Industry "Machines, Technologies, Materials", Issue 7/2016, ISSN: 1313-0226, Publisher: Scientific Technical Union of Mechanical Engineering, pp. 23-26.

7. A.Natrins, K.Lesinskis, Sh.E.Guseynov (2016). *Evaluating country attractiveness by using index approach for strategic decision making process related to expansion of financial service markets.* – Journal of Business Management, ISSN: 1691-5348, 13 p. (Submitted)

8. R.Aleksejevs, Sh.E.Guseynov, R.Guseinovs (2016). *On a multicriteria problem of planning maritime cargo transportation with handling operations in intermediate seaports.* – International Journal of Applied and Computational Mathematics, 31 p. (Submitted) SCOPUS

9. A.Natrins, K.Lesinskis, Sh.E.Guseynov (2016). *Evaluating country attractiveness by using index approach for strategic decision making process related to expansion of financial service markets.* – The 9th Annual Scientific Baltic Business Management

Conference "Challenges of Business Sustainability in the Digital Age" (ASBBMS'16), April 21-23, 2016, Riga, Latvia, Presentation 27 p. http://asbbmc.eu/

10. Sh.E.Guseynov, U.Zaimis, J.V.Aleksejeva, J.Kaupuzs, A.Jansone, A.Grickus (2016). *On a mathematical model describing the motion of solid particles of micro- and nano-size in gas flow.* – Proceedings of the XIII International Scientific Congress "Machines. Technologies. Materials", September 14-17, 2016, Varna, Bulgaria, Issue 23 (209), Volume 1: Technologies, ISSN: 1310-3946, pp. 53-62. http://mtmcongress.com/summer/sbornik/2016-1.pdf

11. Sh.E.Guseynov, U.Zaimis (2016). *On a physico-mathematical model for controlled formation of periodic nanostructures at solid surfaces irradiated by femtosecond laser pulses.* – Proceedings of the 4th International Scientific Conference "Engineering. Technologies. Education. Security", June 01-03, 2016, Veliko Tarnovo, Bulgaria, Issue 9 (195), Volume 1: Information Technologies, Natural and Mathematical Sciences, ISSN: 1310-3946, pp. 54-57.

12. Sh.E.Guseynov, J.S.Rimshans (2016). *On the Ginzburg-Feinberg problem of frequency electromagnetic sounding for unambiguous determination of the electron density in the ionosphere.* – Book of Abstracts of the 11th Latvian Mathematical Conference, April 15-16, 2016, Daugavpils, Latvia, pp. 32-33. http://www.mathematics.lv/lv/11lmb/Abstracts.pdf

13. Sh.E.Guseynov, R.Guseinovs, J.V.Aleksejeva, R.Aleksejevs (2016). *On two approaches for determining countries potential on purpose of export of non-expensive and luxury services.* – Book of Abstracts of the 11th Latvian Mathematical Conference, April 15-16, 2016, Daugavpils, Latvia, pp. 30-31. http://www.mathematics.lv/lv/11lmb/Abstracts.pdf

14. A.Natrins, I.Drikis, Sh.Guseynovs, K.Lesinskis, A.Sarnovics (2016). *The basic principles of formation attractiveness indices of Central and Eastern Europe countries to assess the potential of the financial services and the affluent customers segment.* – Riga: Business and Financial Research Center of the BA School of Business and Finance, 107 pages. (In Latvian: A.Nātriņš, I.Driķis, Š.Guseinovs, K.Lešinskis, A.Sarnovičs (2016). *Centrāleiropas un Austrumeiropas valstu pievilcīguma indeksu izveidošanas pamatprincipi turīgo klientu segmenta un finanšu pakalpojumu potenciāla novērtēšanai.* – Rīga: Banku Augstskolas Biznesa un finanšu pētniecības centrs, 107 lappuses).

Further research and practical exploitation of the results
(Describe further research activities that are planned, describe possibilities to practically exploit results)

1. We will continue the development of analytical and analytico-numerical methods for solving linear and nonlinear classes of inverse problems (coefficient, boundary, geometric and evolutionary inverse problems) that appear in various technical systems and devices of different complexity.

2. We will continue the development of new materials for wear-resistant implants of the human joints including hip joint and technology of their machining with the achievement of high precision and quality of their spherical surfaces.

3. We will continue the development of mathematical models for thorough research of optimal processing mechanism of dispersed granular materials in gravitational flow with horizontal or inclined vibrating sieve classifying screens.

4. We will continue the development of mathematical models and stable analytic-numerical methods for investigation of comparative degree of coherence of key indicators for EU countries to determine: the best strategies of exportation of inexpensive services; the potential of exportation of banking and certain other luxury services.

5. We will continue the development of optimization models for planting, sowing, growing and harvesting agricultural crops to receive guaranteed best results regardless of weather conditions.

6. We will continue the development of physico-mathematical models and the corresponding analytical and numerical methods for controlled formation of periodic nanostructures at solid surfaces of metals, semiconductors and insulators irradiated by femtosecond laser pulses.

7. We will continue to investigate the formation and behaviour of solid nano-sized particles on the surface of metals and semiconductors.

8. We will continue to investigate different problems on application of frequency electromagnetic sounding of artificial Earth satellites as well as near-Earth atmosphere (just only troposphere) and ionosphere (just mesosphere and thermosphere).

9. We will continue the development of multi-criteria models and stable analytical-numerical algorithms for optimization of intermodal transportation of multiproduct cargo.

10. We will develop stable approximation algorithms for solving irregular problems with application to multi-dimensional integral equations.

11. We will develop stable analytico-numerical algorithms for processing of structured and unstructured data arising in medicine and molecular biology.

12. We plan to prepare and publish one monograph as well as two mathematical textbooks.

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

1. The Workshop entitled "Application of mathematical modelling and information technologies in solving scientific-technical, industrial-engineering, economic, financial, environmental and social-humanitarian problems", organized by the Institute of Fundamental Science and Innovative Technologies, Liepaja University in collaboration with the Baltic International Academy, December 15-16, 2016, Liepaja, Latvia. In the framework of this Workshop the following contributions were held:

    - Sh.E.Guseynov, U.Zaimis (2016). *High-precision lapping of spherical surface of titanium alloy by laser irradiation in order to receive high quality and wear-resistant implants of the human hip joint*, 10 pages.
    - Sh.E.Guseynov, A.Grickus (2016). *Mathematical modelling of the processing mechanism of dispersed granular materials in gravitational flow with horizontal or inclined vibrating sieve classifying screens*, 12 pages.
    - Sh.E.Guseynov, J.V.Aleksejeva (2016). *Investigation of comparative degree of coherence of key socioeconomic indicators for the post-socialist countries of Central and Eastern Europe to determine the potential of export banking and certain other luxury services*, 32 pages.
    - Sh.E.Guseynov, J.V.Aleksejeva (2016). *On a multi-criteria model for planning maritime cargo transportation with handling operations in intermediate seaports*, 17 pages.

- Sh.E.Guseynov, U.Zaimis, J.V.Aleksejeva, J.Kaupuzs, A.Jansone, A.Grickus (2016). *On a mathematical model describing the motion of solid particles of micro- and nano-size in gas flow*, 23 pages.
- V.A.Ravichandran, Sh.Iqbal, Sh.E.Guseynov (2016). *Methods of propositional algebra in solving convoluted verbal problems arising in the social-humanitarian fields*, 8 pages.
- U.Untulis, J.Gegeris, Sh.E.Guseynov (2016). *Mathematical modelling of problem of optimal sowing agricultural crops*, 15 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.Aleksejeva, J.Kaupuzs (2016). *What are inverse problems?*, 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	225 000	
1000	**Remuneration**	**102 858**	**193 571**	**195 771**	
2000	**Goods and services**	**22 539**	**26 089**	**27 259**	
2100	Study, work and official missions, official and work trips	4 620	7 611	9 936	
2200	Services	15 250	14 952	15 260	
2300	Stock, materials, energy resources, goods, office supplies and inventory	1 758	2 598	2 063	
2400	Expenses for the purchase of periodicals	911	928		
5000	**Establishment of core capital**	**6 178**	**770**	**1 970**	