TTÜ RESEARCH AND DEVELOPMENT 2016
FOREWORD

I am happy to bring to you the 2016 Annual Research Report of Tallinn University of Technology. It highlights the research activities of faculty, staff, students and postdocs associated with TTÜ during the Year 2016.

The mission of Tallinn University of Technology is to be a promoter of science, technology and innovation, and a leading provider of engineering and economic education in Estonia.

Our commitment to excellent research as well as to practical relevance made us the first choice of most Estonian companies and organizations as a research partner in engineering, information technology, economics as well as in natural and life sciences. Our faculty is devoted to bridging the gap between engineering and IT as well as other disciplines like natural and social sciences, contributing to key international research activities and real-world solutions alike.

The research and innovation carried out by the community of this university is indeed making an impact. It is estimated that, in 2016, TTÜ generated a total economic contribution of EUR 390.1 million Gross Value Added (GVA) and 10,400 jobs in Estonia and EUR 485.0 million GVA and 12,600 jobs globally. The respective contributions for all Estonian Universities was 1.4 billion GVA and 37,000 jobs in Estonia and 1.6 million GVA and 43,900 jobs globally.

In particular, we continue to strive to increase the research impact for Estonian society via collaborative research projects that we conduct together with our strategic research partners. This will help us lay a firm foundation for high level research services and include quality graduates who will be competitive in the job market and successful in self-employment.

An important aspect of the Estonian R&D system is its overwhelming reliance on competitive project-based policy measures, both in funding public universities and private companies. This is particularly glaring in research where ca 80% of all funding is competitive. However, in 2016 the Government decided to allocate additional funding for basic funding of universities from 2017, thereby increasing the level of baseline funding vis-à-vis project-based funding. Nevertheless, there is still a need for the university to intensify its efforts to increase both the number and quality of applications submitted both to the EU and to private organizations and foundations.

With this annual report we wish to provide the reader with a glimpse of work carried out by research groups over the past year. TTÜ would like to make use of this opportunity to express its thanks to the faculty members, students, other employees, and collaboration partners, for excellent cooperation.

In 2017
Renno Veinthal
Vice-Rector for Research
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TTÜ research and development

School of Engineering

Photo: Nearly zero energy nZEB technological test facility, an unique facility for building science. TTÜ photo archive
SCHOOL OF ENGINEERING

Dean: Professor ARVO OORN
e-mail: arvo.oorn@ttu.ee

Vice-Dean for Research: Senior Research Scientist ARGO ROSIN
e-mail: argo.rosin@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)

- Academic staff, total 349
  - Incl. 50 professors, 150 researchers
- Doctoral students, total 222
- Scientific publications, total 456
- Defended doctoral dissertations in 2016, total 29

DEPARTMENTS

DEPARTMENT OF CIVIL ENGINEERING AND ARCHITECTURE
Director: Professor JAREK KURNITSKI, jarek.kurnitski@ttu.ee

DEPARTMENT OF ELECTRICAL POWER ENGINEERING AND MECHATRONICS
Director: Professor IVO PALU, ivo.palu@ttu.ee

DEPARTMENT OF ENERGY TECHNOLOGY
Director: Professor ANDRES SIIRDE, andres.siirde@ttu.ee

DEPARTMENT OF MATERIALS AND ENVIRONMENTAL TECHNOLOGY
Director: Lead Research Scientist MALLE KRUNKS, malle.krunks@ttu.ee

DEPARTMENT OF MECHANICAL AND INDUSTRIAL ENGINEERING
Director: Associate Professor KRISTO KARJUST, kristo.karjust@ttu.ee

TARTU COLLEGE
Director: Professor LEMBIT NEI, lembit.nei@ttu.ee

VIRUMAA COLLEGE
Director: VIKTOR ANDREJEV, viktor.andrejev@ttu.ee
DEPARTMENT OF CIVIL ENGINEERING AND ARCHITECTURE

Director: Professor JAREK KURNITSKI, jarek.kurnitski@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)

- Academic staff, total 87
  - Incl. 18 professors, 18 researchers
- Doctoral students, total 47
- Scientific publications, total 117
- Defended doctoral dissertations in 2016, total 4

The Department conducts research within 7 research groups:

- Architecture and Urban Studies
- Structural Engineering
- Building Lifecycle
- Nearly Zero Energy Buildings nZEB
- Structural and Fluids Mechanics
- Road Engineering and Geodesy
- Water and Environmental Engineering

RESEARCH GROUPS

ARCHITECTURE AND URBAN STUDIES

Head of the research group: Visiting Associate Professor IGNAR FJUK, ignar.fjuk@ttu.ee

The research group is conducting studies on architecture and urban history and theory. The group is focusing on the following periods and topics:

- Urbanism of the beginning of the 20th century (international cooperation with a group from Marburg Herder Institute).
- Architecture of the 1930s, architecture and power (cooperation with Estonian Art Academy).
- Stalinist era city planning. Architecture and ideology (international cooperation with UEDXX research network, cooperation with the Estonian Academy of Arts).
- Soviet architecture. (a) Emerging architectural psychology (participation in Zyrich ETH program 2014–2016 East-West-Central. Re-Building Europe, 1950–1990); (b) Ideology and memory (participation in Marburg Herder Institute HERA Project group).

The general aims of the research group are to open uncovered research areas in the history and theory of architecture and planning; to bring new archival material into architectural research; to upgrade, re-conceptualize and create new positions and methods in researching architecture and planning; to create new platforms for evaluation of architectural heritage of different periods of modernism.

The importance of the research for Estonian society can be seen in creating a fundamental platform for practical design solutions in contemporary architecture. Theoretical re-conceptualisation of the processes of modern and contemporary architecture contributes to the re-evaluation of architectural heritage which is important on a local cultural level, for this research is the task
of Estonian native researchers in the first place, as well as in wider international context (comparative methods). Basic theoretical research on modern architecture and planning history forms data for architectural heritage and historical milieu surveys/expert assessments for emerging architecture, because every new building or planning project has concrete spatial and historical context that needs to be determined, analysed and evaluated -in the context of every new architectural project.

PUBLICATIONS

STRUCTURAL ENGINEERING
Head of the research group: Associate Professor IVAR TALVIK, ivar.talvik@ttu.ee

The studies are related to the analysis of various building structures.

IN 2016
The effect of zero-strength layers of timber members and protection properties by claddings and different insulation materials on structural timber were studied. The research has direct influence on the revision process of Eurocode 5. Timber structures research topics cover also connections of cross-laminated timber elements. The impact of various insulation materials on the fire performance of timber structures was studied. An extensive testing program with timber frame assemblies has been carried out. Research on strength properties of glulam timber at elevated temperatures is going on. Another group worked on resistance of steel columns with different cross sections at elevated temperatures and dynamic properties of pre-stressed cable networks.

PUBLICATIONS

BUILDING LIFECYCLE
Head of the research group: Professor IRENE LILL, irene.lill@ttu.ee

The research of the group reflects the building lifecycle as a whole, integrating the construction process and its outcomes with management strategies, technologies and materials used and also with economics and facilities management. Recent research has included:

• multi-attribute decision making methods for the assessment of different management strategies;
• developing and providing BIM-related know-how;
• different aspects of construction economics and management in the major fields of civil engineering;
• surveys on the building life cycle and technical conditions of housing;
• disaster resilience of built environment;
• utilization of oil shale ash in the production of building materials;
• utilization of oil shale mining waste materials in concrete;
• energy saving and the renovation of buildings;
• regulation of construction activities and drawing up normative materials and standards for the Estonian construction industry.

Members of the group are also active research partners in other faculty and industry projects where their expertise is needed, for instance in nearly-zero energy solutions and their implementation on the renovation of buildings, advising the public and private sector in questions of construction management, building maintenance, etc.

The Research and Testing Laboratory of Building Materials has certified testing personnel, standards, methods and equipment for the evaluation of conformity of various building products: cement, mortar, grout and concrete products and also of natural and artefact stones and insulation products. Researchers of the group are valued experts in the construction industry and conduct research connected with the properties of Portland cement concrete and the utilization of oil shale mining waste materials in concrete.

PUBLICATIONS


NEARLY ZERO ENERGY BUILDINGS nZEB

Head of the research group: Professor JAREK KURNITSKI, jarek.kurnitski@ttu.ee

Nearly Zero Energy nZEB Research Group, established in 2012 is a multi- and interdisciplinary research group representing a strong networking effort within TTÜ among four different disciplines: Energy Performance of Buildings, Building Service Systems, Building Physics and Construction Economics and Management. The main research topics have been focused on technical solutions and system integration for nZEB most urgently needed in Estonia.

Some examples of topics: new heating and ventilation solutions suitable for specific operation conditions in nZEB, new external wall assembly solutions studied with computational analyses and climate chamber tests, office building solar shading and façade analyses with energy simulations and measurements at TTÜ technological facility, daylight and energy analyses for industrial hall buildings, energy pile analyses for ground source heat pump heating and free cooling, energy simulations combined with economic and cost optimality analyses in order to define an extra cost of nZEB and to find optimal solutions for office and apartment buildings, scenario analyses for energy savings and investment needs within the framework of the Estonian energy action plan ENMAK 2030+.

In 2016


PUBLICATIONS


The research group is working on three main topics: (1) Reduction of risks and energy consumption in hydraulic systems; (2) Limit state analysis of ship structures; (3) Acoustic field information on structural integrity.

IN 2016

1. The reduction of energy consumption in hydraulic systems was analysed. A novel algorithm was developed that ensures variable speed pumps (VSPs) working in parallel to run close to the best efficiency point (BEP) provided by the pump manufacturer. The complex optimization task to maximize the total efficiency of the pump system and thereby minimize energy consumption was solved with the customized optimization software using the Levenberg-Marquardt algorithm (LMA). The optimization software can also be used to estimate the optimal number of working pumps.

Improved 1D models were developed to predict the velocity, length and position of the liquid column in the rapid emptying and filling of pipelines. Multiphase flow dynamics in a large-scale inverted siphon in Tallinn storm water system was investigated using CFD (Computational Fluid Dynamics). Experimental and numerical studies of flow dynamics in a pipe with sudden change in diameter were conducted. It was shown that the out-of-the-box CFD solutions fail to predict the real flow dynamics in case of complex geometry.

2. A model was developed to investigate the inner hull failure in ship-ship collisions. The relevancy of the mathematical models in describing the bottom shapes was investigated. A method for the assessment of residual strength of a ship hull damaged in grounding or collision accidents was developed. The strength assessment is based on a coupled beam method that allows time-efficient analysis compared to the finite element approach. New piecewise continuous coordinate functions were implemented to CB method in order to describe the local structural discontinuities more accurately. Three simplified plated structures were analysed in order to validate the CB-method with new functions against the three-dimensional FE-method.

A development of the method for the assessment of residual strength of a ship hull damaged in grounding or collision accidents was initiated by adding the option to account for the openings in ship structures. The strength assessment is based on a coupled beam method that allows time-efficient analysis compared to the finite element approach. New piecewise continuous coordinate functions were implemented to CB method in order to describe the local structural discontinuities more accurately. Three simplified plated structures were analysed in order to validate the CB-method with new functions against the three-dimensional FE-method. This validation was presented in PRADS 2016 conference.

3. The Marine Strategy Framework Directive (MSFD) requires that European Member States develop strategies for achieving or maintaining Good Environmental Status (GES) in the European seas. For the indicator concerning the ambient underwater noise, a combined use of measurements and modelling is considered a very effective way to ascertain the levels and trends of underwater noise in the relevant frequency bands. Ordinarily an individual ship is modelled as a monopole or dipole sound source with the constant angular distribution. Close studies of the spatial distribution of sound radiation from individual ships would further improve the modelling. It was shown that it is possible to calculate the source level based on ship noise recordings in shallow water, if modelling is accurate and AIS data is available.

PUBLICATIONS


ROAD ENGINEERING AND GEODESY

Head of the research group: Professor ARTU ELLMANN, artu.ellmann@ttu.ee

MAIN TOPICS OF RESEARCH IN 2016:

- Monitoring of deformation, wearing and other exploitative properties of pavement and manhole structures of Tallinn city streets constructed in 2014–2016 using laser scanning technology for the evaluation of pavement structures properties based on the actual traffic load, geological and hydrological conditions of Tallinn; development of a specification of requirements for road construction materials.

- Development of the methodology of pavement design: input for the development of the Estonian Pavement Design Manual 2001-52 (incl. KAP software); scientific analysis of pavement design methodology of nearby neighbours (Lithuania, Latvia, Sweden, Germany, Ireland) and parallel calculations (incl. economical) with the Estonian methodology; suggestions to what extent it is reasonable to develop further Estonian methodology or which methodology of the neighbouring country can be overtaken in the future (justified technically and economically).

- Analysis of transport growth and its impact, traffic safety (road safety auditing and inspection, road network impact analysis, safety analysis, etc.).

- Geodetic monitoring and scientific analysis of the Võõbu road construction test sites. The main scope of the research is to identify suitable road construction technology devoted for crossing vast swamp areas.

- Tests and scientific analysis of the load of Särevere old bridge, and scientific study of waterproofing concrete and hydrophobic protection of concrete surface, the analysis stage.

- Analysis of typical reinforced concrete bridges of the Soviet time to increase their load capability in order to bring into compliance with European requirements, including strengthening of bridges.

- Quality analysis of the new geoid model (NKG2015) for the Baltic Sea region, which was elaborated in co-operation -between Nordic and Baltic countries, whereas TTÜ’s geodesy chair acted as a NKG computing centre.

- Continued participation in an Estonian Research Infrastructures Roadmap project Estonian Environmental Observatory, which is a network of experimental sampling stations for environmental research – a system of uniform geographically and climatically integrated field laboratories and automatic stations that is supported by a geomatics and geoinformatics science laboratory.

- Development of geodetic infrastructure (e.g. establishment/validation of gravity databases, geoid modelling computations, mean sea surface modelling; studies of shipborne GNSS to evaluate geoid models at sea) for finalizing hydrographic surveys in the Baltic Sea.

- Development of technological solutions for combining different spatial data acquisition sensors in a mobile platform and corresponding data processing.

- Laser scanning research with relevance to concrete road construction experiments, with relevance to optimization of as-built survey results to be entered into InfraBIM.

THE MAIN RESULTS IN 2016

- Development of the methodology of pavement design.

- Analysis of geodetic monitoring results at the Võõbu road construction test sites, validation of various road construction technologies.

- Suitability of a new Baltic Sea region geoid model (NKG2015) analysed for the usage in engineering applications.

- New spatial data acquisition methods elaborated and tested.

PUBLICATIONS


WATER AND ENVIRONMENTAL ENGINEERING

Head of the research group: Professor KARIN PACHEL, karin.pachel@ttu.ee

This is an interdisciplinary research group, where engineers, hydrologists, water chemists and other specialists from both water and environmental engineering participate. Scientific research is developed in the following directions:

- Sustainable management of water resources and water quality. Hydrological studies of rivers from engineering viewpoint. Climate change and its impact on quantity and quality of water. Floods and droughts.
- Studies on pressures having impact on water quality. Regularities in water quality formation in both natural conditions as well as under various anthropogenic impacts.
- Urban water supply (domestic water) and sewage systems (sewerage, wastewater, stormwater), including pipelines outside buildings, internal pipelines in buildings, treatment facilities, engineering solutions and technologies, studies for improving design and construction. Pharmaceutical residues and heavy metals in municipal wastewater and sludge, as well as elaboration of relevant treatment technologies.

For scientific and experimental research the group uses its own internationally accredited water quality laboratory (http://www.eak.ee/dokumendid/pdf/kasitlusala/L057.pdf).

PUBLICATIONS


DEPARTMENT OF ELECTRICAL POWER ENGINEERING AND MECHATRONICS

Director: Professor IVO PALU, ivo.palu@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)
- Academic staff, total 56
  - Incl. 10 professors, 36 researchers
- Doctoral students, total 62
- Scientific publications in 2016, total 108
- Defended doctoral dissertations in 2016, total 8

The Department conducts research within 8 research groups:
- Mechatronics and Autonomous Systems Centre
- Microgrids and Metrology
- Electrical Machines
- Power Electronics
- High-Voltage
- Power Systems
- Energy Economics
- Fundamentals of Electrical Engineering

MECHATRONICS AND AUTONOMOUS SYSTEMS CENTRE

Head of the research group: Professor MART TAMRE, mart.tamre@ttu.ee

The research is focused on control of smart machines, smart sensing systems and robotic systems for production and service automation. Activity is concentrated on proactive industrial hardware systems and on smart control capable of working in networked systems.

The new technology focus is the improvement of autonomous driving and especially complicated maneuvering capabilities of future cars and optimization of hybrid drive assemblies and their components to reduce energy consumption. The other focus in this direction is optimization of energy consumption for advanced hybrid drives using optimized control algorithms. The technology is combined with multimodal interfaces to provide multiple sensory channels and enhance the controller and operator performance symbiosis.

IN 2016

Proactive system behavior has been investigated on the example of several different sensing principles focusing on the machine vision and AI applications for the new smart vision applications for industrial control and healthcare. 3D visualization, visual perception and virtual reality approaches for smart machines and technology applications have been investigated. One focus has been methodologies for waste materials detection and respective applications to develop high efficiency new waste sorting technologies for paper, plastic and construction waste materials. Different electromagnetic and light spectra have been used, incl. IR and UV, and new hyperspectral technologies were implemented for materials detection. In parallel, reconfigurable robot control and smart algorithms have been investigated and new solutions were proposed both for industrial applications (especially human-machine high effective interaction and control) and for unmanned autonomous control of vehicular systems for open air terrain and indoor industrial applications.
Another focus was on the research of multibody system dynamics, behavior diagnostics and monitoring targeted on modelling and optimization of dynamic systems, the dynamic performance characteristics of both machines (vehicles and technology machines) and human body using model based approach.

The new modelling and control strategy for HEV (hybrid electric vehicle) using MPC (model predictive control) has been developed.

SELECTED PUBLICATIONS


MICROGRIDS AND METROLOGY

Head of the research group: Senior Research Scientist ARGO ROSIN, argo.rosin@ttu.ee

Studies of the research group are focused on (1) electricity supply of enterprises, buildings and home users, incl. electricity efficiency, power quality, reliability; (2) demand side management and energy flow research in networks with alternative energy sources and energy storages; (3) research of electrical lighting and (4) metrology and measurement science.

IN 2016

- Demand side management possibilities and viability for voltage support services in Estonia were studied.
- Design of new control methods was carried out in the framework of the research grant „New Converter Topologies and Control Methods for Electronic Power Distribution Networks“.
- Innovative technological solutions were studied for solving the voltage problems in low voltage grid; the situation with LV fiders tripping in distribution grid was analysed and new measures for improving safety level were developed.
- The power flows in zero energy and resource efficient smart buildings and districts were analysed.
- The measurement methods with 3D Coordinate Measuring Machine were studied; improvement of characterization set-up for detector performance.
- Electro-optical parameters of Silicon were investigated and the quantum gain for high-accuracy measurements of visible light was simulated.

SELECTED PUBLICATIONS


ELECTRICAL MACHINES

Head of the research group: Senior Research Scientist ANTS KALLASTE, ants.kallaste@ttu.ee

The research group is mainly involved in analysis, design, testing, and development of electrical machines, including wind generators. In addition, the research group deals with electrical machine diagnostics,
developing of permanent magnet materials for the use in electrical machines, novel methodologies for design and optimization of electrical machines and drives.

The group is actively involved in wind generator research, including developing, testing and designing of the generators, which supports the development and wider use of environmentally friendly energy sources.

MAIN RESEARCH RESULTS IN 2016:

An international patent was issued on 15th July 2016 for the invention “Permanent Magnet Assisted Synchronous Reluctance Motor” (Owner: Tallinn University of Technology. Authors related to the research group: Anouar Belahcen, Ants Kallaste, and Toomas Vaimann. Priority number: P201400013).

A possibility of using mobile phones for preliminary condition monitoring of electrical machines was proven.

SELECTED PUBLICATIONS


POWER ELECTRONICS

Head of the research group: Lead Research Scientist DMITRI VINNIKOV, dmitri.vinnikov@ttu.ee

Research in the group is focused on the development and experimental validation of new state of the art power electronic converters for such demanding applications as renewable energy systems, rolling stock, automotive and telecom. The key research directions include synthesis of new converter topologies, development of special control and protection algorithms, implementation of new components and elaboration of design guidelines to further improve the efficiency, power density, reliability and flexibility of the on-market power electronic converters. Other research activities are concentrated on the development of power flow control algorithms and new supervision, fault detection, protection and communication methods for the electronic power distribution grids (Micro- and SmartGrids).

The Power Electronics Group of TTÜ is one of the pioneers of the latest advances in the topic of impedance-source converters (ISC), especially, in the field of impedance-source (IS) galvanically isolated DC-DC converters for renewable energy applications.

IN 2016

The research group has proposed and experimentally validated many novel IS DC-DC converter topologies such as a single-switch IS galvanically isolated step-up DC-DC converter, a multi-mode quasi-Z-source series resonant DC-DC converter, a high-performance quasi-Z-source DC-DC converter with reconfigurable buck-boost switching stage and topology-morphing control, etc. The group members have also significantly contributed to the development of the multilevel IS inverters. The novel topology of the three-level neutral point clamped quasi-Z-source inverter (3L-NPC-qZSI) with advanced boost modulation technique was proposed and experimentally validated. This topology was experimentally proven in photovoltaic applications, where it demonstrated excellent input voltage and load regulation capability, continuous input current and enhanced output voltage quality. The multilevel IS inverters family was further extended by two novel topologies proposed by the group members: a multilevel quasi-Z-source inverter with reduced switch count and a multilevel T-source inverter.

The Power Electronics Group is also actively involved in the R&D activities of the European Spallation Source (ESS), which is a joint project involving 17 European countries, aimed to build and operate a next-generation research infrastructure for using neutrons to conduct research on materials. The ESS will be the world’s most powerful neutron radiation source, more than 100 times greater than other similar sources.

Outstanding results were obtained in cooperation with Estonian companies 4Energia, Ubik Solutions and MyWind that have implemented the obtained scientific and practical results in their innovative products.
For example, in cooperation with Ubik Solutions the group members have developed and brought to market the revolutionary power conversion technology for residential and small-to-medium commercial photovoltaic installations, called OPTIVERTER®. OPTIVERTER® is a hybrid technology that for the first time merges the key features of recently popular PV power optimizers and PV microinverters such as shade-tolerant maximum power point tracking (MPPT), galvanic isolation, direct AC grid connectivity, monitoring of energy production and state of health of a PV module, safety cut-off as well as low cost of installation and flexible scaling up of a PV power system.

SELECTED PUBLICATIONS


HIGH-VOLTAGE

Head of the research group: Senior Research Scientist PAUL TAKLAJA, paul.taklaja@ttu.ee

The research is focused on the studies of the high voltage insulation and applications associated with high voltages and strong electrical fields. Most of the research is related to the insulators and insulation used in power lines, both overhead and cable lines are studied. Another scope of research is the effects on high voltage equipment (transformers, cable power lines etc.) caused by high loading, nonlinear loads and power quality. Influence of power quality and dynamic power loading on the equipment, increased thermal and mechanical stress and aging are investigated. The research aims to provide indexes of reliability, considering different stresses to the power transmission networks during their lifetime, taking into account air pollution, weather, wildlife but also influences of characteristics of the future electric loads, materials etc.

IN 2016

• The patterns of renewable energy generation, specifically photovoltaic and wind, were studied. The thermal performance of different types of power cable joints was studied and differences in temperature of power cable layers were determined.

• Different types of covered medium voltage overhead line conductors were studied. The conductors were ranked by their performance in the following categories: insulation puncture durability, frictional durability of insulating layer and insulating layer slippage.

• The levels of partial discharges were measured in various medium voltage power cables of the distribution grid. The results showed that PD activity is present in some cables.

• The physical properties of Soviet era conductors were studied. Values of several key mechanical, thermal and electrical parameters were determined. A methodology for determining the values of conductor absorptivity and emissivity was created.

• Preparations for grid code for 20kV overhead lines were made. An overview of related standards was prepared with an aim to investigate the requirements for exceptions and numerical limitations and norms. The proposal for Estonian standard was drafted.

• Analysis of the relationship between the defects and failures in distribution grid was carried out. Defects were sorted and it was indicated how and over what time certain defects turn into fault.

SELECTED PUBLICATIONS


POWER SYSTEMS

**Head of the research group:** Associate Professor JAKO KILTER, jako.kilter@ttu.ee

Research activities in the group are focused on the development of control and protection algorithms and applications, and performing system analysis considering the challenges in modern and future power systems. The key research areas are focused on real-time control and analysis of power systems based on wide-area information with respect to HVDC and FACTS control, wind power connections, power quality and load modelling. The emphasis is on modern power systems where the level of generation through converters is increasing and consequently the level of system inertia is decreasing. This brings new challenges to the system control, relay protection, and system stability assessment. Other research activities are concentrated on the development and assessment of power quality mitigation methods in transmission and distribution systems considering the availability of modern compensation devices and wide-area information.

IN 2016

The following studies were carried out:

- Analysis of the influence of Rail Baltic high speed train connection to Estonian power system operation was analysed and development of technical scope for connection of this type of customer to power system.
- Development of mathematical models for high voltage cable networks and composing assessment methodology for considering cables for network studies in load flow and dynamic studies.
- Development of new methods and applications for the use of wide-area measurements for power system analysis and control.
- Development of ENTSO-E and Estonian Grid Code requirements and performing corresponding studies.
- Development of transmission network bus load aggregation principles and composing corresponding load models for steady state and dynamic calculations and assessment of the Estonian power system.

The research group also participates in the Horizon 2020 project MIGRATE where its main research activities are related to power quality and wide area applications. In addition, research group is active in different ENTSO-E and CIGRE working groups, where main emphasis is on grid code development, HVDC and system performance aspects.

SELECTED PUBLICATIONS


ENERGY ECONOMICS

**Head of the research group:** Professor JUHAN VALTIN, juhan.valtin@ttu.ee

The main tasks of the research group are power plant and power system optimization, modelling of the electricity market, economic and technical analysis of energy systems, assessment of energy sector development scenarios, analysis of activities needed for their realization, compilation of energy policy. The
research in the group is carried out by using various modelling software, such as the electricity market model Balmorel, the energy system model LEAP EneryPro supported by self-developed programmes for power plant optimization. The members of the research group have ample experience in both modelling and model development. They have also been actively involved in the development of Estonian long term energy strategy and have carried out different contracts to several industrial partners in Estonia.

IN 2016
Research cooperation conducted with Kaunas University of Technology and Lithuanian TSO Litgrid. A specialized dataset was constructed in Balmorel in order to evaluate the profitability of a second power connection between Lithuania and Poland. The project was successfully finished in 2016.

Strong cooperation in the field of energy systems and electricity market modelling was initiated with Technical University of Denmark (DTU).

SELECTED PUBLICATIONS

FUNDAMENTALS OF ELECTRICAL ENGINEERING

Head of the research group: Professor LAURI KUTT, lauri.kutt@ttu.ee

The main activities of the research group are the studies of electric power supply quality, electromagnetic compatibility (EMC) and thermoelectric applications.

The research group operates the EMC laboratory, which is a unique laboratory in Estonia, providing the opportunity to carry out EU directive compatibility testing.

IN 2016

• In the field of electric power quality, scientific activity was carried out in the topics of voltage quality, voltage dips and voltage waveform distortions of distribution networks.

• In the field of electromagnetic compatibility, scientific activities were connected with investigations on the voltage distortions in distribution networks caused by nonlinear loads.

• In the field of thermoelectric applications, the focus was on the development of solar concentrated systems for energy harvesting.

With technical co-sponsorship of IEEE the international conference “2016 Electric Power Quality and Supply Reliability” was held successfully. The conference brought together specialists and scientists from 20 different countries.

SELECTED PUBLICATIONS
DEPARTMENT OF ENERGY TECHNOLOGY

Director: Professor ANDRES SIIRDE, andres.siirde@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)
- Academic staff, total 24
  - Incl. 3 professors, 13 researchers
- Doctoral students, total 13
- Scientific publications, total 22

The Department conducts research within 4 research groups:
- Combustion Processes
- Smart District Heating Systems and Integrated Assessment Analysis of Greenhouse Gases Emissions
- Fuel and Air Analysis (Stationary Sources of Air Emissions) and Thermal Testing
- Chemical Engineering

COMBUSTION PROCESSES

Head of the research group: Lead Research Scientist TÕNU PIHU, tonu.pihu@ttu.ee

The research is focused on investigation of new opportunities for efficient and environmentally friendly utilisation of oil shale and other local fuels. The topics involve the following basic and applied research: (1) environmentally and economically competitive new technologies of low grade fuel based energy production – Clean Estonian Oil Shale; (2) safety, reliability and environmental problems of local fuels fired power units; (3) combined utilization (gasification) of oil shale and biomass for energy production.

IN 2016

The research group has been engaged in the following research topics:
- Investigation of the oil shale combustion processes in oxygen rich environment. Several laboratory combustion tests were carried out.
- Investigation of new opportunities for oil shale and other local fuels efficient and environment friendly utilization.

To ensure Estonian electricity and oil production reliability and reduction of environmental footprint, the relevant co-combustion tests (oil shale and biomass, oil shale and coal) were performed at large power production units. The organic and inorganic carbon content and fine ash particles content in the fly ash were analyzed. The positive impact on emissions was proven.

SELECTED PUBLICATIONS:


SMART DISTRICT HEATING SYSTEMS AND INTEGRATED ASSESSMENT ANALYSIS OF GREENHOUSE GASES EMISSIONS

Head of the research group: Professor ANDRES SIIRDE, andres.siirde@ttu.ee

The studies of the research group were focused on two main directions: (1) developing new technical solutions for the transition of district heating (DH) systems towards an intelligent, highly efficient and regenerative energy supply concept; (2) integrated assessment analysis of greenhouse gases emissions. Modern DH reduces energy consumptions and CO₂ emissions. Transition measures and technical solutions for DH systems are researched for enhancing its energy efficiency. Therefore, processes characterising DH systems were analysed and optimised, taking into account relevant operational boundary conditions and legal frameworks. By optimising the heat generation, distribution and consumption within DH systems the primary energy use has been improved.

IN 2016

The research group has analysed district heating and environmental impacts related topics. Research results have appeared in the following publications.

SELECTED PUBLICATIONS:


FUEL AND AIR ANALYSIS (STATIONARY SOURCES OF AIR EMISSIONS) AND THERMAL TESTING

Head of the research group: Associate Professor ALAR KONIST, alar.konist@ttu.ee

The accredited laboratory group provides accredited sample analyses for various customers. In addition the group is engaged in a more precise characterization of fly ash, in order to enable more effective use of ash that is formed under oxyfuel combustion conditions. The “organic and inorganic” (carbon) portion of ash is a key to success in many new utilization schemes.

IN 2016

A broad-based scientific investigation of sorptive properties and behavior of the inorganic and organic material in ash samples was carried out in order to help identify new commercial opportunities. Modern infrastructure has been applied: 60 kW CFB test facility, TGA/DSC-MS, LA-ICP-MS, WD-XRF, Gas Adsorption Analyser (chemi- and physisorption with micro- and mesopore), Elemental Analyzer (CHNS and O), etc.

SELECTED PUBLICATIONS:


CHEMICAL ENGINEERING

Head of the research group: Professor VAHUR OJA, vahur.oja@ttu.ee

In 2016 the research team has been actively engaged in the following research areas: (1) thermodynamic and transport properties of oxygenated pure compounds; and thermodynamic and transport properties of complex mixtures; (2) oil shale pyrolysis.

In the first sub-field, the activities were directed towards measuring thermodynamic properties of oxygenated organic compounds and narrow boiling range Kukersite oil shale oil fractions. Based on these data, the possibility of developing empirical thermodynamic property estimation techniques based on bulk properties and FTIR spectra was investigated. In the second sub-field pyrolysis of oil shales under various pyrolysis conditions was investigated.
IN 2016

In the first sub-field the research resulted in new experimental data on various thermodynamic properties of oxygenated organic compounds and oils. The data can be used in chemical engineering process design and environmental risk assessment.

In the second sub-field pyrolysis of oil shales under various pyrolysis conditions was investigated as an input to be used further in advanced pyrolysis models.

SELECTED PUBLICATIONS:


DEPARTMENT OF MATERIALS AND ENVIRONMENTAL TECHNOLOGY

Director: Lead Research Scientist MALLE KRUNKS, malle.krunks@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)
- Academic staff, total 55
  - Incl. 5 professors, 44 researchers
- Doctoral students, total 35
- Scientific publications in 2016, total 74
- Defended doctoral dissertations in 2016, total 6

The Department conducts research within 7 research groups:
- Thin Film Chemical technologies
- Inorganic Materials
- Environmental Technology
- Semiconductor Materials Technology
- Polymers and Textile Technology
- Biofunctional Materials
- Wood Technology

RESEARCH GROUPS

THIN FILM CHEMICAL TECHNOLOGIES

Head of the research group: Lead Research Scientist MALLE KRUNKS, malle.krunks@ttu.ee

The main research topics are investigation of thin films and nanomaterials for the: (1) development of a new generation solar cells, electronic devices and sensors, (2) environmental protection purposes. An important goal of the research is to simplify processes, achieve lower production costs, and to develop appropriate technologies to transfer the process to automated mass production.

IN 2016

The formation of Sb$_2$S$_3$ layer by chemical spray pyrolysis method in air was studied. Based on this research, the technological conditions, enabling deposition of single phase Sb$_2$S$_3$ layer, were determined. The capability to apply sprayed Sb$_2$S$_3$ layer as an absorber layer in hybrid solar cells was proved experimentally. Further studies are focused on application of Sb$_2$S$_3$ absorber layer in eta solar cells.

The formation of SnS absorber layer was studied by the chemical spray pyrolysis method using aqueous solutions containing L-cysteine as a novel sulphur source instead of commonly used thiourea. Use of L-cysteine as sulphur source allows using of less acidic aqueous spray solutions. It was found that SnS films deposited from solution containing L-cysteine as sulphur-source indicate phase composition and structure similar to SnS films deposited from thiourea as sulphur source. However, SnS films sprayed from L-cysteine solution contain higher amount of organic residues, indicating that higher deposition temperatures are necessary to remove organic residues from the film. Studies on effect of post-deposition thermal treatments on properties of SnS thin films are in progress.

The effects of the multi-step post-deposition thermal treatments on the structural, optical and electrical properties of CdS and CdTe thin films and out-put characteristics of CdS/CdTe solar cells have been
elicited. Based on this research the physicochemical mechanism of thermal treatments and chlorine doping in CdTe films was proposed.

The effect of Zr doping on the properties of TiO₂ films deposited by chemical spray pyrolysis was studied. It was found that, Zr- doping stabilised the anatase phase, decreased 6 times the rms roughness and increased 4 times the dielectric constant of the film compared to undoped TiO₂. The studies showed that the chemical spray pyrolysis method is suitable for fabrication of dielectric films, which are applicable in thin film electronic devises, for example in TFT devices.

The studies on wetting and photocatalytic properties of ZnO nanostructures obtained by different methods are in progress. It has been proved that Au nanoparticles made by CSP method are effective to cause plasmon resonance effect in ALD-TiO₂ films.

SELECTED PUBLICATIONS


INORGANIC MATERIALS

Head of the research group: Professor ANDRES TRIKKEL, andres.trikkel@ttu.ee

The research is focused on waste management, mainly, in oil shale industry – to reuse oil shale ash and diminish GHG emissions with the aim to clarify chemical-technological fundamentals of the processes in the complex mineral-organic aqueous or gas – solid systems. Research directions are focused on the development of filling and curing materials, using ash as phosphorus sorbent together with extended chemistry of apatites, oil shale or semicoke oxy-combustion and other thermal processes, enabling feasible, environmentally sound, optimized applications using experimental research together with mathematical modelling, and generalization of the novel know-how obtained.

IN 2016

A method for simulating the leaching streams from ash fields and leaching behaviour of various types of oil shale residue was developed to design a leaching reactor for getting precipitated calcium carbonate. Possibilities of producing light-weight aggregates from local industrial residues together with CO₂ abatement were clarified. It was shown that the processes taking place in the L-Ser or L-O-Pser solution at apatite depend strongly on the solution pH and respective amino acid ionic states. The release relative of Cu(2+) ions from Cu substituted apatite in both AA solutions, the formation of respective complexes and the effect of Cu substitution level on L-Ser and L-O-Pser adsorption was clarified. Oxyc-combustion studies of oil shale were continued. Equilibrium composition and flows of gaseous and solid products were described by modelling, widening the list of possible solid phase reactions. Heat duties were calculated for different process regimes (dry and wet circulation). The process of CO₂ binding by dolomite samples was studied in Ca-looping and process modelling was started. It was proven that different oil shale ashes can be granulated and required process parameters were determined in order to regulate the leachability of ash components in soils, to extend and optimize their neutralizing impact, to benefit granulated products with different plant nutrients and to diminish probable contamination of subsoil water and water-bodies.

SELECTED PUBLICATIONS


ENVIRONMENTAL TECHNOLOGY

Head of the research group: Professor MARINA TRAPIIDO, marina.trapido@ttu.ee

The research is directed to extend advanced oxidation technologies application to environment protection from priority pollutants and emerging micropollutants.

IN 2016

The degradation of chlorophene was studied in ultrasound – hydrogen peroxide integrated oxidation system and the mechanism of degradation was proposed. The combined system including photocatalytic oxidation and the following aerobic biological treatment was studied. The operation conditions of a multi-section plug-flow photocatalytic reactor were optimized. The study on the photocatalytic performance of ZnO-based thin films in the oxidation of antibiotics in a small lab-scale reactor equipped with UV-LED was continued. A study on the degradation of artificial sweeteners in different matrices by UVA-radiation activated systems was carried out. The degradation of β-lactam antibiotic amoxicillin by photo-activated H₂O₂ and S₂O₈²⁻ systems in different water matrices (ultrapure water, potable water, groundwater, surface water) was studied. The outcome of the research will provide the scientific basis and recommendations for AOPs implementation for micropollutants control.

The most important results:
- Process integration by the joint application of ultrasound and hydrogen peroxide was found to be an effective option for degradation of micropollutants.
- Specific process conditions accelerating the restoration of photocatalytic activity of the catalyst in case of its deactivation were found.
- Photo-activated persulfate system proved effective for beta-lactam antibiotic degradation in different natural and industrial water matrices.

SELECTED PUBLICATIONS


SEMICONDUCTOR MATERIALS TECHNOLOGY

Head of the research group: Senior Research Scientist MAARJA GROSSBERG, maarja.grossberg@ttu.ee

The aim of the research is the development of low-cost absorber materials and technologies for photovoltaics. The fundamental research is addressed to kesterite-type absorber materials as well as to the development of monograin layer (MGL) and thin film solar cells based on these absorbers. The main research topics include: (1) studies of the influence of growth mechanisms, different thermal and chemical treatments (temperature, environment) on the composition and optoelectronic properties of the kesterite monograin powders and on the corresponding monograin layer solar cell (MGL) performance; (2) development of Al₂O₃ intermediate layers by ALD/PLD methods for kesterite and chalcopyrite MGL solar cells; (3) studies of the influence of the crystal structure ordering in stannite type Cu₂CdSnS₄ on its optoelectronic properties; (4) studies of the possible use of MGL solar cells under environmental conditions of the Moon; (5) studies of optoelectronic properties of 2D materials (WS₂, MoSe₂).

IN 2016
- We were the first to show experimentally the presence of Cu/Cd disordering in the crystal structure of Cu₂CdSnS₄ absorber material for solar cells. We determined the influence of the degree of disordering on the optoelectronic properties of Cu₂CdSnS₄ and found change in the radiative recombination mechanism.
• In close co-operation with different universities we started a new study of MoSe₂ monolayers grown by chemical vapour deposition method on Si/SiO₂ substrate at Rice University, USA. It was shown that MoSe₂ monolayers are not stable in time as previously considered and aging induces local tensile strain in the monolayer that causes exciton localization. A novel theoretical model was used to describe such behaviour of localized excitons in monolayers.

• We studied the influence of the H₂SeO₃ micro-additive on the properties and electrochemical synthesis of the CdS thin films. It was found that the presence of 0.05–0.5 mM of H₂SeO₃ in the electrolyte changes the mechanism of the CdS film formation that facilitates nucleation and a growth of a more dense and uniform polycrystalline CdS film with more stable hexagonal structure. As a result of H₂SeO₃ addition the bandgap energy value of CdS was increased from 2.3 eV to 2.5 eV.

SELECTED PUBLICATIONS


POLYMERS AND TEXTILE TECHNOLOGY

Head of the research group: Professor ANDRES KRUMME, andres.krumme@ttu.ee

Novel nanostructured fibres, yarns and fibrous composites prepared by electrospinning are investigated during fundamental studies of the research team. Conductive polymers, carbon allotropes, ionic liquids or their polymerisation products are used as fillers for the matrix polymer in the nanofibrous composites. Several aspects of use of ionic liquids in this field are studied: new polymerization routes of ionic liquids, effect of ionic liquids on shape/morphology/ conductivity of the fibres and finally, specific behaviour and applications of the new (composite) nanofibers. Conductive polymers are added for improving conductivity and carbon allotropes for improving capacitance of the nanofibers. The study will find the common denominator of these aspects in order to open the route for preparing very attractive fibrous materials for several high-technological fields by electrospinning.

Activities of the research team have high social impact. It is planned to commercialise the new nanofibrous materials in the field of capacitors in the next few years. New, electrospun supercapacitors (see ref. 3) for high frequency applications and for harsh conditions, such as space, are developed in cooperation with Skeleton Technologies OÜ. The main goal of applied study of the research team is utilisation of waste of oil-shale industry in composites with plastic waste for replacing calcium carbonate in such composites. This concept is supported both by oil-shale and plastic industry.

IN 2016

New possibilities were found and explained for using ionic liquids as assisting substance in electrospinning. Usage of carbon rich nanofibres in supercondensators without carbonisation was proved. Production methodology of such fibres was developed and build-up of new type of capacitors explained. Oil-shale oil production residues and primary or secondary polyolefine residues based composite was developed. The mentioned oil production residues in these composites replace traditionally used calcium carbonate.

Results were published, which describe modification and recycling of polyamide waste to 3D printing filaments having novel properties.

SELECTED PUBLICATIONS

BIOFUNCTIONAL MATERIALS

Head of the research group: Senior Research Scientist VITALI SÖRITSKI, vitali.soritski@ttu.ee

The group develops smart biosensing functional materials to propose solutions with considerable potential impact on essential areas of human life such as environmental protection, medical diagnostics and cure. By employing the molecular imprinting technology the group designs and synthesizes polymeric materials capable of selective capturing and detection of small- (amino acid, traces of different antibiotics) and biomacromolecules, such as proteins (e.g. antibodies and neurotrophic factors). The main benefits of these materials, the so-called Molecularly Imprinted Polymers (MIP), are related to their synthetic nature, i.e., excellent chemical and thermal stability associated with reproducible, cost-effective fabrication.

MIPs can be easily integrated with a variety of sensor platforms allowing label-free detection of a target analyte with high sensitivity and selectivity offering thus solutions for design of multi-analyte chemosensors at low cost. The promising practical applications of such sensors could be found in clinical diagnostics, where MIP-based sensors could be implemented in devices for point-of-care testing (POCT). It is expected that POCT market segment will continue to grow at a rapid rate and thus will have immense importance in the healthcare systems both in Estonia and the worldwide. MIPs could be also attractive materials for cost effective fabrication of chemosensors for real-time analysis of hazardous pollutants in aquatic environment as an alternative for traditional costly and lengthy chromatography-based methods.

IN 2016

A method for the synthesis of a MIP film capable of selectively rebinding protein-sized biomolecules was developed. The method is compatible with various label-free techniques, providing facile, robust and real-time detection of immunoglobulins. This is a significant progress beyond state of the art and makes the realized concept potentially suitable for cost-effective fabrication of protein-specific biosensors for express testing in medical diagnostics.

A computational approach was developed allowing rational selection of an optimal functional monomer for building a MIP capable of selectively rebinding macromolecular analytes. The respective results have been accepted as a publication in ‘Journal of Molecular Recognition’.

We have developed a novel method allowing preparation of a MIP for selective recognition of neurotrophic factor protein, cerebral dopamine neurotrophic factor. Implementation of this method can be a prospective platform for building novel MIP-based diagnostic tools for neurodegenerative diseases, where presymptomatic diagnostics does not exist.

SELECTED PUBLICATIONS


WOOD TECHNOLOGY

Head of the research group: Professor JAAN KERS, jaankers@ttu.ee

The aim of the study was to separate the influence of soaking temperature and peeling temperature on the physical properties of rotary-cut birch (Betula pendula Roth) veneer surface and bonding quality. Surface roughness measurements, scanning electron microscopy (SEM), surface integrity testing, color measurements, and wood-adhesive bond testing were conducted with an automated bonding evaluation system.

IN 2016

The effect of chemical modification of fine wood flour (mesh size 0.05 mm) from heat-treated grey alder (Alnus incana) with sodium hydroxide (NaOH) and 3-aminopropyltriethoxysilane (APTES) on the mechanical and physical properties of wood polymer composite (WPC) was investigated.
The impact of moisture content and temperature on crack formation in cross-laminated timber (CLT) panels was investigated.

The effects of fiber modification on the mechanical and physical properties of hemp fiber-mat reinforced polyethylene (PE) film composites were investigated.

Results:

- The study indicated that the used high temperature 70°C in birch (*Betula pendula* Roth) log soaking had positive effect on peeled veneer surface properties and bond strength.
- WPC mixtures from thermally treated wood showed greater impact strength values than untreated composite mixtures.
- In CLT panels stored in a humid and cold environment approximately twice wider cracks occurred compared to CLT panels stored in a dry environment.

**SELECTED PUBLICATIONS**


DEPARTMENT OF MECHANICAL AND INDUSTRIAL ENGINEERING

Acting Director: Associate Professor KRISTO KARJUST, kristo.karjust@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)
- Academic staff, total 67
  - Incl. 13 professors, 32 researchers
- Doctoral students, total 52
- Scientific publications in 2016, total 94
- Defended doctoral dissertations in 2016, total 8

The Department conducts research within 10 research groups:
- Smart Manufacturing and Materials Technologies Competence Centre
- Numerical Methods and Algorithms for Design of Advanced Composite and Nanostructures
- Zero Energy and Resource Efficient Smart Buildings and Districts
- Collaboration Enhancing Sustainable Conceptual Model Development and Implementation for the SME-s in Machinery Domain
- Logistics and Transportation
- Multi-scale Structured Ceramic-based Composites for Extreme Applications
- Thin Coatings/Films Deposition
- Innovative Polycrystalline Diamond (pdc) Drag Bit for Soft Ground Tunnel Boring Machines
- New Technologies for Tunnelling and Underground Works (NETTUN)
- Nanonet of Ceramic Fibers with Targeted Functionalities

RESEARCH GROUPS
SMART MANUFACTURING AND MATERIALS TECHNOLOGIES COMPETENCE CENTRE

Head of the Centre: Associate Professor KRISTO KARJUST, kristo.karjust@ttu.ee

With the growing complexity of production operations the scale and scope of the data to be monitored and controlled simultaneously increases. It requires the implementation of advanced automatic production monitoring systems. Quick and reliable automatic data collection and analysis from the shop floor is one of the applications that has been in focus for many production companies and research institutions. The research covers development of the concept and prototype of the wireless system for data collection and analysis in the workshop, focusing on small and medium sized production companies. The aim is to develop an affordable, effective and highly configurable system based on open-source technologies. Together with the proposed multi-level graphical user interface it will support producers to meet the set targets. The concept of a production monitoring system with predictive functionality was described and a prototype was made. As each production system has its own specifics with a huge variety of possible modifications, the production monitoring system should be flexible for modifications. The trends are: web-based architecture, re-configurability, near real time performance, open-hardware and software, predictive functionality, wireless connectivity, supported by cloud computing. Based on the system concept, the predictive modelling was performed.
IN 2016:
The production monitoring system concept with main modules and prediction functionality was presented. Based on the concept a modular and expandable wireless production monitoring system was built and tested to collect data for predictive modelling.

A two stage tool life expectancy model was developed based on derivation of a discrete analytical tool life prediction model and an artificial neural networks model for determining dependence of the main system parameters.

Experimental studies were conducted for investigation of mechanical properties of the laminated glass panel, residual stresses in the panel and FEM, wavelet based simulation models were developed.

SELECTED PUBLICATIONS:


NUMERICAL METHODS AND ALGORITHMS FOR DESIGN OF ADVANCED COMPOSITE AND NANOSTRUCTURES

Head of the research group: Lead Research Scientist JÜRI MAJAK, juri.majak@ttu.ee

The overall objective of the research is development of computationally cost effective and accurate numerical methods and optimization algorithms for design of advanced composite and nanostructures (multilayer graphene sheets, laminated nanoplates, variable ply angle laminates, multifunctional glass composite panel, FGM with anisotropic layers, etc.). One subobjective is to clarify the accuracy/convergence issues of the Haar wavelet discretization method (HWDM) which are still open and even contradictory. The applicants of the project have proved convergence theorem for HWDM in the case of n-th order ODE (2015, Composite Structures). These results are planned to expand to PDE-s, integro differential equations, also for particular cases. Another subobjective is to continue the development of hierarchical multicriteria optimization methods. Validation of proposed methods on real world applications is planned: multifunctional glass composite panels, smart materials (Radius Fixing OU, Goliath Wind OU).

THE MAIN RESULTS IN 2016:

• Comparison and analysis of numerical methods for structural analysis of functionally graded materials has been performed (FDM, DQM and HWM – Haar wavelet method). The strong formulation based methods with similar complexity of the implementation were selected and the evaluation criteria considered was the accuracy. In the case of FGM structures analyzed the HWM outperforms FDM. In the case of small number of collocation points the best accuracy has been achieved by applying DQM. However, utilization of DQM is complicated in the case of higher mesh (number of collocation points over 100).

• The convergence theorem has been proved for the Haar wavelet method in the case of first order ordinal differential equations, which is not covered by the general convergence theorem.

• The Haar wavelet method was adapted for analysis of nanobeams and the results were compared with other methods with similar complexity of implementation. The Eringen non-local elasticity theory was applied (this is the first or one of the first attempts to apply HWM for analysis of nanostructures).

• A new topic introduced is application of Haar wavelet method for analysis of fractional differential equations. In the case where the order of the fractional derivative \( \alpha \) belongs to interval \([0;1]\), the standard approach (widely used approach) yield the rate of convergence \( 1 + \alpha \). A new approach has been proposed, which allows improving the order of convergence to two. This result is initial and needs further theoretical analysis and numerical validation.

• Development of the fractional Kelvin-Voigt viscoelastic model for analysis of laminated glass structures and Haar wavelet method for numerical solution of the posed problem (commercial software for such a new model is not available yet).
SELECTED PUBLICATIONS:


ZERO ENERGY AND RESOURCE EFFICIENT SMART BUILDINGS AND DISTRICTS

Head of the research group: Senior Research Scientist MEELIS POHLAK, meelis.pohlak@ttu.ee

The research group conducts research in the framework of the Center of Excellence for zero energy and resource efficient smart buildings and districts (ZEBE). Research of the group is focused on resource efficient wooden structures and composites (WSC research group). The WSC research group aims to improve the resource efficiency through wider use of wooden materials by solving critical fire safety and manufacturing issues of wooden structures and composites being current barriers.

IN 2016:

The activities of the research group in ZEBE center started in September 2016 and are related mostly with literature overview, finding out suitable models, tools, etc. The planned activities started can be outlined as:

WP3 T1.1 Web based IS with responsive design (mobile devices support) 1–2 year. Data model development, information acquisition, analysis of development tools.

WP3 T2.1 FEM based structural analysis models 1–4 year. FEM simulation model development.

WP3 T2.2 Wavelet, etc. based structural analysis methods and models 1–5 year. Development of 2D wavelet method for solving boundary value problems covering wood laminates. Matlab based software treatment. Search for simple alternative solutions for evaluation of the solution.

SELECTED PUBLICATIONS:


COLLABORATION ENHANCING SUSTAINABLE CONCEPTUAL MODEL DEVELOPMENT AND IMPLEMENTATION FOR THE SME-s IN MACHINERY DOMAIN

Head of the research group: Associate Professor EDUARD ŠEVTSenko, eduard.sevtsenko@ttu.ee

The aim of current research is collaboration enhancing sustainable conceptual model development and implementation for the SME-s in machinery domain. The conceptual model: a) enables measurement of the project realization and Partner Network maturity levels and supports maturity improvement process; b) enables selection of reliable partners based on the Partner Efficiency Index at the offer preparation stage; c) supports the agreements elaboration process and Virtual Organisation formation.
on the management level; d) enables VO members to measure the KPI of the partners processes during the project implementation.

**IN 2016**

- the solution for SPN was developed: results have been validated and published. Created SPN prototype in ARIS software based on business processes of the following companies: Gunvor Services, Logistics Plus, Smarten Logistics, Mcro AS, Ensto Ensek AS, ABB, Norma, Electronics Enterprise X, Beverages production enterprise Y, Catalyst Baltic, Nefab Packaging, EVR Cargo AS, Haanpaa OU;
- specific mechanism for assessment of the condition of used industrial equipment has been elaborated;
- The risk groups were defined and a Risk Assessment Method for Partner Network of SMEs was proposed;
- a concept of performance evaluation of production equipment by OEE combined with Pareto Analysis was developed.
- a concept of performance analysis of a FMS through modelling and simulation (using Rockwell Arena software) was described.

**SELECTED PUBLICATIONS:**


**LOGISTICS AND TRANSPORTATION**

**Head of the research group:** Professor JUŘI LAVENTJEV, juri.lavrentjev@ttu.ee

Research activity of the team is concentrated on the following research fields:

- Environment-friendly transportation. The research goal is to decrease the transportation impact on the environment. More specifically, the main investigated problem is reducing the noise of vehicles and the traffic flow. Different new materials for noise attenuation have been developed and suggested for different applications in vehicles. Applied research deals with the application of new liquid fuels, its technical and economical aspects.

- Transport planning. The research field of transport planning is related to safe, smooth and sustainable mobility, urban logistics and the relations between transportation and spatial planning. In addition the keywords here are: sustainable mobility and transportation, including the public transport management in the city, regional, country wide and on an international scale, traffic forecasting, transportation surveys, mobility plans, analysis and planning of transport networks, road safety and enforcement.

- Logistics. Research activities in logistics are related with smart transport logistics, transport pricing and partner companies’ performance measurement.

- Supply chain management. Research activities are related with supply chain analysis of the value chain, supply chain collaboration, and sustainable supply chain areas of demand forecasting.

In 2016:

A new technical solution was developed for the so-called noise-damping element the acoustic properties of which are better than those of comparable design elements. The new measuring methodologies have been tentatively assigned to more noise (sound waves) attenuation in the flow channels of different physical conditions.

**SELECTED PUBLICATIONS:**

MULTI-SCALE STRUCTURED CERAMIC-BASED COMPOSITES FOR EXTREME APPLICATIONS

Head of the research group: Professor JAKOB KUBARSEPP, jakob.kubarsepp@ttu.ee

The research is carried out in the following directions:

1. Tribomaterials for a wide range of temperature
   - Research on corrosion resistant Ni- and Co-free cermets with FeCr-type binders based on TiC and WC.
   - Research on contact fatigue of carbide composites (WC-, TiC and Cr₃C₂-based).
   - Development of extremely high-hardness BCN-based composites.
   - Development of technology of Co-free WC-ZrO₂-Ni cermets.
   - Research on 3D printing technology or production of ceramic-metal composites.
   - Development of high-temperature wear resistant electrically conductive CuCr₅ alloys.
   - Development of equipment and methodology for tribotesting at high temperatures (up to 1000°C).

2. Multi-materials systems
   - Thick hard coatings:
     - Development of composite coatings strengthened by hardmetal reinforcement for different wear conditions.
     - Research on HVOF-composite coatings based on Ni- or Fe-alloys and reinforced by hardmetal or cermet (WC-Co, Cr₃C₂-Ni, TiC-NiMo).
     - Development of technology of PTA coatings strengthened by WC/W₂C or WC-Co.
   - Thin hard coatings:
     - Characterizing of nanocrystal diamond (NCD) coatings.
     - Development of technology of microcrystal diamond (MCD) coatings.
     - Development of technology of thin ceramic (AlCrN, TiAlN) coatings.

3. Hierarchically structured multifunctional composites
   - Functionalization of Al₂O₃ nano-fibers by ceramic (ZrO₂, Al₂O₃) coatings using CLD and ALD approach.
   - Development of electro conductive ceramic – based composites by incorporation of the conductive (graphenated fibers) fillers.
   - Development of hierarchically structured ceramic-matrix composites based on alumina (Al₂O₃) and zirconia (ZrO₂).
   - Development of SiO₂-based ceramic materials with reinforcement additives.
   - Research on ultra-high temperature ZrC-based composites (Zr-Mo, TiC-ZrC etc.).

IN 2016

The most important results:
- Achievements in development of Ni- and Co-free TiC-FeCr-type cermets in collaboration with the industrial partner The Swatch Group Research and Development Ltd.
- Achievements in utilization of 3D-printing technology in production of wear resistant ceramic-based composites.
• Development of advanced technologies for production of thick coatings by powder metallurgy, HVOF and PTA methods.

• A novel approach to prepare the electroconductive ceramic-based composites by incorporation of conductive fillers has demonstrated high electrical conductivity of material at extremely low content of graphenated additives (0.3 %).

SELECTED PUBLICATIONS:


THIN COATINGS/FILMS DEPOSITION

Head of the research group: Senior Research Scientist VITALI PODGURSKI, vitali.podgurski@ttu.ee

The studies of the research group are related to two main topics:

1. Adaptation mechanisms of diamond films in dry sliding wear. The aim is to improve the understanding of adaptation mechanisms, particularly, formation of ripple patterns on the wear scars surface and deflection of the diamond films observed during sliding. Both adaptation mechanisms are investigated under different sliding tests conditions and treated within the framework of the entropy concept of the friction.

2. Tribomaterials for a wide range of temperatures. The goal is development and characterization of ceramic matrix composites and cerments to enhance performance and reliability with focus on high temperature and corrosive media tribo-conditions. Deposition of diamond films on WC-Co substrates and testing of mechanical/tribological properties at high temperature.

IN 2016

It was shown that only CrN as a buffer layer possesses a good adhesion between WC-Co and diamond film as well. The diamond films properties were investigated, the morphology changes (rippling) within the wear scars and deflection of films were observed, which influence the tribological properties (wear rate).

Optimal technology for the production of TERS tips was developed further. The goal is to develop advanced type of TERS tips for mass production.

SELECTED PUBLICATIONS:


INNOVATIVE POLYCRYSTALLINE DIAMOND (PDC) DRAG BIT FOR SOFT GROUND TUNNEL BORING MACHINES

Head of the research group: Senior Research Scientist MAKSIM ANTONOV, maksim.antonov@ttu.ee

The research focuses on the production of bio-inspired materials. The animals living in abrasive conditions (deeply under the ground) are studied in cooperation with the Estonian University of Life Sciences. Three types of materials are proposed: (1) for cutting edge, (2) located away from cutting edge with
abrasive sliding only in one direction, and (3) located away from cutting edge but abrasive can slide in both directions. The hybrid structure of such materials is obtained by several technologies from several materials to get material similar to the skin of snake or the mole’s pelt.

In addition, the group conducts research on diamond-metal gradient material development to provide the improvement of toughness of conventional materials produced by brazing of diamond to the substrate. The combined wear-corrosion process important for tools working in wet underground conditions is also studied.

IN 2016

Three first prototypes of bio-inspired materials are produced and components were selected (the patent application is foreseen). The first paper about tribological testing of 3D printed structures was presented during NordTrib2016 conference and was selected for publication in the Journal of Engineering Tribology.

Seven different diamond powders were studied (different size of grains, different coating thickness, mono- or polycrystalline grains). More than 15 different materials (varied diamond powder, sintering technology and gradient structure) were produced. Materials were tested in impact-abrasive conditions and their performance is analysed (the patent is foreseen).

SELECTED PUBLICATIONS:

NEW TECHNOLOGIES FOR TUNNELLING AND UNDERGROUND WORKS (NETTUN)

Head of the research group: Professor RENNO VEINTHAL, renno.veinthal@ttu.ee

NeTTUN is a collaborative integrated FP7 R&D project, aiming at developing New Technologies for Tunnelling and Underground works. The research involves 21 partners (from universities, SME and large companies) from 9 European countries.

A work package (where TTÜ is involved) is dedicated to increase the lifetime of the drag bits used on Tunnel Boring Machines (TBM). The wear of such parts represents a significant cost and waste of production time because of the related maintenance operations, with associated personnel risks that NeTTUN aims at reducing.

IN 2016

To achieve the goal, different tasks have been combined related to:

• the analysis of damaged drag bits for the understanding of the phenomena that occur in the carbide inserts and body of the drag bits, in order to guide the development of materials that will overcome these phenomena;

• numerical modelling of the material flow around a drag bit and of the contact between the drag bit and the ground (by FEM and DEM), in order to optimize the geometric shape and arrangement of drag bits on the cutter head;

• the strategy of the development of new optimised materials with improved wear resistance, by working on mixing different hard phase types, improving the binder behaviour, using new sintering techniques in order to find ways to violate the law of nature concerning the relationships between hardness and toughness;

• the tribological testing of the newly developed materials, in comparison with existing materials, in order to understand the wear phenomena, to rank the materials, and to further improve the development of materials.

The final goal is to develop improved drag bits that would exhibit a lifetime extended by at least 20% over current drag bits.
New materials based on WC were produced and tested in the laboratory, to understand their tribological behaviour and compare their wear resistance in abrasion and in impact-abrasion to reference material. During this part of the project, the group was able to find a material with an improvement of performance of up to 50% in some conditions, compared to the reference material.

The field test of the advanced TBM drag bits will be conducted on the Metro-line construction at Thomson East Coast Line in Singapore with the overall length of 43 km.

An invention “Method of making a double-structured bimodal tungsten cemented carbide composite material” made by the research group resulted in PCT application. The co-ownership agreement was signed by three partners on commercialization of the invention.

SELECTED PUBLICATIONS:


NANONET OF CERAMIC FIBERS WITH TARGETED FUNCTIONALITIES

Head of the research group: Professor IRINA HUSSAINOVA, irina.hussainova@ttu.ee

The studies of the research group are focused on development, optimization and validation of a novel nanonet consisting of an assembly of nanoscaled self-aligned ceramic nanofibers. The nanonet allows consistent and integrated production of multi-material cross-level (from nano to macro) structures by utilizing functional properties advancement via engineered structural and compositional features and providing an added value to the nanonet to be embedded later in a variety of final products. Targeted functionalities are achieved by appropriate functionalization and/or attachment of nanoscale objects. The research concentrates on (i) development of a nanonet with targeted composition, geometry and entanglement; (ii) functionalization to satisfy specific needs; and (iii) potential applications of the nanonet. Two highly demanded market-oriented demonstrators will be produced: (1) highly conductive hierarchically structured ceramic composites, and (2) three-dimensional fibrous scaffolds and membranes.

IN 2016

The main distinguishing results of the research are:

1. The method for catalyst-free CVD functionalization by graphene, graphite or graphene/CNT was developed;
2. The method for chemical functionalization by wet-combustion was developed;
3. Novel approach to electroconductive ceramics filled by graphene covered nanofibers was developed;
4. Graphene encapsulated nanofibers as nanofillers for otherwise insulator materials were tested;
5. Applicability of the graphenated nanonets as scaffolds for bio-applications was proved.

Based on the results of the research, there are four (4) patents pending.

SELECTED PUBLICATIONS:


TARTU COLLEGE

**Acting Director:** Professor LEMBIT NEI, lembit.nei@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)

- Academic staff, total 28
  - Incl. 4 professors, 1 researcher
- Doctoral students, total 8
- Scientific publications in 2016, total 27
- Defended doctoral dissertations in 2016, total 1

The Department conducts research within 2 research groups:

- Environmental Technologies
- Built Environment

ENVIRONMENTAL TECHNOLOGIES

**Head of the research group:** Professor MARI IVASK, mari.ivask@ttu.ee

The main topics of the research group are focused on development of environmentally sustainable technologies, on development of the methods of environmental monitoring and on assessment of environmental quality.

The research group collaborates with other research groups of TTÜ in the areas of ecological building materials and monitoring of indoor air quality of ecological buildings (Built environment research group) and in application of cyber-physical systems in environmental monitoring (Research group of Cyber-physical Systems Engineering).

The research areas are topical in environmental protection and the results help to solve problems of sewage slurry, soil fertility, medicine and to improve the recultivation process in post-mining areas.

IN 2016:

- Afforestation of exhausted mining areas is more successful when different tree species that are well adapted to climatic conditions of region are used. The most effective method is drilling holes and filling them with nutrient-rich compost before planting the trees. Adding compost also has positive effect on decomposer communities.
- Pharmaceuticals entering into the soil may affect microbial activity, plant growth and development, and may have adverse effects on living organisms; development of composting technologies can improve the decomposition process of pharmaceuticals.
- New cytotoxicity tests have been performed on pure Co MNPs and have confirmed the toxicity against PPC-1 (cancer cells) and gastric cancer cells even at low concentrations.
- The CFU of microorganisms of indoor air was higher in reed houses and lower in straw bale houses, the genera of the identified fungi were Alternaria, Aspergillus, Penicillium and Cladosporium, most of these species can present a health risk for humans.

SELECTED PUBLICATIONS:

**BUILT ENVIRONMENT**

**Head of the research group:** Associate Professor AIMEUS aime.ruus@ttu.ee

The research areas the group is engaged in are: (1) built environment, urban and regional planning; (2) community development, economic revitalization, reuse and restoration, urban and rural settlement assessment; (3) heritage conservation in urban planning and historical landscapes and parks; (4) revitalization of brownfields; (5) history of wooden architecture; (6) examination of historical buildings; (7) exploring learning environments and their architectural design; (8) construction materials, aspects of building physics and energy efficiency; (9) cyber-physical systems for buildings and urban and regional planning.

In the framework of the research related to architecture, economy and engineering studies at the beginning of the 19th century in Estonia, the role of Johann Wilhelm Krause as establisher of professional library and professor of economy, technology, forestry and civil engineering was presented. Also, the Tartu cityscape and architecture at the end of the 18th century and the first half of the 19th century in the intellectual context of the European Enlightenment was figured out.

Studies of urban planning were continued, the problems of decreasing towns were studied. Development of two examples – Supilinn and Valga was compared.

Water vapour transmission properties of different linseed oil paints and influence of covering on clay and lime plaster was studied. The information gathered from the experiment enables to get an overview of the different properties of ‘the same product’ and use the data in hygrothermal calculations. The thickness of paint layers varied from 0.8 and 6.2 μm for one-layer primers, from 11.3 to 26.9 μm for one-layer paints and from 17.8 to 40.7 μm for two-layer paints. Water vapour diffusion equivalent air layer thickness $S_d$ was estimated as 0.1 and 0.2 m for 1-layer primers, 0.2 to 0.9 m for 1-layer paints and 0.4 to 0.9 m for 2-layer paints.

The main task in geotechnical studies based on buildings in Estonia, was collecting information on different buildings, foundations, and geotechnical investigations. Exhaustive information for buildings has been collected.

In cooperation with the Research Group of Environmental Studies indoor climate and microbiological studies were carried out. Mean colony forming unit (CFU) values indoors were greater in reed houses. There was also seasonal difference. Mean values were the highest during summer months and the lowest in winter. In spring and autumn the values were in same range. The genera of the identified fungi were Alternaria, Aspergillus, Penicillium and Cladosporium. Most of these species can present a health risk for humans, especially for those with allergies, asthma and weakened immune systems.

**SELECTED PUBLICATIONS:**


VIRUMAA COLLEGE

Director: VIKTOR ANDREJEV, viktor.andrejev@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)
- Academic staff, total 34
  - Incl. 3 researchers
- Scientific publications in 2016, total 14
- Defended doctoral dissertations in 2016, total 2

The Department conducts research within the Oil Shale Competence Center in the field of environmental technologies.

OIL SHALE COMPETENCE CENTER

Head of the center: KALLE PIRK, kalle.pirk@ttu.ee

The Oil Shale Competence Center (OSCC) is focused on applied research in the field of fuels chemistry and technology (in particular oil shale) in order to execute orders for determining the technological properties of different oil shales. The aim of the studies is research of mineral deposits properties and control of technological processes. In addition, the oil shale ash properties are determined and research of possibilities of pyrolysis of various materials is carried out on the basis of corresponding single orders.

IN 2016

Two studies have been started:
- Research of chemical composition of products produced in current oil shale thermal processing processes (in particular solid heat-carrier use).
- Co-processing of oil shale and other organic materials and research of the properties of the produced products.
Photo: New chip developed by TTU researchers.
Author Professor Jaan Raik
SCHOOL OF INFORMATION TECHNOLOGIES

Dean: Professor GERT JERVAN
e-mail: gert.jervan@ttu.ee

Vice-Dean for Research: Professor MAARJA KRUUSMAA
e-mail: maarja.kruusmaa@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)

- Academic staff, total 214
  - Incl. 33 professors, 106 researchers
- Doctoral students, total 137
- Scientific publications, total 240
- Defended doctoral dissertations in 2016, total 14

DEPARTMENTS

DEPARTMENT OF COMPUTER SYSTEMS
Director: Associate Professor MARGUS KRUUS, margus.kruus@ttu.ee

DEPARTMENT OF SOFTWARE SCIENCE
Director: JAAN PENJAM, jaan.penjam@ttu.ee

DEPARTMENT OF HEALTH TECHNOLOGIES
Director: Professor KALJU MEIGAS, kalju@cb.ttu.ee

THOMAS JOHANN SEEBECK DEPARTMENT OF ELECTRONICS
Director: Professor TOOMAS RANG, toomas.rang@ttu.ee

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![Graph showing the distribution of academic staff roles: Professors, Associated Professors, Teaching Assistants, Lecturers / Instructors, Lead Research Scientists, Senior Research Scientists, Research Scientists, Early Stage Researchers.]

- Professors: 30
- Associated Professors: 33
- Teaching Assistants: 29
- Lecturers / Instructors: 32
- Lead Research Scientists: 13
- Senior Research Scientists: 29
- Research Scientists: 44
- Early Stage Researchers: 3

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DEPARTMENT OF COMPUTER SYSTEMS

Director: Associate Professor MARGUS KRUUS, margus.kruus@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)

- Academic staff, total 56
  - Incl. 7 professors, 29 researchers
- Doctoral students, total 29
- Scientific publications, total 76
- Defended doctoral dissertations in 2016, total 5

The Department conducts research within 3 research centres:

- Centre of Dependable Computing Systems Design
- Centre for Birobotics
- Centre for Intelligent Systems

RESEARCH CENTRES:

CENTRE OF DEPENDABLE COMPUTING SYSTEMS

Head of the centre: Professor JAAN RAIK, jaan.raik@ttu.ee

The research covers a wide range of topics in the areas of the design, reliability, verification and testing of digital systems (including multi-/many-core systems):

- study of aging and rejuvenation in nanometer technologies (cooperation with Politecnico di Torino and PUCRS, Brazil);
- dependability, test and fault management for many-core systems (cooperation: IBM, Recore Systems, Testonica Lab OU);
- embedded test instruments for digital systems (cooperation: Testonica Lab OU);
- diagnostic test generation and microprocessor testing;
- verification of computing systems;
- acceleration of algorithms in programmable logic (cooperation: Aveiro University, Portugal);
- algorithms, sensors and signal processing in biomedical applications;
- modeling power in computing systems (cooperation: Politecnico di Torino, STMicroelectronics).

The research group is the initiator of several pan-European actions. It coordinates the Horizon 2020 RIA IMMORTAL and the Horizon 2020 Twinning action TUTORIAL. It also participates in the FP7 collaborative research project BASTION and in the national centre of research excellence EXCITE coordinated by the Department. The research group coordinates the Marie Skłodowska Curie ITN RESCUE project that has been accepted in 2016.

IN 2016

The most significant research results were related to the research on nanoelectronics technology aging and on system-level test and fault management. In addition, the research group designed and implemented a new fault-resilient router chip, which was manufactured by Fraunhofer, Germany.
SELECTED PUBLICATIONS


CENTRE FOR BIOROBOTICS

**Head of the centre:** Professor MAARJA KRUSMAA, maarja.kruusmaa@ttu.ee

The Centre for Biorobotics conducts interdisciplinary research on the borderline of biology and technology. The main focus is on biologically inspired robots and sensors, underwater robotics, flow sensing, sensors for flow sensing and sensor data interpretation.

SELECTED PUBLICATIONS


CENTRE FOR INTELLIGENT SYSTEMS

**Head of the centre:** Associate Professor EDUARD PETLENKOV, eduard.petlenkov@ttu.ee

The main research activities of the Centre for Intelligent Systems are:

- development of Fractional Order Modelling and Control Algorithms (including development of FOMCON toolbox http://fomcon.net);
- preliminary research on development of virtual reality based system for study of synesthesia psychological phenomena;
- intelligent Control Algorithms for Multidimensional Motor Driven Applications (cooperation with the Department of Power Engineering);
- intelligent Control Algorithms for efficient control of District Heating Plants;
- development of an Artificial Intelligence based system for estimation of insurance risks;
- modelling and model based analysis of students’ behavior.

IN 2016

- Development of a fractional-order retuning controller that can be incorporated into PID controllers based industrial systems and improve control quality without making changes in existing control loops.
- The developed algorithm was implemented both in software functional blocks and hardware.
- Artificial Neural Networks based model of Ground Source Heat Pump was identified and applied to estimation of ground temperature changes (in cooperation with the Department of Civil Engineering).
• Artificial Intelligence Methods based algorithms for control of 3D crane and ABS have been developed and tested on laboratory prototypes (cooperation with the Department of Power Engineering).

• A concept of virtual reality based system for study of synesthesia psychological phenomena was designed.

• Intelligent algorithms for control of two types of District Heating Plants were developed and implemented in Distributed Control Software Valmet DNA as functional blocks. One of the algorithms has been already successfully tested and applied for control of a District Heating Plant in Rapla.

• Artificial Intelligence Methods based system for estimation of motor insurance risks was developed and implemented in software.

• A model that estimates students’ study results on the basis of their behavior during the study process was developed.

• A novel measurement method and a device for capillary electrophoresis are being designed (in cooperation with the Department of Chemical Engineering).

SELECTED PUBLICATIONS


DEPARTMENT OF SOFTWARE SCIENCE

**Director:** JAAN PENJAM, jaan.penjam@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)

- Academic staff, total 95
  - Incl. 12 professors, 43 researchers
- Doctoral students, total 59
- Scientific publications in 2016, total 98
- Defended doctoral dissertations in 2016, total 5

The Department conducts research within 10 research units:

- Centre for Digital Forensics and Cyber Security
- Laboratory of Socio-Technical Systems
- Laboratory of Language Technology
- Laboratory of Proactive Technologies
- High-Assurance Software Laboratory
- Nonlinear Control Systems Group
- Model-Based Software Engineering Group
- Large-Scale Systems Group
- Data Science Group

The Department of Software Science (DSS) is a newly established department of the School of Information Technologies that was formed recently on the basis of the research groups of the former Department of Computer Science, Department of Computer Control, Department of Informatics and the Institute of Cybernetics. The research fields of DSS include logic, data analysis, programming languages, high-assurance software, model based software engineering, large-scale systems, digital forensics and cyber security, socio-technical systems, proactive technologies, nonlinear control systems, and human language technology. The research groups of DSS participate in the Estonian Centre of Excellence in ICT Research EXCITE and in the Centre of Excellence in Estonian Studies CEES. DSS is also partner in several other H2020 projects.

RESEARCH GROUPS

CENTRE FOR DIGITAL FORENSICS AND CYBER SECURITY

**Head of the centre:** Associate Professor RAIN OTTIS, rain.ottis@ttu.ee

TTU Centre for Digital Forensics and Cyber Security works towards enhancement of the competence and ability of Estonian computer security field through education, research and development. We strive towards becoming an institution providing the best master’s and doctoral studies in the field of cyber security in the Baltics and Nordic countries. The centre is a part of TTU Department of Computer Science.

The centre focuses on the development of the field of cyber security. The goals stemming from this can be elaborated as follows:

- Raising the competence and ability of Estonian digital forensics and cyber security through education, research and development.
- Focusing the relevant actions of TTÜ according to Estonian national cyber security strategy.
- The creation and dissemination of sufficiently certified infrastructure for services.
• The mapping of marketing channels for joint marketing efforts in the cyber security field to further international sales of courses and research results.
• Education of the employees of our partners in the cyber security matters.
• Informing the target groups and public about the resources of the Centre and supporting activities for this.
• Cooperation and preparation for technological interchange with other relevant fields of research;
• Participation in digital forensics and cyber security projects.

LABORATORY OF SOCIO-TECHNICAL SYSTEMS

Head of the laboratory: Professor KULDAR TAVETER, kuldar.taveter@ttu.ee

The research group carries out interdisciplinary research work at the intersection of agent technologies, service-oriented architectures, information systems, social sciences, and psychology. In particular, we apply the methodology called agent-oriented modeling (AOM) to the modeling, simulation, and prototyping of complex (sociotechnical) systems, including systems for e-governance, smart cities and smart communities, and crisis management, as well as to the simulation of real-world social phenomena.

SELECTED PUBLICATIONS 2016:

LABORATORY OF LANGUAGE TECHNOLOGY

Head of the laboratory: Senior Research Scientist TANEL ALUMÄE, tanel.alumae@phon.ioc.ee

The research fields of the research group are:
• Speech and language technology (speech and speaker recognition, natural language processing).
• Speech analysis and experimental phonetics (Estonian prosody and sound system, foreign accent in speech, phonetic databases).

SELECTED PUBLICATIONS 2016:

LABORATORY OF PROACTIVE TECHNOLOGIES

Head of the laboratory: Professor LEO MÕTUS, leo.motus@ttu.ee

The laboratory focuses on theoretical and practical study of networked systems built from stationary and/or mobile software-intensive (proactive) components. Typical components are pervasive computing systems. The research is partitioned into three threads: (1) modelling and verification of situation-aware interaction-centred computation; (2) methods and technologies for acquiring situational information; (3) methods for interpretation of situational information for (proactive) decision making. The long-term
goal of the laboratory is the ability to detect and partially control the emergent behaviour in pervasive computing systems.

SELECTED PUBLICATIONS 2016


HIGH-ASSURANCE SOFTWARE LABORATORY

Head of the laboratory: Lead Research Scientist TARMO UUSTALU, tarmo.uustalu@ttu.ee

This group conducts research into theories, methods and tools for developing high-assurance software, specializing on both proofs (certified software) and testing.

IN 2016

Capretta’s delay datatype quotiented by weak bisimilarity was shown to deliver free omega-cppos, assuming countable choice, and to be the initial omega-complete pointed classifying monad. A different partiality datatype constructed with the help of a higher inductive type was shown to be a monad without the countable choice axiom.

Stateful runners were generalized to a novel structure of interaction morphisms, describing well-behaved interactions of a monadic computation and a comonadic execution platform. Interaction morphisms were shown to be a natural concept with a number of neat properties. In particular, they are monoids in a suitable monoidal category, and the category of interaction morphisms exhibits a lot of structure.

Update lenses as comonad coalgebras were generalized to update-update lenses, a structure for bidirectional transformations with monoids of updates for both the source and view database. Update-update lenses are comonad morphisms.

A generic framework was devised for specifying relaxed memories, based on a flexible concept of a backlog (reordering box); execution of a program on a relaxed memory is constrained by a history-dependent independence relation. An algorithm for exploring the executions of a program on a relaxed memory was devised that generates exactly one representative of every equivalence class of executions, the Foata normal form.

The Kameda-Weiner method of finding a minimal nondeterministic finite automaton (NFA) of a regular language was reinterpreted in terms of atoms of the language. A method for generating NFAs was proposed that provides a unified view of the construction of several known types of canonical NFAs.

A new characterization of reversibility of a cellular automaton was given in terms of a strengthening of surjectivity and a weakening of injectivity (post-surjectivity and pre-injectivity). For sofic groups it was proved that post-surjective cellular automata are pre-injective, “almost dualizing” Gromov’s theorem that injective cellular automata on sofic groups are surjective.

An aspect-oriented technique of modelling, verification and model-based testing was developed based on Uppaal timed automata. Non-interference of aspects is verified based on assume-guarantee assertions. The approach was validated on a crisis management system case study.

A model-based mutation technique was introduced for evaluating the robustness of web services. From the specification of a Web service, a test model is designed using Uppaal timed automata and the conformance between the model and the implementation is validated via online model-based testing with the Uppaal TRON tool. A set of mutation operators are applied to the test model generating various mutant models; valid mutant models are used for online test generation against the service implementation. The technique was tried on a blog web service.
NONLINEAR CONTROL SYSTEMS

Head of the research group: Lead Research Scientist ÜLLE KOTTA, kotta@ioc.ee

The Laboratory of Control Systems is a leading Estonian research unit in automatic control, focusing on control theory and symbolic software, supporting fundamental/applied research and teaching.

The research directions include nonlinear and robust control systems, modeling of control systems, learning and planning in robotic systems, formal testing and verification methods for distributed and embedded systems.

The goal is to carry on basic research in nonlinear control theory, which has a firm base in applied mathematics. The group’s research activities are directed towards developing theoretical and symbolic computation tools for modelling, analysis and synthesis of nonlinear control systems.

The group has made significant contributions in developing algebraic methods both for continuous- and discrete-time nonlinear control systems. A universal algebraic formalism has been developed that unifies the study of very different problems. In this formalism, sequences of subspaces of the differential forms, associated with the control system, are defined and provide a lot of information about the structural properties of the system. During recent years we have applied the algebraic methods for the study of a number of fundamental properties of a control system; like feedback linearizability, accessibility, identifiability, system (input-output and transfer) equivalence, irreducibility and realizability of the system in the classical state space form. Most procedures have been implemented in the computer algebra system Mathematica.

SELECTED PUBLICATIONS 2016


MODEL-BASED SOFTWARE ENGINEERING

Head of the research group: Director of the department JAAN PENJAM, jaan.penjam@ttu.ee

The research of the group is aiming at a tool development that enables modeling and simulation of complex systems and automated program composition. We do research and take advantage of the following fields:

- visual specification languages;
- compiler compilation;
- model-based software engineering;
- ontology-driven software development;
• propositional calculus;
• structural program synthesis – a proof search based program synthesis paradigm;
• expert systems;
• machine learning;
• data management;
• hybrid (continuous time and discrete event based) simulations.

During a number of decades several software tools that facilitate program synthesis features have been developed by the group:
• Priz – for mainframes IBM 370, ES;
• ExpertPriz – A Priz version for PC with built-in expert system engine;
• C-Priz - A Priz version for PC implemented in C; first tool in the line that facilitated a graphical user interface;
• NUT – an X11 based tool for engineering modeling running on Sun Solaris and Linux (support discontinued);
• CoCoViLa – the current Java-based tool for model based visual program composition.

SELECTED PUBLICATIONS 2016


LARGE-SCALE SYSTEMS

Head of the research group: Professor DIRK DRAHEIM, dirk.draheim@ttu.ee

The research group conducts research in large- and ultra-large-scale IT systems.
The studies are concentrated on the investigation of architecture, design, realization and management of IT system landscapes, high-volume data-intensive systems, high-volume workflow-intensive systems, massively resource-intensive systems, and highly distributed systems.

SELECTED PUBLICATIONS 2016


DATA SCIENCE

Head of the research group: Professor REIN KUUSIK, rein.kuusik1@ttu.ee

The research fields of the research group are:

- Computational linguistics;
- Data mining and Machine learning.

A language-independent system has been created for testing dictionaries of the WordNet type (there are about 70 of them in the world). It was shown that all dictionaries of this type contain tens of thousands of errors that the new testing system effectively detects. Cooperation with the authors of the Estonian WordNet, for example, reduced the number of polysemic errors in the Estonian WordNet by 97%.

An existing algorithm of zero-factor-free determinacy analysis was developed in order to find out how to detect object’s belonging to a class. It is based on finding closed sets and their generators at the same time. As a bases for describing underlying data three types of rules can be found: class detection rules, (positive) association rules, negative association rules. The usage methodology was developed.

SELECTED PUBLICATIONS 2016


DEPARTMENT OF HEALTH TECHNOLOGIES

Director: Professor KALU MEIGAS, kalu@cb.ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)

- Academic staff, total 27
  - Incl. 8 professors, 15 researchers
- Doctoral students, total 23
- Scientific publications, total 31
- Defended doctoral dissertations in 2016, total 3

The Department conducts research within 6 research groups:

- Brain Bioelectrical Signals
- Non-invasive Optical Monitoring of Blood Pressure and Cardiovascular System
- Biofluid Optics
- Sleep Medicine/Sudden Cardiac Death
- Centre for Cardiovascular Medicine
- eMed Laboratory
- eNMR Laboratory

RESEARCH GROUPS

BRAIN BIOELECTRICAL SIGNALS

Head of the research group: Senior Research Scientist MAIA BACHMANN, maia@cb.ttu.ee

In 2016 the main efforts were aimed to investigation of EEG based indicators for detection of mental disorders such as depression and the effect of environmental factors on human brain bioelectrical activity directly related to mental disorders.

The study on indicators for detection of depression employs EEG from 18 channels for 34 subjects (17 depressive and 17 control). The experiments indicated maximum difference for SASI values in channel Pz. Therefore, channel Pz was selected for comparison of two methods. The results of statistical analysis show that SASI values are significantly higher for the depressive than for the control group (p = 3.577e–05), while DFA values are significantly lower for the depressive group (p = 0.033). SASI has superior discrimination ability with classification accuracy of 76.5%, while the classification accuracy of DFA was 70.6%. Linear combination of SASI and DFA resulted in 91.2% classification accuracy.

Our studies indicated gender differences in the brain functional connectivity between male and female depression. The experiments were performed on 37 unmedicated subjects with MDD (16 male, 21 female) and 37 age and gender-matched healthy subjects. Synchronization likelihood (SL) method was used to estimate functional connectivity between EEG signals recorded from 30 channels and filtered into six frequency bands. The results of the study indicate a significant difference between EEG of male and female major depressive disorder (MDD).

An important part of the investigations was aimed to explain the mechanism of the effect of low-level modulated microwave radiation on brain bioelectrical oscillations. The proposed model of excitation by low-level microwave radiation is based on the influence of water polarization on hydrogen bonding forces between water molecules, related to this the enhancement of diffusion and consequences on neurotransmitters transit time and neuron resting potential. Modulated microwave radiation causes periodic alteration of the neurophysiologic parameters and parametric excitation of brain bioelectric oscillations. The experiments to detect the logical outcome of the mechanism on the physiological level were carried out on 15 human volunteers. The 450 MHz microwave radiation modulated at 7, 40 and 1000 Hz frequencies was applied at the field power density of 0.16 mW/cm². The experimental results support the proposed mechanism indicating the EEG enhancement at the frequencies predicted by theory.
MAIN RESULTS

- Single-channel EEG analysis using an original linear spectral asymmetry index SASI provides acceptable sensitivity for detection of depression comparable to that achieved using nonlinear DFA method.
- Synchronization likelihood estimated a significant difference in functional connectivity between male and female depressive EEG.

The suggested nonthermal mechanism, free of the restrictions related to field strength or time constant, is the first one providing explanation of low-level microwave radiation effects and includes its experimental confirmation.

SELECTED PUBLICATIONS

Hinrikus, Hii; Bachmann, Maie; Karai, Denis; Lass, Jaanus (2016). Mechanism of low-level microwave radiation effect on nervous system. Electromagnetic biology and medicine, 1−11.


NON-INVASIVE OPTICAL MONITORING OF BLOOD PRESSURE AND CARDIOVASCULAR SYSTEM

Head of the research group: Professor KALJU MEIGAS, kalju@cb.ttu.ee

Our previous studies have revealed that it is possible to estimate parameters from the photoplethysmographic signal, which are correlating with arterial stiffness. The photoplethysmography method is a non-invasive, optical, relatively simple and inexpensive method that can replace expensive and operator dependent methods (ultrasound measurement, SphymoCor) for arterial stiffness estimation. A study was carried out during the reporting period, where the relationships between the parameters from photoplethysmography and direct stiffness parameters of arterial regions were investigated. Direct arterial stiffness parameters were estimated using blood pressure and ultrasound measurements. The study was carried out on 10 healthy subjects between 40 to 60 years of age. Ultrasound measurements were carried out on hand, leg and carotid arteries and photoplethysmographic signals were registered from different large and peripheral arteries. The photoplethysmographic signal was offline processed using MATLAB environment. The first results show that there is possible correlation between parameters. However, for more precise analysis additional studies on a larger number of subjects need to be carried out.

The stroke volume of heart is an important parameter in the prevention and treatment of cardiovascular diseases. In clinical practices the stroke volume is estimated using ultrasound measurement, but it is a relatively expensive and operator dependent method. Measurement and analysis of impedance cardiography offers also a possibility to estimate stroke volume. This method is inexpensive in comparison with ultrasound measurement and also the training of an operator is not needed. However, the impedance cardiographic method estimates stroke volume indirectly and therefore there can be imprecision in the results. The Hotman System estimates stroke volume using the impedance cardiographic method. The accuracy of the Hotman System was investigated using ultrasound measurements as a reference method for stroke volume estimation. The study was conducted on ten healthy subjects (5 male and 5 female subjects) and the measurements were carried out using the Hotman System and ultrasound device. As a result, it was found that the Hotman System overestimates the stroke volume on an average of 20 ml, which is about 20% of the absolute value of stroke volume. It is a relatively large deviation, which is not related to the accuracy of ultrasound measurement. The repeatability of the ultrasound measurement was checked and the results of stroke volume were also within reference values. It has been suggested to carry out more experiments in order to find the source of imprecision in the Hotman System.

IN 2016:

- Algorithm is developed for the waveform analysis of photoplethysmographic signal in frequency domain. The first results show possible correlation between extracted parameters from frequency analysis and direct arterial stiffness parameters that were estimated using blood pressure and ultrasound measurements.
- Hotman System, which is based on the bioimpedance method, overestimates the stroke volume on an average of 20 ml, which is about 20% of the absolute value of stroke volume.

BIOFLUID OPTICS

Head of the research group: Professor IVO FRIDOLIN, ivo@cb.ttu.ee

The aim of the research is to develop a novel optical technology for monitoring of uremic toxins (UTOx) related to the malnutrition-inflammation syndrome on the end stage renal disease patients and to cardiovascular disease (CVD), helping doctors to improve the life quality of the patients, and decrease hospitalisations and interventions.
The uremic toxins are classified as: (i) small, (ii) middle and (iii) protein bound. Moreover, no standard laboratory analyses are available for a number of protein bound and small uremic toxins measurements in the biological fluids so far. Many of the uremic toxins are candidate markers of cardiovascular disease and inflammation. For this reason an appropriate high performance liquid chromatography (HPLC) and LC-MS method, capable of identifying and quantifying more uremic toxins compared to the existing standard laboratory methods, was developed.

IN 2016:

- The contribution and removal dynamics of the main fluorophores during 99 dialysis sessions, (including 57 hemodialysis and 42 hemodiafiltration treatments) was evaluated by analysing the spent dialysate samples to prove the hypothesis whether the fluorescence of spent dialysate can be utilized for monitoring removal of any of the protein bound uremic solute. The highest contribution (35 ± 11%) was found to arise from IS with strong correlation between contribution values at the start and end of dialysis (R² = 0.90). The reduction ratio of indoxyl sulfate was very close to the decrease of the total fluorescence signal of the spent dialysate (49 ± 14% vs 51 ± 13% respectively, P = 0.30, N = 99) and there was strong correlation between these reduction ratio values (R² = 0.86). This proofs experimentally the hypothesis that the fluorescence signal at this wavelength region has high potential to be utilized for monitoring the removal of slowly dialyzed uremic toxin indoxyl sulfate.

- On-line fluorescence measurements were carried out to illustrate the technological possibility for real-time dialysis fluorescence monitoring, reflecting the removal of the main fluorophores from blood into spent dialysate.

- The contribution of the fluorescence of 4-pyridoxic acid (4-PA) to the total fluorescence of spent dialysate (Ex/Em 220–500 nm) was estimated with the aim of evaluating the removal of this vitamin B-6 metabolite from the blood of patients (N=10) with end-stage renal disease (ESRD) and receiving regularly pyridoxin injections after dialysis treatment. 4-PA in dialysate samples was identified and quantified using HPLC with fluorescent and MS/MS detection. Among many peaks in averaged HPLC chromatogram of spent dialysate in the wavelength region of Ex320/Em430 nm, 4-PA was the biggest peak with contribution of 42.2±17.0% at the beginning and 47.7±18.0% in the end of the dialysis. High correlation (R=0.88-0.95) between 4-PA concentration and fluorescence intensity of spent dialysate was found in the region of Ex310-330/Em415-500 nm, respectively. It was concluded that 4-PA elimination from the blood of ESRD patients can be potentially followed using monitoring of the fluorescence of the spent dialysate during dialysis treatments.

- A unique method compared to earlier known state of the art for determining middle and protein bound uremic toxins in the spent dialysate utilizing fluorescence spectroscopy led to two more patent publications in 2016 in addition to the earlier patents and patent applications:

SELECTED PUBLICATIONS


SLEEP MEDICINE/SUDDEN CARDIAC DEATH

Head of the research group: Senior Research Scientist JURI KAIK

Assessment of ventricular repolarization duration and variability by analysing ECG QT interval is a commonly accepted diagnostic and prognostic marker for determining the elevated risk for potentially life-threatening arrhythmias. Novel QT interval variability algorithms, developed in Technomedicum of Tallinn University of Technology, are applicable to the majority of ECG registration methods – rest ECG, ECG 24 hours’ monitoring, stress test, etc. The main field of research in this year was application of these methods to ECG polysomnographic recordings, which allows not only to detect patients with various sleep apnea levels, but also to determine the risk of cardiac complications.
IN 2016:

Continuing development of a device for monitoring various physiological signals as ECG, arterial blood pressure, breathing frequency, blood saturation. The most significant changes are connected with ambulatory evaluation of sleep quality in order to create software and hardware for a novel sleep monitoring device.

CENTRE FOR CARDIOVASCULAR MEDICINE

Head of the centre: Professor MARGUS VILIGMAA, margus@cb.ttu.ee

We have studied the effect of aldehyde modification on antioxidant enzyme activity in diabetic patients in co-operation with Russian Cardiology Centre in Moscow. Accurate measurement of aortic length in routine medical practice has still not been achieved. Our investigation was oriented towards the evaluation of the impact of demographic and anthropometric data on aortic length and the construction of a predictive equation for the aortic length estimation. Aortic length, measured on computed tomography (CT) images, was taken as actual aortic length and used in multiple linear regression analysis as a dependent variable for construction of the equation for aortic length estimation.

We participated in a meta-analysis of genome-wide association studies for estimated glomerular filtration rate (eGFR), combining data across 133,413 individuals with replication in up to 42,166 individuals. We have identified 24 new and confirmed 29 previously identified loci. Of these 53 loci, 19 associate with eGFR among individuals with diabetes.

The LDL lowering therapies have a major role in reduction in cardiovascular events. We have studied monoclonal antibodies to proprotein convertasesubtilisin kexin type 9 (PCSK9) as they represent a new therapeutic option, reducing LDL cholesterol by an additional 40–70% on top of other lipid lowering therapies.

We investigated associations between self-reported tooth loss and cardiovascular outcomes in a global stable coronary heart disease cohort of 15,456 patients from 39 countries with stable coronary heart disease.

IN 2016

The effect of aldehyde modification on antioxidant enzyme activity in diabetic patients was studied. The activity of commercially available antioxidant enzymes (catalase, glutathione peroxidase [GPx], and CuZn-superoxide dismutase [SOD]) was determined in vitro prior to and after aldehyde modification. The activity of erythrocyte CuZn-SOD was assayed in blood drawn from healthy donors, diabetic patients with uncompensated carbohydrate metabolism, and diabetic patients after glucose-lowering therapy. In vitro aldehyde modification had no effect on catalase activity, but diminished GPx and CuZn-SOD activity. In diabetic patients with uncompensated carbohydrate metabolism, glucose-lowering therapy significantly increased CuZn-SOD activity, the effect being especially pronounced after administration of metformin. It is likely that metformin antagonizes the aldehyde-induced inhibition of erythrocyte CuZn-SOD in diabetic patients more effectively than sulfonylurea drugs.

It was demonstrated, that about 65 per cent of the variations in aorta length could be explained by such determinants as height, weight and age. The equation-derived aortic length showed better accuracy than the aortic length estimated by approximation to jugulum-symphysis distance when compared with actual aortic length.

Reduced glomerular filtration rate defines chronic kidney disease and is associated with cardiovascular and all-cause mortality. A meta-analysis of genome-wide association studies for eGFR was conducted. Using bioinformatics, it was shown that identified genes at eGFR loci are enriched for expression in kidney tissues and in pathways relevant for kidney development and transmembrane transporter activity, kidney structure, and regulation of glucose metabolism. Chromatin state mapping and DNase I hypersensitivity analyses across adult tissues demonstrate preferential mapping of associated variants to regulatory regions in kidney but not extra-renal tissues. These findings suggest that genetic determinants of eGFR are mediated largely through direct effects within the kidney and highlight important cell types and biological pathways.

The LDL lowering therapies have a major role in reduction in cardiovascular events. Statins have been shown to be highly effective and safe in numerous randomized clinical trials, and have become the irreplaceable first-line treatment against atherogenic dyslipidemia. However, even with optimal statin and other traditional treatment, there still remains 60% to 80% of residual cardiovascular risk. Monoclonal antibodies to proprotein convertasesubtilisin kexin type 9 (PCSK9) represent a new therapeutic option, reducing LDL cholesterol by an additional 40–70% on top of other lipid lowering therapies. Some more novel lipid-lowering therapies and HDL-raising interventions are emerging, however, they require large cardiovascular outcome trials. Clinicians should be aware of the results of outcome trials with novel drugs in treatment of atherogenic dyslipidaemia in order to offer the most efficacious and safe treatment to their patients.
Associations were investigated between self-reported tooth loss and cardiovascular (CV) outcomes in a global stable coronary heart disease (CHD) cohort of 15,456 patients from 39 countries with stable CHD (prior myocardial infarction [MI], prior revascularization, or multivessel CHD) in the STABILITY trial. At baseline, patients reported number of teeth (“26–32 [All]”, “20–25”, “15–19”, “1–14”, and “No Teeth”) and were followed for 3.7 years. Cox regression models adjusted for CV risk factors and socioeconomic status, determined associations between tooth loss level (“26–32” teeth: lowest level; “No Teeth”: highest level) and CV outcomes.

SELECTED PUBLICATIONS


eMED LABORATORY

**Head of the laboratory:** Professor PEETER ROSS, peeter.ross@ttu.ee

Scientific work is concentrating on the effect of the use of e-health services on diagnostic and treatment processes in public health and healthcare. The research topics include investigation of the actors and processes influencing the implementation of shared workflow, the use of digital medical databases in the development of digital decision support systems, and research of a medical text as a sublanguage of medicine.

The research area also includes health and medical data exploitation in developing new e-health services for citizens and healthcare professionals, data sharing among healthcare professionals and with the citizens, process reengineering in healthcare, telemedicine services for the patients and personal health record services and patient motivation.

Estonian government has acknowledged TTÜ as one of the leading partners in the implementation of government approved „Estonian e-Health Strategic Plan until 2020“. The strategy addresses the quality and infrastructure of health data, personalised e-services and personal medicine, comprehensive case handling and integrating services, monitoring and analysis of the performance of health services and development of remote services.

eNMR LABORATORY

**Head of the laboratory:** Lead Research Scientist AGO SAMOSON, ago.samoson@ttu.ee

NMR is a remarkably universal analytical method since essential spin interactions can be reliably calculated. The spectra allow in principle a 3D reproduction of the entire spin system, even dynamics of it. We custom-develop NMR sensors- probeheads. Key engineering aspects comprise numerical modeling, micro-machining and radio-frequency circuit design. One of the most important parameters is the rate of so called magic angle spinning, where a solid or soft matter under study is rotated in magnetic field. In many cases the higher rates improve resolution and sensitivity. Recently we were able to reach 150 kHz which allows to use 1H nuclei for signal detection instead of conventional 13C. Immediate sensitivity increase is over two orders of magnitude. We apply the technology in contemporary priority areas: biomedical research and development of F-ion batteries as a Li-alternative for energy storage.

SELECTED PUBLICATIONS


Chen, Ruiyong; Maawad, Emad; Knapp, Michael; Witter, Raiker; et al. (2016). Lithiation-driven structural transition of VO2F into disordered rock-salt LixVO2F. RSC Advances, Vol. 6, Issue: 69, 65112–65118.
THOMAS JOHANN SEEBECK DEPARTMENT OF ELECTRONICS

**Director:** Professor TOOMAS RANG, toomas.rang@ttu.ee

**MAIN FIGURES 2016 (as of Jan. 01, 2017)**
- Academic staff, total 36
  - Incl. 6 professors, 19 researchers
- Doctoral students, total 26
- Scientific publications, total 35
- Defended doctoral dissertations in 2016, total 2

The base of modern electronics explicitly embodies in cognition and communication, which formulates the results through generating, processing, transmitting and retransmitting, and deporting/retaining of signals (data). It realizes itself through networking of components, in their mutual communication and in the increase of autonomous aptness of components through the development of different unified hardware platforms, in which the combination of signal processing and data transforming takes place under strongly optimized energy consumption limitations. The research conducted at the Thomas Johann Seebeck Department of Electronics (TJS ELIN) follows these trends very actively.

THE DEPARTMENT CONDUCTS RESEARCH WITHIN 1 RESEARCH GROUP:

**IMPEDANCE SPECTROSCOPY AND COGNITRONICS:**
**SIGNALS, ALGORITHMS, ENERGY SAVING SOLUTIONS**

**Head of the research group:** Professor TOOMAS RANG, toomas.rang@ttu.ee

The main goal of the work is to find effective signal processing methods and algorithms for the synthesis of excitation signals and to process the response signals in frequency domain for optimizing the sensor systems of complex multicomponent signals under consideration. Additionally, new algorithms for underwater noise measurement methodology and standards for Baltic Sea have been initiated based on measurement results for determination of noise level in living areas of marine species and of localization/identification of noise sources. New activities connected with the European Spallation Source consortium in Lund, Sweden started for development and realization of specific electronic boards for their experimental infrastructure.

The following earlier started studies are continued:
- Development of an information system providing continuous and long-term monitoring of the human Central Aortic Blood Pressure (CAP) variations using non-invasive and health-safe way from the Electrical Bio-Impedance (EBI) measurements from the radial artery on the arm.
- The research activities in evaluation of voice over IP combined solutions with wireless mesh networks for emergencies like flooding, earthquakes etc.
- The experimental and numerical experiments in the field of semiconductor electronics.
- The research activities together with Tartu University in the framework of Centre of Excellence EXCITE for the development of microfluidic components for disposable Point-of-Care Test devices.
IN 2016

The following studies were performed:

- Development of mathematical methods (chirp transform) for wide frequency band chirp signal applications to be used in impedance spectroscopy of biological objects.
- Development of algorithm based on high speed impedance spectroscopy for binary sequential excitation or on non-equal sampling of chirp signals (US Patent application).
- Development and realization of novel high voltage diffusion-welded SiC stacks based on Cree Inc. SiC structures. The results are based on cooperation with researchers from the Russian Academy of Science, A.F. Ioffe Physico-Technical Institute in St. Petersburg.
- Together with researchers from Lund University, Sweden, the new algorithm was developed for sparse signal reconstruction that can reconstruct the signal quicker (reduced computational complexity) or during the same time, but with higher exactness of reconstruction (better resolution and improved model order estimation).
- Development of novel applications with the focus on wearable health sensorics using Internet of Things (IoT) technologies and applications.
- Development of RL-CAA, a novel algorithm for channel assignment in wireless body area networks. The algorithm was tested taking into account requirements of the IEEE 802.15.6 standard (body area network).

SELECTED PUBLICATIONS


School of Science

Photo: 480 million year old bryozoan fossil *Chasmogonoporella* on a slab of kukersite oil shale from the Aidu opencast mine, NE Estonia. Specimen from the collections of the Department of Geology (www.geokogud.info/specimen/90427). Author of the photo Gennadi Baranov.
SCHOOL OF SCIENCE

Dean: Professor TÕNIS KANGER
e-mail: tonis.kanger@ttu.ee
Vice-Dean for Research: Associate Professor URMAS ARUMÄE
e-mail: urmas.arumae@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)
- Academic staff, total 234
  - Incl. 25 professors, 144 researchers
- Doctoral students, total 159
- Scientific publications, total 369
- Defended doctoral dissertations in 2016, total 20

DEPARTMENTS

DEPARTMENT OF CHEMISTRY AND BIOTECHNOLOGY
Director: Professor IVAR JÄRNING, ivar.jarving@ttu.ee

DEPARTMENT OF CYBERNETICS
Director: Professor ANDRUS SALUPERE, andrus.salupere@ttu.ee

DEPARTMENT OF GEOLOGY
Director: Senior Research Scientist ATKO HEINSALU, atko.heinsalu@ttu.ee

DEPARTMENT OF MARINE SYSTEMS
Director: Professor JÜRI ELKEN, juri.elken@ttu.ee
DEPARTMENT OF GEOLOGY

Director: Senior Research Scientist ATKO HEINSALU, atko.heinsalu@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)

- Academic staff, total 30
  - Incl. 3 professors, 20 researchers.
- Doctoral students, total 17
- Scientific publications, total 86
- Defended doctoral dissertations in 2016, total 1

The Department conducts research within 3 research divisions and the Department of Collections

- Division of Bedrock Geology
- Division of Isotope Geology
- Division of Quaternary Geology
- Department of Collections

DIVISIONS

DIVISION OF BEDROCK GEOLOGY

Head: Professor OLLIE HINTS, olle.hints@ttu.ee

The research of the working group is focused on Early Paleozoic paleobiology, paleoclimate, paleoenvironmental change and integrated bio- and chemostratigraphy. The Baltoscandian rocks, which constitute one of the best archives of Paleozoic Earth history worldwide, are used as a natural laboratory, complemented by data from other paleocontinents and regions (e.g. Siberia, North America and Central Europe etc.). The main scientific questions targeted by the group are related to the evolution and diversification of biosphere, extinction events and their connections with climate change and environmental perturbations, paleobiogeography, functioning of fossil ecosystems, geochemical cycling and its changes through time.

IN 2016

- Oxygen isotope records from conodont apatite enabled reconstructing Silurian global climate history, showing direct links between major geobioevents and climate change.
- New integrated quantitative stratigraphic model for Baltoscandian chitinozoan biostratigraphy, K-bentonites and carbon isotope signatures allowed evaluating age-relations between biotic and environmental changes and reconstructing paleobiodiversity at the highest resolution.
- Based on Ordovician-Silurian succession an updated carbon isotope curve was created for the Baltic region with particular emphasis on Guttenberg, Hirnantian and Ireviken events, allowing new environmental interpretations and chemostratigraphic correlations.
- Combined bio- and chemostratigraphy improved correlation tools and allowed precise dating of key succession and events.
- In paleontological studies new taxa were described and biogeographic and stratigraphic distribution of different fossil groups was analysed globally and within the Baltic region.

SELECTED PUBLICATIONS:


DIVISION OF ISOTOPE GEOLOGY

Head: Senior Research Scientist REIN VAIKMAE, rein.vaiikmae@ttu.ee

The studies of the research group are focused on: (1) groundwater isotopic composition, age, origin and numerical models; (2) isotopic signatures of paleoclimatic and environmental change in polar areas; (3) CO2 capture and geological storage.

IN 2016

• Large quantities of methane were stored into marine sediments along Norwegian shelf during the glaciations. Authigenic carbonate crusts were formed simultaneously with methane release after deglaciation of Scandinavian Ice Sheet. The timing of crust formation associated with methane seeps across the seabed was analysed. The impact on atmospheric methane concentrations and the possible response to global climate change was discussed.

• It was determined that groundwater in the North Estonian Ordovician-Cambrian aquifer system represents a mixture of waters originating from modern precipitation, glacial meltwater and relict Na-CI. The isotopic and chemical composition of groundwater indicates that the influence of Pleistocene glaciations on the geochemical evolution of groundwater has been far more extensive than previously thought. These findings should be taken into account in future decisions concerning the management of groundwater resources.

• The spatial composition of groundwater and modern precipitation in the Baltic Artesian Basin area revealed that the isotopic composition of shallow groundwater is depleted with respect to weighted mean annual values in local precipitation. Hypothetically, the long vegetation period allows plants to transpire a substantial portion of the summer precipitation input, which causes the groundwater recharge to be strongly biased towards the spring snowmelt and autumn precipitation.

SELECTED PUBLICATIONS:


DIVISION OF QUATERNARY GEOLOGY

Head: Professor SIIM VESKI, siim.veski@ttu.ee

The research group aims at reconstruction of post-glacial paleoecology, paleoenvironmental and paleoclimatic change, both natural and man-made, at high temporal resolution in Estonia and neighbouring areas during the last 15,000 years through a multidisciplinary and multiproxy study of natural archives such as lake, bog and marine sediments. The group is focused on three overlapping research subjects: (1) late-glacial abrupt changes; (2) Holocene natural and man-made related changes and (3) development of the Baltic Sea basin.

IN 2016

• Research was focused on the development, testing and application of pollen inferred spatio-temporal climate and vegetation models.
Based on the Baltic late Weichselian (14,000 to 11,000 BP) paleobiological dataset (from algae to mammals) the climate change and biological turnover rate speeds were compared with the modern period. We found that at the beginning of the Holocene climatic warming was accompanied by the fastest species extinction, which is comparable in magnitude to the changes observed today.

The Late-Glacial glacier retreat chronology and the associated vegetation change in North Estonia was clarified.

Links between the boreal forest species composition, past climate change, forest fires and human activities were examined throughout the Holocene period.

Traces of the 1875 AD Iceland Askja volcanic eruption were discovered in bog sediments of Latvia which allows independent dating and anchoring of paleoecological events.

The impact of the crusade wars on the landscape and environment of northern Latvia between the 13th–16th centuries (medieval Livonia) was evaluated.

SELECTED PUBLICATIONS:

DIVISION OF COLLECTIONS

Head of Collections: URSULA TOOM, ursula.toom@ttu.ee

The Department of Geology holds the largest georepository in Estonia (fossils, rock samples, drill cores, etc., archive and the electronic information system). They form an integral part of the Department’s research programme and are regularly used by geologists all over the world. The collections have been funded by the state. The fossil collections have been deposited in special storage rooms in the campus. Drill cores (5000 boxes, 4–6 m cores in each box) are stored in the newly built Sarghaua Earth Science Centre drill core repositories. The Division of Collections is a partner in the national research infrastructure roadmap object “Natural history archives and information network (NATARC)”, which develops services related to hosting and computing of scientific repositories and data archives.
DEPARTMENT OF CHEMISTRY AND BIOTECHNOLOGY

Director: Senior Research Scientist IVAR JÄRVING, ivar.jarving@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)

- Academic staff, total 110
  - Incl. 11 professors, 67 researchers.
- Doctoral students, total 93
- Scientific publications, total 93
- Defended doctoral dissertations in 2016, total 11

The department conducts research within 24 research groups:

- Nucleotide Metabolism in Sponges
- Molecular Neurobiology
- Plant-Microbe Interactions
- Metalloproteomics
- Plant Genetics
- Mechanisms of Neuronal Death and Survival and their Control by Neurotrophic Factors
- Immunology
- Potyviruses
- Helicobacter Pylori-Induced Liver Damages
- Reproductive Biology
- Interaction between Plant Viruses and Their Hosts
- Transcriptional interference
- Angiogenesis
- Smart Synthesis with Small Cycles: Exploring Chemistry of the Activated Cyclopropanes
- Molecular Science
- Oxidation
- Systems Biology of Bacteria
- Metabolism of Lipids and Lipoproteins
- Advancing Analytical and Computational Chemistry Methods for Regulatory Decisions
- Aerogels as Materials for Chemical Analysis
- Supramolecular Chemistry
- Catalysis
- Green Chemistry
- Food Research
RESEARCH GROUPS

NUCLEOTIDE METABOLISM IN SPONGES

Head of the research group: Lead Research Scientist MERIKE KELVE, merike.kelve@ttu.ee

The aim of the research is the growth of sponges or their associated microbes for the production of bioactive compounds to supply biological material for clinical trials. The studies are carried out in the framework of a multi-disciplinary alliance of more than 10 academic and industrial partners that will excel in research and training through integration of complementary expertise in cell biology, microbiology, natural product chemistry, genomics & transcriptomics and socio-economics.

MAIN RESULTS IN 2016:

1. Additional biochemical characterization of deoxynucleotide-5-phosphate-N-glycosidase (DNPH1).
2. The in silico phylogenetic analysis of DNPH1 genes.
5. The novel type of ribonuclease which specifically degrades 2’5’-phosphodiester bond: isolation of enzymatically active fraction from the extract of the oyster Crassostrea gigas, the analysis of the peptides/proteins in this fraction, using the method of mass-spectrometry to identify the carrier of the ribonuclease activity.
6. 2’5’-oligoadenylate synthetases (OAS) in Metazoa: expression, characterization of their enzymatic activities, establishing their gene structures. These data will be used for writing a paper about the presence of sponge-type OASS among Metazoa.
7. Evolutionary aspects of purine metabolism: the absence of the enzymes specific to the purine de novo biosynthesis pathway in several branches of Tree of Life (Demospongia, Ctenophora).
8. The metagenomic analysis of the freshwater sponge Ephydatia muelleri. One of the aims of the analysis was the search of genes of E. muelleri coding for the specific enzymes of purine in vivo biosynthesis pathway. The results coincide with our previous conclusions about the lack of purine in vivo biosynthesis in demosponges.

SELECTED PUBLICATIONS


MOLECULAR NEUROBIOLOGY

Head of the research group: Professor TÖNIS TIMMUSK, tonis.timmusk@ttu.ee

In 2016, the main emphasis of the research was on molecular mechanisms of gene expression, including transcription, mRNA and protein subcellular localization, translation, posttranslational modifications and signaling in the nervous system health and disease, and in oncogenesis.

Specifically the following studies were carried out: (1) Molecular mechanisms controlling neural activity-regulated transcription and translation of the neurotrophin BDNF; (2) Transcriptional deregulation in Huntington’s disease; (3) TrkB signaling; (4) The functions of the basic helix-loop-helix transcription factor TCF4 in the nervous system of mammals and Drosophila and its deregulation in Pitt-Hopkins syndrome and schizophrenia; (5) Synaptic functions of the dendritically localized Neuralized1 as an ubiquitination ligase and transcriptional regulator.

SELECTED PUBLICATIONS

PLANT-MICROBE INTERACTIONS

**Head of the research group:** Professor ERKKI TRUVE, erkki.truve@ttu.ee

The research of the working group is focused on genetic, molecular and cellular aspects of plant-microbe interactions. We concentrate on one RNA virus genus – sobemoviruses, but study also the roles of cytoskeleton and some anther-specific genes in maize development. In addition, we have started to identify viruses infecting cereals in Estonia, using next-generation sequencing techniques. We use predominantly different cereals as well as the model plant Arabidopsis thaliana and various tobaccos as experimental (host) plant species.

We study the following aspects of plant-microbe interactions: (1) characterization of different species of the Sobemovirus genus, their genome organizations, functions of genes, mechanisms of propagation, transport and spread; (2) viral and endogenous suppressors of RNA silencing as the major players to control the infections in plants; (3) the role of myosins in Arabidopsis development and plant-microbe interactions; (4) novel genes determining the development of anthers as well as in meiotic cell divisions in corn; (5) viruses infecting cereals in Estonia.

IN 2016:

1. We discovered that protein ABCE1, highly conserved among archae and eucaryotes, is, besides its function as a translation factor and RNA silencing suppressor, able to regulate the progression of the S phase of a human cell cycle.
2. We demonstrated that the simultaneous knockdown of several different Arabidopsis myosin genes leads to abnormal reaction of plants to changing gravitational field.
3. We described the chemical bonds between the viral Vpg and genomic RNA for one calicivirus and one norovirus.

GROUP OF METALLOPROTEOMICS

**Head of the research group:** Professor PEEP PALUMAA, peep.palumaa@ttu.ee

The amyloid deposition in the form of extracellular fibrillar aggregates of amyloid-β (Aβ) peptide is a critical pathological event in Alzheimer's disease. We have introduced a novel cellular system for studies of toxicity of Aβ peptides in vitro, which consisted of SH SY5Y cell line differentiated with retinoic acid and BDNF. The effects of peptide concentration and incubation time on viability and morphology of the neuron-like differentiated cells has been determined. The analysis show that only Aβ42 was toxic in the new model system by covering the cells with a tight coat of fibrillar Aβ, causing beading of neurites and inducing apoptosis (manuscript submitted to Neuroscience Letters).

By using ESI TOF MS technology copper-binding properties of metal-chelating drugs of Wilson's disease have been determined, which are of fundamental importance in their therapeutic action.

SELECTED PUBLICATIONS:


PLANT GENETICS

**Head of the research group:** Senior Research Scientist KADRI JÄRVE, kadri.jarve@ttu.ee

We study genetic and molecular aspects of plant-microbe interactions. We concentrate on crop (potato, spring wheat) resistance to fungal diseases. In a wide cross with a wild species we have generated a spring wheat line resistant to powdery mildew and, in an ongoing project, in collaboration with Dr. M.
Valarik and Dr. J. Šáfář (Czech Republic), we are working on identification of the novel gene for resistance (Qpm.tut.4A), originating from T. militinae and located on chromosome 4A.

We are participating in the state programme for ‘Conservation of genetic resources for food and agriculture’ by generating, collecting and analyzing (SSR markers + phenotyping) collections of wheat and potato.

IN 2016:

- We localized the Qpm.tut.4A gene on a 640 kb fragment coding for appr. 80 genes (by chromosome walking).
- Qpm.tut.4A was carried over to the Estonian elite spring wheat variety ‘Moomi’.
- We identified a wheat cultivars haplotype of hexaploid wheat prevailing in Nordic spring carrying a large (3% of the chromosome) deletion in the distal end of a chromosome. As the recombination rate for the 4AL chromosome arm carrying the deletion is extremely low, the deletion might be useful in heritage studies of hexaploid wheat in Northern Europe.

SELECTED PUBLICATIONS:


MECHANISMS OF NEURONAL DEATH AND SURVIVAL AND THEIR CONTROL BY NEUROTROPHIC FACTORS

Head of the research group: Associate Professor URMAS ARUMÄE, urmas.arumae@ttu.ee

In 2016 we focused on the gene chip study to compare the transcriptomes in the newborn and adult murine sympathetic neurons and identify the genes that change significantly during maturation of these neurons. Postnatal maturation of neurons includes strengthening of many significant neuronal features but is virtually not studied. An area of interest to our group is the newborn sympathetic neurons in the state of programmed cell death where about half of the neurons die naturally by apoptosis. This period ends spontaneously both in vivo and in vitro with the same time schedule and is thus genetically determined. However, almost nothing is known of this genetic program. Our gene chip analysis identified a panel of genes whose levels significantly changed during neuronal maturation. It is noteworthy that the classical apoptotic genes were not significantly changed, suggesting new, uncharacterized maturational mechanisms. We have selected several potentially interesting genes whose levels changed significantly, and are currently studying their roles in the neuronal maturation. This study is published in Frontiers in Cellular Neuroscience.

Two projects were performed in collaboration with the University of Helsinki. First, we studied the fate of a novel neurotrophic factor CDNf after its injection into the rat striatum. We showed that CDNf is rapidly removed from the brain, and part of it is internalized by the neurons. It is noteworthy that CDNf is retrogradely transported via dopaminergic neurons to the some of these neurons. Most probably this is the way how striatally injected CDNf protects the dopaminergic neurons in the animal models of Parkinson’s disease. Second, we have studied the effect of two protein kinase C modulators on the death receptor Fas-induced apoptosis in Jurkat cells, and shown that both significantly inhibit this apoptosis. The role of protein kinase C in the apoptosis is poorly known and we are currently pursuing the studies on that line.

In collaboration with Minerva Foundation Institute, Biomedicum Helsinki, we also studied the mechanism of action of neurotrophin receptor p75NTR.

SELECTED PUBLICATIONS:

IMMUNOLOGY

Head of the research group: Senior Research Scientist SIRJE RUUTEL BOUDINOT, sirje.boudinot@ttu.ee

The studies of the research group are directed at the impact of regulators of G protein signaling 16 in autoimmune pathologies of the Central Nervous System, focusing on Multiple Sclerosis (MS).

A number of recent reports support the implication of RGS16 in neuro-inflammation and viral infection. Genetic associations with such diseases and direct implication of inflammatory pathways – including the interferon (IFN) response – strongly suggest that RGS16 is a key regulator of the progression of such pathologies. We are investigating the impact of RGS16 on autoimmunity pathways of the CNS, focusing on the EAE model in the mouse and on MS in human patients. Currently no curative treatment for MS exists, however several disease modifying and symptomatic treatments are available.

IN 2016

We have established a colony of Rgs16 KO mice in our facilities and our preliminary analyses showed that RGS16 had a critical role in EAE, with a significant gender difference.

We demonstrated that ablation of Regulator of G-protein Signalling 16 (RGS16) does have an effect on the clinical course of EAE in female but not in male mice. It was also shown that RGS16 does not augment nor restrict phytocannabinoid treatment effects in C57/BL6 mice. In addition it was found that RGS16 could be involved in the humoral response in vivo: the effect of RGS16 on auto-antibody production was significantly gender dependent.

In parallel, we have also undertaken the study of RGS16 expression in PBMCs, and of the RGS16 haplotype sequences in MS patients, in collaboration with Dr Toomas Toomsoo (East Tallinn Hospital) and Dr Katrin Gross-Paju (West Tallinn Central Hospital). We have analysed modest numbers of patients (<40 patients), depending on treatment and clinical course of the disease. While no SNP was identified, expression studies showed a trend towards lower expression of RGS16 in untreated patients. We also looked at the effects of G protein signalling pathway components RGS16, RGS1, VAV1, and CXCR4 on immune cell migration and its regulation of various cytokines. IFNβ treatment significantly downregulates RGS1, VAV1 and CXCR4 expression while Copaxone treatment did not cause different expression of RGS1, VAV1 and CXCR4 compared to healthy controls.

SELECTED PUBLICATIONS:


POTYVIRUSES

Head of the research group: Professor LILIAN JARVEKÜLG, lilian.jarvekulg@ttu.ee

The research group is engaged in fundamental and applied research of Potato potyviruses (PVY and PVA).

Potato virus Y (PVY) is the most important and widespread virus infecting potato (Solanum tuberosum), and belongs to the top 5 economically most influential plant viruses. Recently, new recombinant genotypes of PVY have appeared and their incidence is increasing throughout the world. In Estonia, the non-recombinant PVY strain used to be most common, but it now seems to have been replaced by the recombinant genotypes, as has been reported for many European countries. To study the present genetic diversity of PVY in Estonian potato, about 300 potato samples from different parts of Estonia were selected for characterization of the infecting PVY genotypes using serology, RT-PCR, sequence analyses and biotests.

Potato virus A (PVA), is closely related to PVY but is not so harmful. Both viruses have been used as model systems in the L.Järvekülg group’s studies for a long time. We investigate potyviruses (PVY and PVA)
from the aspect of plant virus-host interactions, virus structure, the relationships of the virus structure and function. As applied research, identification and characterization of new recombinant strains of Pvy in Estonia is being carried out.

IN 2016:

- The spread of potato viruses in seed potato cultivated in Estonia from 2005–2013 has been investigated with the results demonstrating Pvy as the virus prevailing in seed potato and ‘Laura’ as the potato variety most resistant to Pvy infection. PYY strains present in Estonia seed potato have been identified and characterized based on complex diagnostics (Biotest, ELISA, RT-PCR). It appeared that PvyWilga and PvyTit proved to be the most spread Pvy recombinants here. It can be concluded that PvyO in Estonia mainly has been replaced by recombinant genotypes mentioned above. Apart from these, some Pvy recombinants specific to Estonia were identified.

- When analyzing PVA CP structure by means of SAXS analysis, fluorescence spectroscopy and electron microscopy, unusual properties of PVA CP and the ability to form short virus-like particles of different shape (including rod-shaped and also spherical particles) was demonstrated. It is possible that these properties of PVA CP are applicable in the development of vaccine candidates based on the virus-like particles.

- An analysis of material on the possibility to use PVA CP VLPs as nano-carriers for the development of anti-melanoma vaccine candidate PVA CP VLP-mel is almost complete.

SELECTED PUBLICATIONS:


HELCOBACTER PYLORI-INDUCED LIVER DAMAGES

Head of the research group: Research Scientist PIRJO SPUU, pirjo.spuul@ttu.ee

The goal of the research is to explore the role of a recently uncovered aspect of Helicobacter pylori (HP) infection to liver damage. HP induces the formation of peculiar cellular structures named invadosomes in infected hepatocytes. Different strains, with distinct pathogenic outcomes, induce invadosomes with distinctive features. The specific aim is to identify the virulence factors that govern invadosomes specificities, then to correlate these findings with the subversion of the host cell functions. The specific questions are:

- What are the virulence factors of HP governing invadosome characteristics and how do they correlate with the upregulation of inflammatory cytokines in hepatocytes?
- How do these various types of invadosomes alter the behavior of hepatocytes?
- What are the signaling pathways activated by HP that control the subcellular organisation of invadosomes?

The study is expected to increase our understanding of the mechanisms behind bacteria-induced carcinogenesis. Revealing the cellular functions targeted by HP and correlating these findings with the induction of differential invadosomes should help to get new insights into liver diseases. The research explores a novel aspect of HP infection as it has a particular focus on matrix damages and associated alterations of HP-infected hepatocyte micro-environment caused by the newly discovered invadosomes. Targeting the host signal transduction pathways and key players in carcinogenesis is the first step for the development of novel drugs with reduced risks for emergence of drug resistance.

IN 2016

The research team started the work at the beginning of 2016. We have set up a biosafety level 2 (BSL2) laboratory and a permission to work with human pathogens has been granted by the Labor Inspectorate. Cultivation of HP was started in the BSL2 lab and preliminary results show that invadosomes with distinct characteristics affect cell migration differentially. We have also tested the HP strains that possess or lack the potential virulence factor CagA and it seems that CagA is involved in changes in cell shape and destroying the cell-cell contacts.
SELECTED PUBLICATIONS:


REPRODUCTIVE BIOLOGY

Head of the research group: Associate Professor AGNE VELTHUT-MEIKAS, agne.velthut@ttu.ee

Infertility is a world-wide problem with medical, socio-economical as well as psychological aspects. According to the European Society of Human Reproduction and Embryology, medical intervention is sought for by 15% of couples who wish to conceive their biological offspring (www.eshre.eu). This rate does not differ by countries. The most widely used method for helping couples with infertility problems is in vitro fertilization (IVF). During this procedure, the oocyte and sperm cells are mixed in a cell culture dish and the developing embryos are thereafter transferred back to the uterus. However, the success rate of this method is only about 30−35%, meaning that the general knowledge of human reproductive biology is far from complete.

The research group is mainly focused on the problems of female infertility and we investigate the biological processes in human ovary. The main goal is to describe intercellular molecular interactions in the ovary and to find factors that would aid in discriminating between viable and non-viable oocytes. Various genome-wide high-throughput technologies are used in this research: next-generation sequencing, proteomics and data analysis methods in the field of systems biology to mention a few. Collaboration takes place with all infertility clinics in Estonia in order to collect biological samples (ovarian granulosa cells, ovarian biopsies, follicular fluid, and blood samples) from fertile and infertile women.

IN 2016

The target genes of selected micro rnas and their roles in pre-ovulatory ovarian follicule were inves-tigated.

INTERACTION BETWEEN PLANT VIRUSES AND THEIR HOSTS

Head of the research group: Research Scientist ALLAN OLSPERT, allan.olspert@ttu.ee

The research is focused on the interaction between plant viruses and their hosts. In positive-strand RNA virus family Potyviridae, the mechanism of transcriptional slippage is used for the regulation of gene expression. Transcriptional slippage produces “edited” RNAs with an additional nucleotide at a specific location in RNA and with different coding capacity. These transcripts are also potentially subjects of alternative RNA decay pathways and are excluded from replication by viral polymerase. There may also be differences in the rates of translation and packaging in comparison to unaltered RNAs. In addition we aim to further characterize the details of potyvirus replication and to elucidate whether host RNA surveillance pathways have a significant role in maintaining the desired level of gene expression resulting from slippage. This will also increase our knowledge about RNA decay mechanisms in plant cells in general, and the potential viral modulators of these pathways.

The research has perspective wider impact on crop protection and agriculture. Furthermore, a number of medically important human pathogens such as measles, mumps, and Ebola virus also utilize transcriptional slippage. Therefore, in-depth understanding of viral polymerase slippage, polymerase error rates, frequencies and destinations of modified genomes may have implications beyond the fore-mentioned fields.

IN 2016

The research group was established in 2016. Preliminary work has focused on establishing credible methodology and experimental setup to tackle the scientific questions at hand. During this we have found regions in the 5’ area of potyviral genome that in contrast to the earlier results are not necessary for
replication and viral infection. Based on the published data and additional experiments we have described the determinants and characteristics of transcriptional slippage. We have found key nucleotide positions involved in modulating slippage rate and we are testing the method of action of these nucleotides.

SELECTED PUBLICATIONS:

TRANSCRIPTIONAL INTERFERENCE

Head of the research group: Associate Professor MART SPEEK, mart.speek@ttu.ee

Gene transcription is regulated by complex interplay of interactions between chromatin remodelers, histone and DNA chemical modifications and RNA polymerase II. Perturbations in chromatin structure or RNA polymerase traffic could result in changes or disruption of gene expression. We have recently demonstrated that intronic L1 retrotransposons and long non-coding RNA genes cause transcriptional interference (TI) in a large number of human genes. This novel concept of gene regulation is characterized by intron retention, forced exonization and cryptic polyadenylation. However, the molecular details of these effects in normal as well as disease conditions are unknown. We plan to study the molecular basis of TI by using nucleosome scanning, RNA polymerase profiling by ChIP and various other techniques. We believe that deciphering the molecular mechanisms of TI is important to understand the molecular basis of different human diseases in order to develop effective strategies for gene therapy.

A major obstacle in Alzheimer disease (AD) research is lack of basic knowledge in understanding the proteolysis of amyloid beta precursor protein (APP). Accumulation of amyloid beta, a short peptide, derived from APP is critical in AD initiation and progression. Two proteases, termed beta- and gamma-secretase, are directly involved in this process. Importantly, a rate limiting step in accumulation of amyloid beta is proteolysis by beta-secretase. However, almost nothing is known about the regulation of beta-secretase gene BACE1. Recent studies suggested that a noncoding RNA, containing several retroelements, derived from opposite strand of BACE1 is a key player in regulation of beta-secretase expression. And this RNA could strongly interfere with BACE1 expression.

We have recently demonstrated that long noncoding RNAs are involved in transcriptional interference of a large number of human genes (Kaer et al., PLoS One. 2011;6(10):e26099). We propose that studies on the BACE1 regulation at chromatin level (nucleosome occupation, RNA polymerase elongation, epigenetic marks, promoter analysis, etc.) would help to reveal the critical role of anti-BACE1 noncoding RNA (AS) in AD. In the initial phase of study, we determined distribution of BACE1-AS transcripts in 14 different human tissues. We also mapped transcription initiation and termination sites of these transcripts and determined the locations of putative promoters. This information would help to better understand the functional role of BACE1-AS in Alzheimer disease.

SELECTED PUBLICATIONS

ANGIOGENESIS

Head of the research group: Associate Professor ANDRES VALKNA, andres.valkna@ttu.ee

Angiogenesis, a formation of new blood vessels from pre-existing vessels is a normal physiological process that is closely linked with cell proliferation and apoptosis of vascular endothelial cells. It is a fundamental step in transition of benign tumors to malignant.
We have recently discovered that soluble extracellular domain of CD44, a cell surface protein functioning as a receptor for hyaluronan (HA), is capable of inhibiting vascular endothelial cell proliferation. This effect ultimately realizes in inhibition of tumor growth in vivo.

The aim of the research is to further investigate the molecular mechanism of CD44-mediated angiogenesis inhibition and angiogenesis wider. We will exploit it using traditional methods in cell and molecular biology but also using functional genomics and transcriptomics.

THE MOST IMPORTANT RESULTS IN 2016:

Our results show that CD44 KO mice display significantly higher blood vessel growth in response to angiogenesis stimulation in vivo than wild type mice. This strongly supports our previous results and suggests that CD44 and/or its soluble forms could function as physiological angiogenesis inhibitors. Systemic delivery of CD44-3MUT most probably mimics the effect of endogenous sCD44.

SMART SYNTHESIS WITH SMALL CYCLES:
EXPLORING CHEMISTRY OF THE ACTIVATED CYCLOPROPANES

Head of the research group: Senior Research Scientist DZMITRY KANANOVICH, dzmitry.kananovich@ttu.ee

This small research group was established in the autumn of 2016. The main tasks of the studies are:

- investigation of cyclopropane C-H activation reactions;
- combining benefits of metal catalysis, organocatalysis and green chemistry, using activated cyclopropanes as substrates in ring cleavage reactions;
- using early transition metals for formation of C-C and C-X bonds;
- studying host-guest interactions by UV, CD and NMR spectroscopy in order to design new supramolecular catalytic systems.

IN 2016

A considerable progress has been achieved in realization of several project tasks:

- Facile two-step conversion of carboxylic esters into distally fluorinated ketones via intermediate formation of tertiary cyclopropanols has been developed.

  The approach is based on oxidation of sulfinate salts (e.g. sodium triflinate and analogues) with tert-butyl hydroperoxide in presence of copper catalyst. This generate active high valent trifluoromethyl copper species which enable cyclopropanol ring cleavage. The mechanism of the reaction has been studied and intermediate formation of trifluoromethyl copper species has been confirmed by 19F NMR spectroscopy. The method is suitable for preparation of β-trifluoromethyl ketones as well as similar compounds.

- A novel approach for highly enantioselective synthesis of epoxyketones via aerobic oxidation of cyclopropanols has been elaborated. Enantiomerically pure epoxyketones are valuable building blocks for production of pharmaceuticals and bioactive compounds. One of the most effective methods to synthesize epoxyketones is based upon the Weitz-Scheffer epoxidation. However, despite of extensive development of its asymmetric versions in recent decades, there are still several practical shortcomings, e.g. a limited scope of substrates. For example, vinyl ketones cannot be transformed into the corresponding epoxides.

  To fill this gap, we have developed a novel facile two-step approach for asymmetric synthesis of epoxyketones from easily available cyclopropanols. Aerobic oxidation of cyclopropanols proceeds readily in the presence of Mn(III) catalysts to afford 1,2-dioxalan-3-ols in high yield. The latter can be further transformed into the corresponding enantiomerically enriched epoxyketons (with up to 97% ee) by treatment with organic base (DBU) in the presence of immobilized poly-L-leucine catalyst.

- Remote metalation of cyclopropanes was realized. Remarkable that it can be performed selective at cyclopropane C-H bonds even in the presence of neighboring aryl groups.

  As we anticipated, the reaction is completely diastereoselective, i.e. occurs at C-H bond from the side of directing group. Lithiated cyclopropane species are configurationaly stable, so we expect that elaboration of enantioselective version is also possible. Reactions of metalated species with electrophiles (e.g. D2O, TMSCl, B(Oi-Pr)3) proceed with retention of strained three-carbon ring making this method suitable for cyclopropane functionalization. We continue screening of ap-
appropriate metalation conditions and directing groups, as well as reactions of metalated species with various electrophiles, to determine the scope of the method and its limitations. The proposed approach is a useful supplement to recently developed methods of cyclopropane C-H-activation by the means of transition metal catalysis.

MOLECULAR SCIENCE

Head of the research group: Research Scientist PAVEL STARKOV, pavel.starkov@ttu.ee

Dr P Starkov joined TTÜ in 2016 to establish a well-equipped research group in Chemistry. In 2016, he was awarded Estonian Research Council Starting Grant and TTÜ Young Investigator Funding to pursue his independent investigations.

The focus of our group is on translating advances in synthetic organic chemistry to the fields of Catalysis, Chemical Biology and Materials Science by means of delivering alternative and/or significantly improved solutions. The work we have embarked on, focuses on the development of new frameworks for organocatalysis and transition metal-catalysed processes; extending boron chemistry to create new boron-based reactions, reagents and catalysts; development of new boron-based frameworks for 2D materials and organic cages. Additionally, we work on rewiring innate and aberrant cell signalling processes within the context of a living cell by designing cell-permeable small molecule-based bifunctional constructs. In all these approaches, we rely on growing expertise of our own research group at TTÜ.

IN 2016

We have gained some early insights into new boron-based catalysts and reactions and obtained a new boroxoaromatic building block for the use in 2D framework and organic cages.

We have started work on both cell biology and synthetic chemistry section of our bifunctional small-molecules section. We have created an iterative protocol for efficient preparation of short, medium and potentially very long linkers of controlled size and carrying orthogonal functionalities for use in our molecular/chemical biology studies.

We prepared a cross-linker equipped version of SU6668, a nonspecific protein kinase inhibitor, for use in biochemical/mass-spec studies by research groups at the University of Tartu.

SELECTED PUBLICATION


OXIDATION

Head of the research group: Professor MARGUS LOPP, margus.lopp@ttu.ee

The main research objects of the group are asymmetric catalytic oxidation reactions. Both, organocatalytic and metal-catalyzed reactions are studied. From metal-catalyzed reactions different metal complexes and ligands for asymmetric oxidation reactions were studied. From organocatalytic reactions use of chiral catalysts and phase transfer catalysts were studied. Also, use of different asymmetric chemistry methods in the synthesis of natural and other bioactive compounds is studied. The industrial chemistry subgroup is studying biomass degradation possibilities and oil shale kerogen oxidation possibilities in order to obtain necessary valuable chemicals.

THE MOST IMPORTANT RESULTS IN 2016:

New bioactive compounds were synthesized and tested on their anti-viral and on Trk receptor antagonist activity. The structure-activity relationship was elucidated.

A new method to perform kinetic resolution of several racemic epoxides with chiral Ti-complexes was developed.

The possibilities to transform biomass to necessary chemicals and a methodology to analyze the results was studied and developed.
SELECTED PUBLICATIONS


SYSTEMS BIOLOGY OF BACTERIA

Head of the research group: Professor RAIVO VILU, raivo.vilu@ttu.ee

The main directions of the research in the lab are as follows: systems biology of bacteria, development of models and software for the studies of metabolism of bacteria, development of omics-methods (metabolomics etc.) for the studies of microbial consortia, carrying out applied research in food technologies and nutritional studies.

IN 2016:

A prototype software environment for running novel metabolic models was developed and introduced into laboratory practice.

An isothermal microcalorimetry method was developed for the functional characterization of complex microbial consortia. The method was applied in the study of human fecal consortia. The method together with omics-methods is a unique tool for the functional studies of microbiomes not only from fecal samples but from very different sources.

A model of casein hydrolysis for the cheeses produced using thermophilic starter bacteria using MS-based proteomics was developed, and computational methods for the quantitative description of hydrolysis processes were developed.

SELECTED PUBLICATIONS:


METABOLISM OF LIPIDS AND LIPOPROTEINS

Head of the research group: Professor NIGULAS SAMEL, nigulas.samel@ttu.ee

Lipids and lipoproteins have shown to play many dynamic roles in regulating a wide array of cellular activities including metabolic and gene regulation, energy production, and signalling pathways. Lipid mediators (prostaglandins, leukotrienes and other oxylipins) have been linked to the immune and inflammatory responses, cell proliferation and apoptosis, as well as shown to be essential determinants in many pathologies, including diabetes, cancer, cardiovascular and neurodegenerative disorders. Lipid and lipoprotein producing and metabolizing enzymes and lipid-regulating metabolic cascades have been targeted for drug development. The main goals of the research team are: elucidation of fundamental structural, catalytic and regulatory aspects of enzymes responsible for biosynthesis of lipid mediators, and study of regulatory mechanisms of lipoprotein metabolism and endothelial lipolysis.

IN 2016:

An improved method of production of recombinant hPGHS-2 in the yeast Pichia pastoris was elaborated. The His₆-tagged hPGHS-2 was expressed intracellularly in P. pastoris under the control of a constitutive or methanol-inducible promoter. For protein purification a novel elution method, treatment of the affinity resin with bovine carboxypeptidase A, was employed.

A calorimetric method has been developed for determination of lipoprotein lipase activity and ligand interactions in human plasma. It was shown how apolipoproteins and angiopoietin-like proteins influence lipoprotein lipase in human plasma. The method can also be used for comparisons of the properties
of plasma samples from hyperlipidemic patients and control subjects as well as for testing of drug
candidates developed with the aim to affect the lipoprotein lipase system.

SELECTED PUBLICATIONS
pastoris and removal of the C-terminal tag with bovine carboxypeptidase A. Journal of Biotechnology, 231,
224–231.
in human plasma by isothermal titration calorimetry. Journal of Lipid Research, 58, 279–288. First Published
on November 14, 2016.

ADVANCING ANALYTICAL AND COMPUTATIONAL CHEMISTRY
METHODS FOR REGULATORY DECISIONS

Head of the research group: Senior Research Scientist MERIKE VAHER, merike.vaher@ttu.ee

The aim of the research is development and application of a variety of analytical methodologies
(primarily capillary electrophoresis) for analysis of different classes of compounds (banned chemicals,
drugs, polyphenols, fermentable sugars) in complex matrices such as environmental samples, body flu-
ids, biomass, and herbal extracts. The results obtained will be used to develop an expert system using
quantitative structure-activity relationship (QSAR).

IN 2016
An indirect capillary electrophoresis method for a quantitative determination of mono-, di- and oligosac-
charides was developed to investigate biomass degradation, the isomerization of glucose into fructose
and conversion of fructose to 5-hydroxymethylfurfural (5-HMF) in ionic liquids (ILs). Three chromophores
(2,6-pyridinedicarboxylic-, maleic-, phthalic acids) were used to perform indirect detection. The simultaneous
separation of the underivatized mono-, di- and oligosaccharides was performed using four celloctetra
oligomers (cellotriose, cellotetraose, cellopentaose, cellohexaose), eight carbohydrates (xylose, fructose, glucose,
galactose, lactose, cellobiose, raffinose, sucrose), two organic acids (acetic acid, levulinic acid) and 5-HMF.
The pretreatment efficiency of ILs combined with heat for woody biomass consisting of spruce, birch
and pine was investigated. The winter wheat straw was used as a comparison and with the aim to
enhance its digestibility during enzymatic hydrolysis whereby the influence of IL-treatment to cellulose
resistance for hydrolysis was investigated. Considering the wood species, the most common and indus-
trially important wood species in Northern Europe were chosen in the present work and the goal was
to obtain fermentable sugars and their degradation product, i.e. (5-HMF), which is a known valuable
platform chemical. Further, the differences in the yields of IL- obtainable carbohydrates between these
species were studied. The highest sugar yields were obtained to glucose in the case of spruce and ara-
binose in the case of pine sapwood. The highest 5-HMF yield was obtained for spruce heartwood with
longer treatment time (100 h). However, regarding woody biomass, the present work is focused more
on the study and analysis of the IL-containing liquid part, wood hydrolysate, after IL-treatment aiming
to answer the analysis challenges related to this fraction.

In order to model ionic liquid properties with QSPR/QSAR methodology, our inhouse software was aug-
mented by a set of quantum chemically derived electrostatic molecular descriptors including Politzer-
Murray descriptors and surface potential histograms. Nonlinear models with cross-terms based on
theoretical descriptors were developed for the prediction of Kamlet-Taft (K-T) solvatochromic parameters
that, according to the literature, are often used to guide the rational selection of ionic liquids for biomass
pretreatment. One of the main goals of the study was to search for ionic liquids that are good solvents
of cellulose. Since a general correlation between K-T solvatochromic parameters and published cellulose
solubility values could not be established, similarity searches based on surface potential histograms were
performed to find new ionic liquids suitable for cellulose dissolution. A database containing 822 cations
and 154 anions of known ionic liquids was collected from the literature. Similarity search across 126588
possible combinations of ions was performed by taking 7 best known IL solvents having cellulose (Avicel)
solubilities > 50 g/mol as reference structures. As a result, a list of ionic liquids was proposed whose
cellulose dissolution ability had not been experimentally determined according to the scientific literature.
The most important outcome was the design/making of the model of a portable narcotic tester based
on capillary electrophoresis technology, the development and validation of methodology for determina-
tion of a broad spectrum of illicit substances in human saliva.
SELECTED PUBLICATIONS:

AEROGELS AS MATERIALS FOR CHEMICAL ANALYSIS

**Head of the research group:** Lead Research Scientist MIKHEL KOEL, mihkel.koel@ttu.ee

Composite materials based on silica aerogel and modified carbon aerogels are studied.

IN 2016

The modification of organic aerogels with metals and nitrogen was studied using different methods. Silica aerogel-based composite materials, where cellulose could be the composite making polymer, were studied. Also, use of ionic liquids and solvents for this type of composite materials was studied.

Experiments on combine inorganic (silica and carbon) aerogels with cellulosic material were carried out to obtain flexible porous materials. Experiments were performed to incorporate different metals and nitrogen into the structure of aerogels. The obtained aerogels were analysed against their physical, optical and electrochemical properties.

It became clear that ionic liquids can be used for making composite materials based on aerogels. These materials can be used for preparation of sensor materials.

SELECTED PUBLICATIONS:

SUPRAMOLECULAR CHEMISTRY

**Head of the research group:** Associate Professor RIINA AAV, riina.aav@ttu.ee

The research is concentrated on the studies of chiral urea-based molecular containers. More specifically their synthesis, molecular and supramolecular structure and their interactions are under investigation. Supramolecular chemistry unites approaches of organic, analytical and physical chemistry to study matter in a broader way. Molecular containers are able to form host-guest complexes with other molecules and in a special case of inclusion complexes, a small molecule is fully encapsulated by the macrocycle. These complexes are held together by non-covalent interactions. The group is mainly interested in macrocycles that belong to cucurbituril family, the hemicucurbiturils. Cucurbiturils are non-toxic compounds and are applied in material science for example in molecular Velcro, hydrogels and -capsules as well as in biomedical applications for selective drug-delivery. The first enantiomerically pure members of cucurbituril family were prepared by our group. Hemicucurbiturils are more dynamic than normal cucurbiturils and their binding properties differ from other macrocycles, therefore they have high potential to be applied in material science and medicine.

IN 2016:
• The nomenclature of cucurbiturils was developed and published in Comprehensive Supramolecular Chemistry II.
• It was shown that the chiral (allR)cyclohexanohemicucurbit[8]uril (cychC[8]) binds anions in purely protic solvent with remarkable selectivity. The cychC[8] portals open and close to fully encapsulate anions in 1:1 ratio, resembling a molecular Pacman. Comprehensive gas, solution and solid phase studies prove that the binding is governed by the size, shape and charge distribution of...
the bound anion. The octameric cycH[8] offers a unique example of template-controlled design of an electroneutral host for binding large anions in a competitive polar solvent.

- Work on separation of isomers and homologues and their quantitative and stereochemical analysis is continued.
- Several crystal structures of new compounds were determined.

SELECTED PUBLICATIONS:


CATALYSIS

Head of the research group: Professor TÖNIS KANGER, tonis.kanger@ttu.ee

The main research objects of the group are asymmetric catalytic reactions.

IN 2016

The organocatalytic and metal-catalyzed reactions were studied. From organocatalytic reactions two types of catalysis – aminocatalysis and hydrogen bond catalysis were studied. Cascade reactions providing several new chemical bonds in one step were investigated. It increases atom-efficiency, decreases the number of steps needed and makes the whole process environmentally more benign (the number of work-up steps and amount of solvent is diminished).

Non-toxic calcium was used in metal-catalyzed reactions.

The investigation of halogen bond catalytic reactions was started as a new topic.

There main results:

- Asymmetric synthesis of 1,2,3-trisubstituted piperidines. Aminocatalytic and hydrogen bond catalysed reactions were elaborated and applied for the synthesis of target compounds.
- A new hydrogen bond catalytic method of asymmetric [2,3]-sigmatropic rearrangement was elaborated. Derivatives of homoallyl alcohols were obtained by this method from allyloxy oxindole derivatives in high yields and enantiomeric purities.
- The origin of high chemo- and stereoselectivity of aza-Michael reaction of isatin was shown by means of DFT calculations. It was found that in addition to hydrogen bond several other non-covalent interactions, such as n-n interactions of aromatic rings and sulfur-n interactions are of importance.

SELECTED PUBLICATIONS:


GREEN CHEMISTRY

Head of the research group: Professor NICHOLAS GATHERGOOD, nicholas.gathergood@ttu.ee

Our green and sustainable chemistry research group follows a ‘benign by design’ philosophy. This includes using biorenewable starting materials, developing cleaner and greener alternative synthetic procedures and studying new catalytic methodologies. In addition toxicity, ecotoxicity and biodegradation assessment of the novel compounds prepared enables priority of preferred more environmentally friendly
Chemicals. Classes of our groups target molecules range from ionic liquids, surfactants, macrocycles, cyclopropanes, γ-hydroxy-carboxylic acids, opiates and supramolecular compounds. Host-guest interactions are an important aspect of our research. Sensor applications, drug delivery and chiral recognition are all areas of interest. By studying in tandem, green toxicology, green chemistry and drug discovery, we propose that progress in these three fields is possible simultaneously. This concept is underpinned by medicinal chemistry projects studied by our group, with collaborators throughout Europe, developing new antimicrobials, analgesics and cancer therapeutics.

IN 2016

The following developments and studies were performed:

- Biocatalytic synthesis of (+)-cloprostenol and prostaglandin F2α derivatives for testing of their influence on the LPL activity (in plasma).
- Research in the field of lipase-catalyzed derivatization of γ-, δ- and ε-lactones; resolution of their enantiomers; lipase-catalyzed acylation.
- Elaboration of a technologically valid enzymatic method for the regioselective acylation of isosorbide; synthesis of a testing quantity (in the hundred-gram-scale) of monomethacrylate of isosorbide for our industrial partner (Polymer company, Finland).
- Development of cleaner synthetic methods to prepare greener ionic liquids and surfactant compounds; (eco)toxicity, biodegradation and green chemistry metrics analysis.
- Degradation of Organophosphate Pesticides Using Pyridinium Based Functional Surfactants.
- Synthesis of opiate derivatives for study in catalysis and host guest applications, DNA binding studies and as analgesics.
- High throughput screening of opiate receptor signalling based on a Luciferase reporter assay in development.
- Novel copper-catalyzed oxidative ring-opening reaction of tertiary cyclopropanols leading to synthetically valuable fluorinated ketones.
- Supramolecular chiral chemistry and porphyrin chemistry; synthesis, evaluation and elaboration of metal porphyrin dimer complexes

The most important scientific results:

Back-to-back full paper covers articles in the leading journal Green Chemistry report our integrated approach to the design of safer chemicals. This work considers the resources required to synthesize the compounds, the antimicrobial activity of the new chemicals, biodegradation under Closed Bottle Test conditions, and identification of persistent breakdown products. A high atom economy and efficient green synthesis of surfactants based on aminoacids was demonstrated. A fully mineralisable pyridinium ionic liquid was demonstrated. Sustainable natural alkaloids were incorportated into C3-symmetry ligands and DNA binding studies completed.

SELECTED PUBLICATIONS


FOOD RESEARCH

Head of the research group: Professor TOOMAS PAALME, toomas.paalme@ttu.ee

The activities of the group cover the studies of: (1) food biotechnology and systems biology; (2) flavor and aroma; (3) stability and quality; (4) nutrition and digestion; (5) food production and nutrition network.
In 2016

The following studies were performed:

- Vitamins and other bioactives in food and yeast. The main objectives were the development of simultaneous determination methods for B group of vitamins and studies of vitamin and cofactor metabolism in food processing and nutrition network. It was shown that digestion of cofactors into absorbable in gut vitamers starts already during processing. The brush boarder membrane fraction was isolated from porcine duodenum and perspectives of using it for determination of bioavailable vitamins was studied. In addition the effects of vitamins and other bioactive compounds on fermentation processes were evaluated. The research was carried out in cooperation with Estonian Competence Center of Food and Fermentation Technologies (CCFFT).

- Digestion and metabolism of dietary fiber by intestinal bacteria. The effects of dietary fiber on microbial composition (microbiota) of the large intestine, its metabolism and health effects were studied. The peculiarities in polysaccharide metabolism, energetics and in composition of fecal microbiota were correlated with overweight of children. The growth and metabolism of B. thetaiotaomicron was studied in the artificial environment simulating the large intestine.

- Composition and evolution of microbial consortia in food. The objective of the study is the development of methods for ensuring quality of spontaneously fermented foods. This includes development of analytical methods for establishment of composition of microbial consortia as well as identification of gene combinations ensuring the strain and the process stability in technological conditions applied. The second goal is to develop the methods for tracing the spoilage organisms in production chain, particularly fungi. Studies were carried out using sourdough breads as a model system.

- Systems biology of lactic acid bacteria. The objective of the study is the development of high yield processes of production of lactic acid starter cultures by optimizing the protein production expenses. For increasing acid tolerance the accelerated evolution method which enabled improvement of the acidification rate for 20% was developed. To study the molecular mechanisms of acid production the site directed gene mutations were introduced.

- The role of peptides in nitrogen nutrition of industrial yeasts. This project studies the role of peptides as nitrogen source for yeast strains (both S. cerevisiae and non-Saccharomyces strains) used in various industrial fermentation processes. A research platform has been developed which is based on i) in silico modelling of hydrolysis of proteins of defined structure using proteases with different specificity, ii) following production of peptide mixtures of suitable composition, and iii) application of these peptide mixtures as a nitrogen source in different fermentation processes (cider, wine, bioethanol). Peptide consumption is analyzed by mass spectrometry. The results obtained so far indicate a big variation in capability of different yeasts to consume peptides, depending on the presence of simple nitrogen sources (e.g. NH$_3$ or free amino acids) as well as on the composition of peptides. The project is being implemented in cooperation with CCFFT and Lallemand Inc.

- Food structure and reology. The effects of raw materials, technology and preservation methods on food structure and quality were studied. The main items were bread staling, lactose crystallization and ice recrystallization, gelling properties of furcellaran. The ice structuring proteins (ISP) were isolated from Baltic sprats and herring and their effect on microcrystalline structure of ice cream was tested.

- Food sensory and instrumental analysis. The aim is the development of methods for studies of food sensory profiles and stability. The studies concentrate on the development of off-flavors and aroma, for example in herbs. Aroma profiles of food were studied using SPME and GC/MS-O methods. The development of aroma and taste during cider, wine and kvass fermentation was studied.

SELECTED PUBLICATIONS:


DEPARTMENT OF CYBERNETICS

Director: Professor ANDRUS SALUPERE, andrus.salupere@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)
- Academic staff, total 59
  - Incl. 7 professors, 29 researchers.
- Doctoral students, total 18
- Scientific publications, total 98
- Defended doctoral dissertations in 2016, total 3

The Department conducts research within 10 research groups:
- Wave Engineering Laboratory
- Laboratory of Systems Biology
- Semiconductor Physics
- Theoretical Physics
- Mathematical Analysis
- Group and Semigroup Theory
- Inverse Problems and Stochastic Methods
- Rheology of Composites
- Photoelasticity
- Nonlinear Wave Dynamics

WAVE ENGINEERING LABORATORY

Head of the research group: Lead Research Scientist TARMO SOOMERE, soomere@cs.ioc.ee

The laboratory (wavelab.ioc.ee) was formed on 1 January 2009 to promote and provide a structure for research in water waves and coastal engineering within the Department of Mechanics and Applied Mathematics, Institute of Cybernetics and now it is one of the core labs of the Department of Cybernetics.

The team focuses on complex and nonlinear phenomena in wave dynamics and coastal engineering, and the applications of mathematical methods in wave studies. The scope of research involves, but is not limited to, long wave theory and applications (with emphasize on fast-ferry waves, shallow-water solitons, set-up and run-up phenomena, tsunami research, and generic aspects of coastal hazards), surface wave modelling, wave climate studies, and wave-driven phenomena in coastal engineering, with application to integrated coastal zone management. The rapidly emerging new foci are the use of Lagrangian transport of different substances in marine environment for marine and maritime spatial planning, adequate description of hydrodynamic (wave and water level) extremes, and preventive methods for mitigation of marine-induced hazards.

IN 2016

A comprehensive overview has been presented about the Baltic Sea wave climate, its extremes and spatio-temporal variations since the 1940s. Significant wave heights extracted from altimetry data from all existing satellites are cross-validated against available in situ wave measurements in the Baltic Sea.

Vessel-generated very deep asymmetric depression waves, similar to Riemann waves, with a depth of up to 2.5 m often occur in one of the channels (the Malamocco – Marghera channel) in the Venice Lagoon and propagate large distances into the shallow lagoon. By contrast, depression waves associated with large ships in other (the Lido and Giudecca) channels are much smaller (~0.3–0.4 m).
The slopes of trends for maxima of local storm surge heights vary from almost zero for the open Baltic Proper coast up to 5–7 cm/decade in the eastern Gulf of Finland and Gulf of Riga, suggesting a rotation of wind direction in strong storms in the Baltic Sea basin.

The presence of an upwelling event may override the classic Ekman-type drift of the surface layer and considerably slow down surface currents of surrounding water. Temporal scales of current-driven Lagrangian transport and the probability for the hits to the nearshore by pollution originating from a major fairway in the Gulf of Finland are evaluated using three-dimensional velocity fields for 1965–2004. An extensible, low-cost drifter control unit is designed and tested for use in inland water bodies or near-coast regions.

SELECTED PUBLICATIONS


LABORATORY OF SYSTEMS BIOLOGY

Head of the research group: Senior Research Scientist MARKO VENDELIN, markov@ioc.ee

The main aim of the laboratory is to study regulation of intracellular processes and understand functional influences of intracellular interactions. For this, a mixture of experimental and theoretical approaches are used.

IN 2016

In cardiac excitation-contraction coupling (ECC), calcium enters the cytosol via L-type Ca\(^{2+}\) channels (LTC) and reverse Na\(^+\)/Ca\(^{2+}\)-exchange (NCX\(_{\text{rev}}\)), or is released from the sarcoplasmic reticulum (SR) by Ca\(^{2+}\)-induced Ca\(^{2+}\)-release (CICR). The magnitude of Ca\(^{2+}\) influx via the different pathways varies with the state of the cell and is difficult to assess quantitatively, because changes in Ca\(^{2+}\) influx through one pathway affect the others. In our laboratory, we developed a method to quantify the Ca\(^{2+}\) influx pathways. The novelty of our method lies in the mathematical analysis of measured transsarcolemmal Ca\(^{2+}\) currents and their impact on the corresponding Ca\(^{2+}\) transient during gradual inhibition of the currents in action potential (AP) clamp. The developed method was tested using an excitation-contraction model and showed that the method was able to recover calcium fluxes from noisy synthetic data. We applied the approach to trout ventricular myocytes and quantified the relative contributions of different Ca\(^{2+}\) influx pathways in ECC and determined the kinetics of these fluxes. In summary, the developed method resolves the major problem how to separate highly interconnected fluxes in AP clamp and allows to study Ca\(^{2+}\) fluxes in cardiomyocytes under conditions close to in vivo.

Adequate intracellular energy transfer is crucial for proper cardiac function. In energy starved failing hearts, partial restoration of energy transfer can rescue mechanical performance. There are two types of diffusion obstacles that interfere with energy transfer from mitochondria to ATPases: mitochondrial outer membrane (MOM) with voltage-dependent anion channel (VDAC) permeable to small hydrophilic molecules and cytoplasmatic diffusion barriers grouping ATP-producers and -consumers. So far, there is no method developed to clearly distinguish the contributions of cytoplasmatic barriers and MOM to the overall diffusion restriction. Furthermore, the number of open VDACs in vivo remains unknown. The aim of our work was to establish the partitioning of intracellular diffusion obstacles in cardiomyocytes. We studied the response of mitochondrial oxidative phosphorylation of permeabilized rat cardiomyocytes to changes in extracellular ADP by recording 3D image stacks of NADH autofluorescence. Using cell-specific mathematical models, the permeability of MOM and cytoplasmatic barriers was determined. It was found that only ~ 2% of VDACs are accessible to cytosolic ADP and cytoplasmatic diffusion barriers reduce the apparent diffusion coefficient by 6–10 ×. In cardiomyocytes, diffusion barriers in the cytoplasm and by the MOM restrict ADP/ATP diffusion to similar extents suggesting a major role of both barriers in energy transfer and other intracellular processes.

SELECTED PUBLICATIONS


SEMICONDUCTOR PHYSICS

Head of the research group: Professor JÜRI KRUSTOK, jyri.krustok@ttu.ee

The research topics in the Semiconductor Physics Group are mainly related to semiconductor physics in close collaboration with the Department of Materials and Environmental Technology. Most studies involve optical and electrical characterization of absorber materials for solar cells and search of new semiconductor materials. Low temperature photoluminescence spectroscopy, Raman spectroscopy, XRD, XPS, Hall effect, capacitance spectroscopy and modulation spectroscopy are the main experimental methods. The studied materials include Cu$_2$ZnSn(S$_2$Se$_5$)$_2$, ZnO, TiO$_2$, CuInSe$_2$, MoSe$_2$, SnS, Sb$_2$S$_3$, CdTe.

IN 2016

Thin film CZTSe solar cells from Barcelona were studied by measuring temperature dependent electrical properties. We showed how grain boundary states affect impedance measurements and how we can obtain useful information from low temperature impedance data by using CPE element in the ordinary equivalent circuit of solar cell.

The role of different Se treatments on defect structure and PL properties of CZTSe thin films were studied together with researchers from Northumbria University. We discovered a material where so-called BB band was visible at temperatures T = 6 – 300 K for the first time.

The role of H ion implantation on defect structure of CuInSe$_2$ single crystals grown at Strachclyde University was studied. PL bands showed a red-shift and the average depth of potential fluctuations was increasing with increasing H dose.

A new study of CVD grown MoSe$_2$ monolayers from Rice University in close co-operation with different universities was started. It was shown that the so-called aged MoSe$_2$ monolayers, which were considered to be extremely stable in ambient conditions, are not stable at all and their properties change after about 1 year. We discovered that the surface roughness was increased and exciton PL peaks were red-shifted of about 70 meV in aged monolayers. Such behavior was explained by a local tensile strain and exciton localization. A theoretical model of localized excitons, published in 2005 was applied for the first time on CVD grown monolayers.

TiO$_2$:Zr thin films were grown by the chemical spray pyrolysis (CSP) method and the phase composition and properties of films with different Zr concentration were studied. The results indicate that CSP is a suitable and relatively cheap method to deposit Zr-doped TiO$_2$ films for electronic, incl. photocatalytic and photovoltaic applications.

Gold nanoparticles were distributed by spray pyrolysis technique on bare glass substrates and on glass covered by titanium dioxide thin films grown by atomic layer deposition, and were embedded in titanium dioxide layers. Plasmonic absorption was detected in the visible spectral range. The particles deposited on glass and on 80 nm thick titanium dioxide film resulted in appearance of an absorption band peaking at 550 nm. The plasmonic absorption maxima shifted towards longer wavelengths after embedding the particles into a top TiO$_2$ layer.

SnS films were grown in air by chemical spray pyrolysis method using aqueous solutions containing SnCl$_2$ and SC(NH$_2$)$_2$ at molar ratios of 1:1 and 1:8 and a substrate temperature of 200°C. All samples were studied using X-ray diffractometry, Raman spectroscopy, energy-dispersive X-ray analysis, and ultraviolet-visible spectroscopy.

SELECTED PUBLICATIONS


THEORETICAL PHYSICS

Head of the research group: Professor JAAN KALDA, kalda@ioc.ee

The research group is involved in the following studies:

Photovoltaic materials. The group has been studying the basic physical properties (stability, electronic and optical properties) of novel photovoltaic materials (hybrid-perovskite and CZTS) by using quantum chemical and density functional theory based computational methods.
Localized oscillations in solids. The efforts are focused on solving the key issues regarding the ILM-s (Intrinsic Localized Modes) and LLM-s (Intrinsic Localized Modes), polarization and conditions of excitation of ILM- as well as LLM-s in different 3-D crystals with long-range interactions.

Algebraic formalism of dynamical systems. The aim of the research is to create an algebraic formalism for researching the properties of homogeneous time scale dynamical systems (accessibility, linearizability etc.), based on the vector fields.

Lunar surface photogrammetry. The target is the mapping of Apollo 12 lunar expedition landing site with the use of photographs made in situ by the crew.

Wave equations for superspins. The studies of relativistic wave equations for arbitrary superspins are carried out.

SO(1,4) Superalgebras. The existence of SO(1,4) superalgebras is investigated.

Turbulent mixing. The research group has complemented the Fokker-Planck equation describing the Lagrangean statistics of material elements with a term describing the effect of finite time correlations of real turbulent flows, and related the parameter values to the statistical integral of motion of Lagrangean dynamics.

Econophysics. The scale-free properties of the Estonian economical network are studied based on the database of wire transfers of Swedbank. It has been shown that there is a clustering of vertices (companies) into sub-groups, so called cliques or communities, which appear to have a considerable correlation with the industry attributes.

IN 2016

The most notable research results obtained are:

- The dependence of the band gap (CZTS-Se crystal) from the mixing parameter in the hybrid calculations was investigated.
- The properties of the transversal ILM moving along the zigzag chain of atoms and Ge crystal with real interaction potential were studied.
- Using the concept of Lie derivatives, the accessibility conditions for systems obeying homogeneous time scale were formulated in terms of vector fields.
- Novel Fokker-Planck equation was derived for the description of Lagrangean statistics in real time-correlated turbulent velocity fields.
- It was shown that the Estonian economic network obeys multifractal properties.
- Based on a series of photographic images, a three-dimensional model of landing site of Apollo 12 was constructed.
- Novel superalgebra, where Poincare algebra is substituted with de’Sitter SO(1,4) algebra, was derived.

SELECTED PUBLICATIONS


MATHEMATICAL ANALYSIS

Head of the research group: Senior Research Scientist GERT TAMBERG, gert.tamberg@ttu.ee

The research group studies:

- the generalized Shannon sampling operators that mean the representations of functions in terms of series, where the expansion coefficients are its samples and expansion functions are translates of certain kernel function. In the case of Kantorovich-type sampling operators we take, instead of point estimates, some local averages as Fejer-type singular integrals;
- applications of the generalized sampling operators in Signal Processing, especially in imaging applications, where the generalized sampling operators are a natural tool for image resampling; applications in HDR imaging and the applications of sampling operators in time series analysis and linear prediction are also studied;
• the generalized summability methods that mean the case where the elements of the sequence belong to the Banach space and the elements of the matrix are linear bounded operators. The estimations of the rapidity of the convergence are essential if we use the computational techniques. The problems of convergence acceleration are particularly topical. We prove the Tauberian remainder theorems in the case of the generalized methods of summability.

IN 2016

We considered sampling operators, defined using an even band-limited kernel function. Approximation properties of generalized sampling operators in Lebesgue spaces were studied. We generalized the Kantorovich-type sampling operators. We used Fejer-type singular integrals, which allowed us to estimate the order of approximation via a modulus of smoothness of higher order. Norms of generalized Kantorovich-type sampling operators were also estimated and the approximation properties of generalized sampling operators in the case of functions with bounded variation were studied.

We used image-resampling algorithms, based on sampling operators in super resolution algorithms. The studies about possibilities to apply sampling operators in time series analysis and linear prediction were started.

We proved the Tauberian remainder theorems in the case of the generalized methods of summability. We weakened the Tauberian conditions in the case of the generalized methods of summability.

SELECTED PUBLICATIONS


GROUP AND SEMIGROUP THEORY

Head of the research group: Professor PEETER PUUSEMP, peeter.puusemp@ttu.ee

The research is focused on

• the study of the connection between groups and their endomorphism semigroups,
• the applications of group theory.
• The aim is to describe some well-known classes of finite groups by their endomorphism semigroups and to decide whether a group is determined by its endomorphism semigroup in the class of all groups or not.

MAIN RESULTS IN 2016:

• It was proved that all 51 finite groups of order 32 are determined by their endomorphism semigroups in the class of all groups.
• There exist exactly 14 non-isomorphic groups of order 36. It is proved that three of them are not determined by their endomorphism semigroups in the class of all groups. All groups that have an endomorphism semigroup isomorphic to the endomorphism semigroup of a group of order 36 are described.
• The distribution of the multi-party Diffie-Hellman common secret keys was studied with the platform group being an arbitrary finite cyclic group. As a result, it was proved that the secret keys are not uniformly distributed.

SELECTED PUBLICATIONS


INVERSE PROBLEMS AND STOCHASTIC METHODS

Head of the research group: Professor JAAN JANNO, jaan.janno@ttu.ee

The research is concentrated on: (1) analysis on inverse problems in science and technology; (2) development of stochastic methods for inverse problems and other applications.
MAIN RESULTS IN 2016:

- Investigation of inverse problems for parabolic differential equations containing generalized fractional derivatives was started. First the case when the equation contains a perturbation of a classical fractional derivative (e.g. integral defining the derivative is complemented by a convolution of a power function with a negative exponent by a certain kernel). Existence, uniqueness and stability of a solution of an inverse problem to determine the order of the derivative and the kernel was proved. Next a more general inverse problem was taken into consideration. There the unknown is an arbitrary positive and decreasing function under an integral defining the generalized fractional derivative. A corresponding inverse problem was formulated in an equivalent form of an evolutionary integral equation. The uniqueness of the solution was proved and sufficient conditions for the existence and stability were established. (J. Janno, K. Kasemets, N. Kinash)

- Jointly with P. Piironen (University of Helsinki) the Fractional Brownian motion from bayesian methods was studied. Especially the question "What kind of information from the unknown hurst parameter H can one retrieve by sampling one, but arbitrary, realisation of the FBM?" was in the focus. By using statistical inversion several laws of large numbers were proved in order to show that the expectation of the posterior distribution after finite sampling converges optimally to the true value of H and the limit distribution is normal. Moreover, jointly with J. Christiina (Lausanne), it was proved that it is possible to derive a lower bound for the difference of the background metric g and the inclusion metric on a manifold M. (L. Päivärinta)

- Cooperation continued with the Estonian Environment Agency. In the framework of this cooperation different nonparametric methods on estimation of Estonian forestry proportion were applied. Also, different forestry growth models were composed. (M. Pihlak)

SELECTED PUBLICATIONS


RHEOLOGY OF COMPOSITES

Head of the research group: Senior Research Scientist HEIKO HERRMANN, hh@cens.ioc.ee

The research topic is concerned with the mechanical properties of composites containing short fibres. The main application is steel fiber reinforced concrete, a construction material, the use of which is gaining momentum in the building industry. The mechanical properties largely depend on the orientation of the short fibers, which in turn is influenced by the production process of the parts. In particular the flow of the fresh concrete mass, which is mixed with the fibers, determines the fiber orientations. In this context the research on stereoscopic semi-immersive 3D visualization (virtual reality) has been developed, which is conducted on the self-developed “Kyb3” system.

One of the most important factors to determine the mechanical properties of a fiber composite material is the orientation of the fibres in the matrix. Their orientation might differ in distinct parts of the structural element as dependent from the casting techniques and mould materials.

IN 2016

Three main results have been obtained:

1. For the use in load bearing structures, a constitutive mapping is necessary to calculate the design load and to predict cracking behaviour. A constitutive mapping based on the use of isotropic tensor functions of the strain tensor and the orientation tensor has been proposed. The model solves some issues of other approaches.

2. An algorithm to retrieve the single fibre’s orientation information out of SFRC samples scanned through a μCT scanner has been developed. The software implemented with the algorithm includes a data filtering component to remove the noise from the datasets and prepare them correctly for the analysis.

3. Numerical simulations of the flow of fiber concrete show that the surface quality (slipperiness) of the formwork should have an influence on the fiber orientations. The experimental setup for
the casting experiments with polymers (Carbopol, Stabilize) as replacement matrix is set up and experiments are being performed.

SELECTED PUBLICATIONS


PHOTOELASTICITY

Head of the research group: Senior Research Scientist JOHAN ANTON, johan@ioc.ee

In more than 50 years the Laboratory of Photoelasticity has developed theory, methods and measurement technology for determining residual stresses in glass articles of complicated shapes. This technology, photoelastic tomography, is implemented in the automated polariscope AP, accompanied with intelligent algorithms for measuring residual stresses in drinking glasses, bottles, electric lamps, optical fibre preforms, cathode-ray tubes, etc. To measure residual stresses in architectural glass panels and automotive glazing a polariscope SCALP, based on the scattered light method, has been developed. This measurement methodology is used in many glass factories all over the world.

IN 2016

The most remarkable results are the stress analysis in Prints Rupert drops and the development of a new method for measuring stress in chemically strengthened glass.

Prince Rupert’s drops (PRDs), also known as Batavian tears, have existed since the early 17th century. They are made of a silicate glass of a high thermal expansion coefficient and have the shape of a tadpole. Typically, the diameter of the head of a PRD is in the range of 5–15 mm and that of the tail is 0.5 to 3.0 mm. PRDs have exceptional strength properties: the head of a PRD can withstand an impact with a small hammer, or compression between tungsten carbide platen to high loads of ~15 000 N, but the tail can be broken with just finger pressure leading to catastrophic disintegration of the PRD. We show here that the high strength of a PRD comes from large surface compressive stresses in the range of 400–700 MPa, determined by using techniques of integrated photoelasticity. The surface compressive stresses can suppress Hertzian cone cracking during an impact with a small hammer or compression between platen. Finally, it is argued that when the compressive force on a PRD is very high, plasticity in the PRD occurs, which leads to its eventual destruction with increasing load.

A new non-destructive gradient scattered light method is presented for micron-scale stress profile measurement in chemically strengthened (chemically tempered, ion exchanged) glass. Direct non-destructive stress measurement in the surface layer (<100 μm) of chemically strengthened glass is reported for the first time. This is accomplished by passing a narrow laser beam through the surface layer of the glass at a considerable large incidence angle of 81.9°. The theory of gradient scattered light method is based on the ray tracing of ordinary and extraordinary rays in chemically strengthened glass and calculating the optical retardation distribution along the curved ray path. The experimental approach relies on recording the scattered light intensity and calculating the optical retardation distribution from it. The experimental procedure is developed to the level of full automation and the measurement time is less than 10 s.

SELECTED PUBLICATIONS


NONLINEAR WAVE DYNAMICS

Head of the research group: Professor ANDRUS SALUPERE, andrus.salupere@ttu.ee

The group has focused on the following research problems:

1. Analysis of waves in microstructured solids. A large-scale analysis of dispersive and nonlinear effects is carried out to reveal mechanisms of wave profile distortions, including waves in hierarchical microstructured solids.
2. Solitons and solitary waves. The mechanisms of emergence of soliton ensembles and solitonic structures are examined for cases with complicated dispersion. The emergence of solitons is analyzed making use of Boussinesq-type (two-wave) models and KdV-type (one-wave) models which describe waves in microstructured solids and mechanical waves in biomembranes.

3. The theory of continua and internal variables. The description of the internal structure of materials is considered using internal fields. The corresponding mathematical models of wave motion in microstructured solids take consistently into account nonlinear, dispersive and temperature effects and a possible multiscale of a microstructure.

4. Nondestructive testing of materials. Nonhomogeneous materials (including laminated materials) are under consideration. Methods for determination of mechanical properties of materials and for detection of defects in laminated objects are developed.

IN 2016

Reflection and transmission of elastic waves at the interface between two distinct micromorphic media was considered in the one-dimensional setting. A dual internal variable approach was used for the description of the influence of the microstructure on the global motion. It has been shown that reflection and transition coefficients for plane waves depend on the coupling between macro- and micro-motions as well as on the choice of the microstructural interaction at the interface.

Description of heat conduction in microstructured solids was presented in the framework of the dual internal variables. Microtemperature was considered as a macrotemperature fluctuation. The macroscale heat conduction was described by a parabolic equation which is coupled with the hyperbolic equation for the microtemperature. Numerical simulations demonstrate the formation and propagation of thermoelastic waves in microstructured solids under thermal loading.

A coupled model was derived for describing the propagation of mechanical wave that accompanies the (electrical) nerve pulse during its propagation along the nerve axon. The model results in a system of equations that combine the FitzHugh-Nagumo equations for electrical signals and a Boussinesq-type equation for description of propagation of mechanical waves. First numerical experiments demonstrate that soliton-like waves can be formed from arbitrary inputs.

An original signal processing method called delayed Time Reversal-Nonlinear Elastic Wave Spectroscopy was developed. The method could be used to amplify a signal in certain regions of the material under Non Destructive Testing. It allows to optimize and change the shape of the received focused wave in the material, either by making the focusing sharper by decreasing the side lobes or making it wider by modifying the actual focusing peak. It is also possible to use the focused signal as a delta-basis to construct a signal with arbitrary envelope or reduce the side lobes of the focused signal. These concepts are shown to work well in the simulations and the physical experiments.

SELECTED PUBLICATIONS


DEPARTMENT OF MARINE SYSTEMS

Director: Professor JURI ELKEN, juri.elken@msi.ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)

- Academic staff, total 35
  - Incl. 4 professors, 28 researchers.
- Doctoral students, total 15
- Scientific publications, total 67
- Defended doctoral dissertations in 2016, total 5

The Department conducts research within 2 research groups:

- Dynamics of Gradient Systems
- Modelling and Remote Sensing of Marine Dynamics

RESEARCH GROUPS

DYNAMICS OF GRADIENT SYSTEMS

Head of the research group: Professor URMAS LIPS, urmas.lips@msi.ttu.ee

The research topic is focused on multiscale physical processes that significantly control the biogeochemical cycles of substances as well as mixing and dispersion of particles and pollutants, especially in the boundary layers and in the pycnoclines (seasonal thermocline and halocline) of the Baltic Sea. The in-situ observations using new technologies combined with high-resolution numerical simulations and laboratory experiments are the main study method. A major task in hydrodynamics is to make a step forward in the quantitative description of sub-mesoscale processes and their impact, both their direct and large-scale/distant influence on water and matter exchange between sub-basins, coastal and open sea and different layers. Marine ecology studies are concentrated on lower trophic levels: pelagic and benthic primary producers and benthic invertebrates – on their dynamics and role in nutrient cycles in the eutrophied Baltic Sea. Practical outcomes of the research are the development and application of novel marine monitoring and assessment methods as well as environmental impact assessment of different marine development plans and projects.

IN 2016

Regular high-resolution measurements enable to determine statistical parameters and spatio-temporal variability of mesoscale and sub-mesoscale processes in the Gulf of Finland. Dominating westerly winds cause a deeper position of the seasonal thermocline in the northern gulf, and therefore the wind impulse needed to initiate an upwelling event of certain intensity must be larger near the northern coast than near the southern coast. Long-term easterly winds cause upward movement of the thermocline in the entire gulf thus supporting the development of upwelling near the southern coast. The westerly winds lead to the reversed vertical movement of the thermocline, and the development of upwelling near the northern coast is suppressed. An important role of sub-mesoscale processes in the energy cascade from larger to smaller scales has been revealed: in the interval of 10–0.5 km, the horizontal temperature variance spectra convert to a −2 slope while quasi-geostrophic turbulence should follow a −3 slope.

The analysis of numerical simulation and wind data showed that basin scale circulation in the Gulf of Riga is predominantly anticyclonic in summer months (negative wind field vorticity, strong stratification) and cyclonic in autumn-winter (positive wind field vorticity, weak stratification). Thus, the seasonal and inter-annual variability of the wind field determine the spreading patterns of the river discharge (also nutrients) in the gulf. The Daugava River discharge forms an anticyclonic bulge and jet current along the eastern coast; the river volume flux divides approximately into halves between them. The water inflow from the Baltic Proper through the Irbe Strait (flow over the sill) may in certain conditions realize in the form of mesoscale cyclonic eddies in the northern Gulf of Riga.
Investigation of geographically close populations of the spring bloom diatom, Skeletonema marinoi, showed that the populations are locally adapted and have a competitive advantage in their native environment. This indicates that differential selection pressure might support the genetic differentiation of the populations. The same species also showed genetic differentiation on temporal and spatial scales during a spring bloom in different basins of the Baltic Sea. Temporal genetic differentiation indicates the presence of different phenotypes in the bloom, which are adapted to different environmental conditions, e.g. low nutrient concentrations, and help the species to participate in the bloom for a longer period.

The entrapment and feeding of the mixotrophic ciliate Mesodinium rubrum in the mucus threads in cultures with toxic Dinophysis was described and quantified. In cooperation with a scientific group from University of Copenhagen it was documented for the first time that kleptochloroplasts (without prey nuclear material) taken up by D. acuta exhibit photoregulation, where photosynthetic pigments are produced to improve growth under both high and low irradiances. The obtained results help to explain how D. acuta is able to survive for extended periods experiencing prey starvation and low light environment. The evidence of phosphate and nitrate uptake by the migratory dinoflagellate H. triquetra in a cold environment in the absence of light was documented verifying the previous hypothesis based on field studies in the stratified Baltic Sea.

SELECTED PUBLICATIONS

MODELLING AND REMOTE SENSING OF MARINE DYNAMICS
Head of the research group: Professor URMAS RAUDSEPP, urmas.raudsepp@msi.ttu.ee

The research is directed to: (1) studies on cause-response relationships of large-scale circulation patterns and biogeochemical fields in the Baltic Sea; (2) development and operational implementation of marine monitoring methods, which are based on satellite and airborne remote sensing as well as on bio-optical measurements; marine physics, water quality, sea ice, atmospheric processes etc.; (3) bulk processing and statistical analysis of large remote sensing datasets for process studies in marine research; (4) development, testing and implementation of real time marine operational measurement systems; (5) development of coupled circulation-wave-ice-atmospheric models for climate and process oriented studies, near-real time marine services and reanalyses; (6) sea and ocean hazards in the coastal zone including tsunami, rogue waves, extreme storms and storm surges, ship generated waves, internal waves, their dynamics in the coastal zone and impact on coast.

IN 2016

Numerical modelling of waves, circulation and biogeochemical processes in the Baltic Sea was continued. Validation methods for numerical model results were further elaborated and harmonized for different European seas. Impact of pollution from shipping on the Baltic Sea marine ecosystem and dispersion of pollutants were studied by applying a 3D hydrodynamics model coupled with a biogeochemical model. The multi-year simulations of the circulation and nutrient dynamics in Lake Peipus and the Võrtsjärv were performed. In a fine spatial scale, the impact of road construction on SPM concentrations was studied by applying a high-resolution model in the coastal zone of the Tallinn Bay.

The wave-current interactions were studied to estimate the effect of wave fields on sea level, water currents and temperature, and sea surface currents and sea level height on significant wave height. Wave and circulation models were coupled and numerical simulations were conducted in the Baltic Sea in order to quantify the effects of Stokes-Coriolis forcing, wave dependent momentum transfer and wave dependent kinetic energy flux. High-resolution wave modelling for Finnish Archipelago area was performed in order to test the performance of SWAN/WAM and WAVEWATCH models (in co-operation with FMI). WAM with 1 nm resolution was set up operationally for the Baltic Sea in the framework of Copernicus activities. Research of wave impact on benthic communities and shoreline changes was continued.
Remote sensing algorithms/methods for retrieval of wave field parameters (significant wave height, wave propagation direction, wavelength) from space borne synthetic aperture radar and coastal radar imagery were elaborated. An analysis of active and passive remote sensing imagery was carried out to describe statistically the ice conditions in the Baltic Sea over a 16-year period.

Analytical, experimental and numerical studies of tsunami, rough wave and nonlinear wave theory and dynamics were advanced.

An oil spill detection and monitoring system consisting of a ferry-box system, innovative buoys, coastal radar data and UAV technology was further developed and tested. The methodology for processing of a very high resolution wave and ice data from coastal radar observations was implemented. Engineering solutions for reliability and persistency of real-time sea level and wave measurement network were refined.

**SELECTED PUBLICATIONS**


TOOP countries and partner organisations

Coordinator: Tallinn University of Technology (Estonia)

51 organisations from 21 countries: Austria, Belgium, Bulgaria, Denmark, Estonia, Finland, Germany, Greece, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Sweden, Turkey

3 sectors: public administration organisations, research organisations, private companies

For more information, please contact the coordinator:

Prof. Dr. Robert Krimmer, Tallinn University of Technology
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SCHOOL OF BUSINESS AND GOVERNANCE

Dean: Professor ENN LISTRA
e-mail: enn.listra@ttu.ee

Vice-Dean for Research: Professor TIINA RANDMA-LIIV
e-mail: tiina.randma-liiv@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)
- Academic staff, total 178
  - Incl. 25 professors, 34 researchers
- Doctoral students, total 120
- Scientific publications, total 359
- Defended doctoral dissertations in 2016, total 12

DEPARTMENTS

DEPARTMENT OF BUSINESS ADMINISTRATION
Acting Director: TOOMAS PILISTE, toomas.piliste@ttu.ee

DEPARTMENT OF ECONOMICS AND FINANCE
Director: Professor KADRI MANNASOO, kadri.mannasoo@ttu.ee

DEPARTMENT OF LAW
Director: Professor TANEL KERIKMAE, tanel.kerikmae@ttu.ee

RAGNAR NURKSE DEPARTMENT OF INNOVATION AND GOVERNANCE
Director: Senior Research Scientist ERKKI KARO, erikki.karo@ttu.ee
DEPARTMENT OF ECONOMICS AND FINANCE

Director: Professor KADRI MANNASOO, kadri.mannasoo@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)

- Academic staff, total 32
  - Incl. 6 professors, 2 researchers.
- Doctoral students, total 26
- Scientific publications, total 37
- Defended doctoral dissertations in 2016, total 1

The Department conducts research within one research group:

RESEARCH GROUP OF FINANCE AND ECONOMIC ANALYSIS

Head of the research group: Professor KADRI MANNASOO, kadri.mannasoo@ttu.ee

The Department of Economics and Finance carries out academic research with clear applied and policy-oriented perspectives. The research is cross-disciplinary and focuses on linkages between different sectors of the modern market economy in a globalised world. The emphasis is on studies of economic change and development and how policy choices support sustainable growth, efficient resource use, economic and financial stability, and social cohesion. The research methodology is based on rigorous empirical analysis and topics of particular importance for the rapidly transforming Estonian economy.

IN 2016

The research topics included productivity, human capital development and capacity building, policy impact analysis and financial issues related to financial institutions, non-financial companies and financial markets in sustaining financial stability and a smoothly operating financial system.

SELECTED PUBLICATIONS


RAGNAR NURKSE DEPARTMENT OF INNOVATION AND GOVERNANCE

**Director:** Senior Research Scientist ERKKI KARO, erkki.karo@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)
- Academic staff, total 32
  - Incl. 8 professors, 19 researchers.
- Doctoral students, total 46
- Scientific publications, total 86
- Defended doctoral dissertations in 2016, total 5

The Department conducts research within 7 research groups:
- Governance
- e-Governance
- Fiscal Governance
- Technology Governance and Innovation Policy
- Public Management and Policy
- Public Sector Innovation
- Philosophy of Science and Technology

RESEARCH GROUPS

GOVERNANCE

**Head of the research group:** Professor WOLFGANG DRECHSLER, wolfgang.drechsler@ttu.ee

The group has focused on the analysis of governance theories and paradigms in the context of modern socio-technical changes. Special focus has been on the following topics: (a) comparative analysis of global paradigms of governance (comparison of Western and non-Western/Asian paradigms and traditions); (b) the impact of technological changes on governance, including the emergence of the concept of smart city and the impact of P2P technologies on production and consumption traditions and governance models.

In addition to high-impact publications with unique contributions on these topics, the group has also been active in knowledge transfer to society: e.g. Dr. Kostakis acted as P2P technology adviser to the Office of Prime Minister in Greece; Prof. Drechsler is one of the most known experts on non-Western and Asian governance paradigms who has been invited to several conferences and (Asian) universities to present his research on the topic. In addition, the whole group has actively contributed (research, outreach activities) to the globally visible work of P2P Lab and P2P Foundation.

**SELECTED PUBLICATIONS**


e-GOVERNANCE

Head of the research group: Professor ROBERT KRIMMER, robert.krimmer@ttu.ee

The group has focused on building up an independent e-Governance research stream at TTÜ with specific focus on the following topics: (a) developing principles and methods for user-centric development of e-Governance services and systems; (b) social science research on the use of new identity management technologies and open data in the public sector as well as carrying out pilot projects in the framework of H2020 projects; (c) development of frameworks and models for securing verifiability of and trust in e-voting.

In 2016, the group initiated and coordinated the Estonian pilot of the Open Government Intelligence H2020 project (http://www.opengovintelligence.eu), succeeded in gaining financing for the first Erasmus Mundus joint MA degree in TTÜ on Public Sector innovation and e-Governance, and put together an EU-wide consortium of academic and policy organizations (from 20 countries) that gained for 2017–2019 financing for the largest e-government and public sector innovation project in the EU on the once-only principle (www.toop.eu). In addition, the group members have been active in advising and studying different countries (Estonia, Switzerland, Australia, South Korea, Japan etc.) on how to build user-centric e-Governance systems. This work has been carried out by both senior and junior researchers (e.g. in 2016, M. Nielsen carried out his PhD studies at the UNU-eGov group that supports UN in developing global e-governance capabilities).

SELECTED PUBLICATIONS


FISCAL GOVERNANCE

Head of the research group: Professor RINGA RAUDLA, ringa.raudla@ttu.ee

The group has been researching the impact of fiscal and financial policy bureaucracies (its structure, principles of policy coordination and learning etc.) on fiscal and financial policies in the Baltic Sea region (comparison between the Baltics and Scandinavia). This is a relatively novel theoretical and empirical focus as the Baltic Sea region is unique in its economic and political integration patterns (economically highly interlinked economies functioning in different monetary systems and fiscal traditions). The group is relatively young, but it has already gained global recognition for its research work, e.g. Prof. Raudla was elected to the editorial board of the leading journal on governance and institutional analysis Governance and initiated a permanent working group on fiscal governance and administration at IASA (governance and public administration research society with the widest reach globally).

SELECTED PUBLICATIONS


TECHNOLOGY GOVERNANCE AND INNOVATION POLICY

Head of the research group: Researcher-Professor RAINER KATTEL, rainer.kattel@ttu.ee

The group focuses on the analysis of Estonian research, development and innovation policies, including international comparisons, domestic policy analysis and evaluation. In 2016, special focus was on the impact of EU-wide policy concepts – societal challenges, smart specialization – on the formation, design and implementation of Estonian and Central and Eastern European RDI strategies, policies and policy mixes. The basic research of 2016 led to the initiation of 3 applied research projects funded by the Estonian Research Council on the evaluation of H2020 from the perspective of EU13, final assessment of the Estonian national R&D programs from the period 2007–2013, and on developing principles for RDI policies in the context of growing impact of global value chains and its’ different governance systems.

The members of the research group were also active in the global arena. Prof. Kattel worked as guest professor at the Earth Institute at Columbia University and Dr. Karo as JSPS post-doctoral fellow at National Graduate Institute for Policy Studies (GRIPS, Tokyo, Japan). Prof. Kattel was also elected researcher-professor of the Estonian Academy of Sciences on innovation studies for 2016–2018.

SELECTED PUBLICATIONS


PUBLIC MANAGEMENT AND POLICY

Head of the research group: Professor TIINA RANDMA-LIIV, tiina.randma-liiv@ttu.ee

The research group focused on publishing research carried out in the framework of FP7 project “Coordinating for Cohesion in the Public Sector of the Future (COCOPS)”. The main focus was on the impact of the financial and fiscal crisis on public administrations and public management practices in Estonia and across Europe. The group co-published its research also together with leading EU scholars (e.g. Prof. Randma-Liiv, and W. Kickert co-edited a special issue on "Fiscal Crisis and European Public Administration: Comparative Policy Responses" in the Journal of Comparative Policy Analysis). Also, the group prepared several successful project proposals to continue its domestic and international research: Dr. Sarapuu was awarded a personal grant by the Estonian Research Council and the group as a whole participated in the preparation of a successful H2020 project (TROPICO), both starting in 2017. Dr. Sarapuu became the co-chair of one of the core and longest lasting permanent study groups at eGPA ‘Governance of Public Sector Organizations’ as well as member of the steering group of NISPACee. Prof. Randma Liiv was awarded the National Science Prize in social science category by the Estonian Government.

SELECTED PUBLICATIONS


PUBLIC SECTOR INNOVATION

Head of the research group: Senior Research Scientist VEIKO LEMBER, veiko.lember@ttu.ee

The research group focuses on the development of the globally emerging theories of public sector innovation, with rather unique focus on technology driven innovations (i.e. emergence of machine to machine coordination in the public policy processes). Most other research groups in this area focus on organizational and managerial innovations and the group has also contributed to the latter streams, i.e. the role of co-production, public procurement processes, iLabs and state owned enterprises as instruments of innovation in the public sector. The group has actively collaborated both with Estonian policy makers (through participation in the work of the social and public sector innovation taskforce active at the Office of the Prime Minister of Estonia) and internationally (e.g. Dr. Tõnurist worked also at the OECD OPSI). In addition, the group members are coordinating several permanent study groups at EGPA that are focused on public sector innovation (Public Administration, Technology and Innovation; Behavioral Public Administration).

SELECTED PUBLICATIONS


PHILOSOPHY OF SCIENCE AND TECHNOLOGY

Head of the research group: Professor AHTI-VEIKKO PIETARINEN, ahti-veikko.pietarinen@ttu.ee

The group has focused on the initiation of the new research stream on ‘abduction in the age of fundamental uncertainty’ financed by the Estonian Research Council (2016-2018) as well as continuing research and publication activities in the core areas of competences (Peirce and pragmatism, philosophy of S&T in general). The group has also attracted foreign researchers (Dr. Chiffi joined in 2016) who have further expanded the research foci of the group (i.e. philosophical research of clinical medicine and RCTs). Through these developments, the group has become more integrated with general orientation of Ragnar Nurkse Department and TTÜ in general (i.e. abduction is the main analytical approach in the context of fundamental uncertainty characterizing innovation and technological development, tackling societal challenges and wicked issues).

SELECTED PUBLICATIONS


DEPARTMENT OF LAW

Director: Professor TANEL KERIKMAE, tanel.kerikmae@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)

- Academic staff, total 23
  - Incl. 4 professors, 19 researchers.
- Doctoral students, total 6
- Scientific publications, total 113
- Defended doctoral dissertations in 2016, total 2

The Department conducts research within 2 research groups:

- European Law and Technology
- The Impact of Regional Cultural, Economic, Social and Political Processes in the Globalizing World

RESEARCH GROUPS

EUROPEAN LAW AND TECHNOLOGY

Head of the research group: Professor TANEL KERIKMAE, tanel.kerikmae@ttu.ee

The main aim of the research group is to focus the main competences on the regulation of the European Digital Market and the development of technology.

IN 2016

The research group successfully joined several large-scale projects in the field of e-medicine (under the leadership of Health Information Management SA), and research activities directly linked to e-governance and digitalisation in cooperation with Ministry of Economic Affairs and Ministry of Justice. The group has also provided expertise for Folke Bernadotte Academy to execute research in regional level. Knowledge transfer of the research results has been possible within the cooperation with H2020 project (to South-East Asia) and with the Estonian Ministry of Foreign Affairs (Development Aid Projects to Eastern Neighbourhood countries). Research was initiated with law firms and international research networks in the field of artificial intelligence and automated decision making in legal space. The relevant fields of research are law & technology based problematics on the basic rights and freedoms. The specific fields related to economic space in general, including competition law and European Model norms analysis are also topical. Cooperation was launched with international Cluster of Applied Ethics.

SELECTED PUBLICATIONS


THE IMPACT OF REGIONAL CULTURAL, ECONOMIC, SOCIAL AND POLITICAL PROCESSES IN THE GLOBALIZING WORLD

Head of the research group: Professor PEETER MUURSEPP, peeter.muursepp@ttu.ee

Different regions have been addressed in detail and the findings have been generalized with the purpose of specifying important global processes. The main regional foci for the group are the European Union, the Caspian region, the Asia-Pacific region and the Middle East, as well as Russia and Ukraine in the context of security studies. Research on the Caspian region was supported by a Marie Curie Programme project and studying the Asia-Pacific region has been supported by NATO. The head of the research group has been analysing the essence of science as a component of culture during different historical periods.

Research carried out by the group is relevant to social development on the international scale in the direct sense. This concerns international security and systematic socio-economic development of less developed regions.

IN 2016

Research was concentrated at further developments of the theory of informality. It is preoccupied with mechanisms and transactions that, even if they remain unnoticed, unregistered or in general fail to be perceived as systematic, are likely to affect policymaking and policy implementation. The informality framework has been used to propose and debate alternatives of explanations in the development of a welfare state in the former socialist countries, especially in the Caspian region.

Further results were obtained while analysing the reception of NATO in the media of the Asia-Pacific region. The research group played a major role in completing a detailed study on the Russia-Ukraine conflict. The impact of various cultural factors on the formation of international systems and/or political or security environments has been researched. The theoretical framework of these studies relies on comparative analysis of political and security cultures. An integrated value concept was created that results in a complementary connection between the value in exchange and value in use theories. New aspects of the essence of scientific knowledge as a component of culture were analysed both from the historical and the philosophical point of view.

SELECTED PUBLICATIONS:


DEPARTMENT OF BUSINESS ADMINISTRATION

Director: TOOMAS PILISTE, toomas.piliste@ttu.ee

MAIN FIGURES 2016 (as of Jan. 01, 2017)

- Academic staff, total 69
  - Incl. 7 professors, 7 researchers.
- Doctoral students, total 40
- Scientific publications, total 78
- Defended doctoral dissertations in 2016, total 4

The Department conducts research within 7 research groups:

- Entrepreneurship
- Urban and Residential Studies
- Accounting
- Marketing
- Organisation Management
- Work Environment
- Environmental Economics

RESEARCH GROUPS

ENTREPRENEURSHIP

Head of the research group: Professor URVE VENESAAR, urve.venesaar@ttu.ee

The theme of the research group: Development of entrepreneurship education and the concept of entrepreneurial university, knowledge transfer from university and innovation in enterprises.

The research on the development of entrepreneurship education and the concept of entrepreneurial university focuses on the creation of a novel teaching and learning concept with the aim of increasing the employability of graduates in the labour market. The results of the impact survey of entrepreneurship education directed at students have been used for implementing several changes related to the organisation of studies in order to improve learning methods and assessment criteria.

The research includes also knowledge and technology transfer from university to enterprises and business innovation strategies (including open innovation) and smart specialisation topics. As a result of these studies, institutional factors influencing international knowledge transfer were identified and methods for analysing knowledge networks for small and medium-sized rural enterprises were improved.

IN 2016

As an innovative component of the concept of entrepreneurship education, the model of entrepreneurial competencies was used for developing the entrepreneurship education modules, including in the areas of technology entrepreneurship, start-ups and commercialization of research results. Self-assessment models for students, teachers and universities were developed, the piloting of which included more than 400 students. As a more general topic, the outcomes of Estonian entrepreneurship policy and the rationale of changes undertaken in entrepreneurship policy were assessed.

The most important research results in the field of university and industry knowledge transfer were connected to exploring the relationship between spatial and non-spatial forms of proximity in university to
industry knowledge transfer and to the development of analytical framework for exploring institutional factors in international commercialization of university IP. Work began to analyse the innovation ecosystem of rural territories considering the innovation relevant networks within a multi-actor, multi-level and multi-dimensional framework to understand the role of a territory-based ecosystem for the innovations, and the role of different actors in this ecosystem. Two rural territories in two different small countries (Estonia and Portugal) on the edges of the Europe were compared and analysed. The results of the study will contribute to the innovation policy studies, suggest new angle from the rural territories perspective, offer working solutions and reveal a number of fragilities when planning any actions.

In addition, the methods for analysing the economic impact of environment regulations in maritime sector and clean shipping were developed and piloted.

SELECTED PUBLICATIONS


URBAN AND RESIDENTIAL STUDIES

Head of the research group: Professor KATRIN PAADAM, katrin.paadam@ttu.ee

The research group applies an integrated approach towards the analysis of urban residential and public spaces with intertwined social and material dimensions, also in an interdisciplinary perspective (collaborating with architectural, civil engineering, planning, business and economic studies) in order to conceptualise multiple dual relationships between spatial processes (e.g. urban renewal, residential regeneration, gentrification, spatial conversion, suburbanisation and sprawl) and social processes (e.g. valuation of space in user practices, needs, preferences and opportunities of individuals and groups); between the formation of individual capacities in experiences in the fields of human conduct and structural conditions (e.g. policies and markets; material structures). This is to aim at an understanding of the nature and change of contemporary urban realities. The research involves studies of the formation of meaning structures in the experience of institutional, professional and citizen/resident groups informing their actions, construction of identities, the reconstruction of symbolic capital of the city and the consequent urban images. As such, urban dynamics is at the core of analysis of interconnectivities between individual and collective behaviour patterns (incl. civic initiatives on the level of neighbourhoods and public spaces) in the city, urban and residential policies, residential markets, public space and the related businesses, and branding strategies. With regard to also the encounters at the level of local, regional and global processes, this knowledge contributes to assessment of the demands for urban spatial strategy, the prospects for the development of resilient practices and quality of life in the city on different interacting spatial scales, its potential attractiveness in terms of living, investments and tourist destination.

IN 2016

The research group has been acting as a consultant and investigator of the ongoing project ‘Tallinn Main Street’ (2015–2017), to be implemented as a major regeneration project of the central area in the city in the nearest future. The members of the research group are continuously acting as invited experts on the study and practice of urban and residential issues (e.g. Tallinn Municipality).

SELECTED PUBLICATIONS


ACCOUNTING

Head of the research group: Professor JAAN ALVER, jaan.alver@ttu.ee

The research is focused on three main areas: (1) reporting of social entrepreneurship and corporate social responsibility reporting in Estonia; (2) accounting in Estonia in 1900–1940; (3) integrated analysis of the corporate system.

IN 2016

The development of the Estonian business terminology in 1900–1940 was studied.

In the frames of the topic “Social and Environmental Accounting”, the current state of environmental management in Estonia was researched and ISO 14001 certified Estonian companies were mapped. The research of Performance Management Systems (PMSs) was carried out in cooperation with Vaasa University and it concentrated on finding critical checkpoints in the success of PMSs.

SELECTED PUBLICATIONS


MARKETING

Head of the research group: Associated Professor ANU LEPPIMAN, anu.leppiman@ttu.ee

The research topics were related to Experience Marketing, Experience Service Design, Ethics Auditing and Consumer Behaviour. The main research interest of the research group lies in studying: (1) consumer behaviour with the help of the experience pyramid model, (2) experience service design, identifying educational experiences. The project-based Experience Marketing Studies rest upon theoretical and empirical international and national economic analysis. Various methodological approaches are applied and integrated, i.e. empirical studies about using the experience pyramid to study product and service design together with researchers of the University of Lapland. The project includes research covering the following topics: consumers in the experience design and increased effectiveness and visibility of the off-the-job organizational skills training by creating a holistic customer experience. Anu Leppiman is the first internationally certified expert in this area in Estonia.

IN 2016

The research focused on the process of value creation in knowledge-intensive business services (training and consultancy services, etc.) from the customers’ perspective. The factors that influence value perception by customers were investigated. The results of this study contribute mainly to the development of three domains of science: 1) to the field of service design by providing insights on when knowledge-intensive service begins, when it ends, and what is the process in between from the customers’ perspective; 2) to the domains of experience economy and value theory by suggesting a new theoretical concept of value; and 3) to the value theory domain by delivering a model of the value co-creation process from customers’ perspective and describing the constituents of value and explaining their influence on value formation.

SELECTED PUBLICATIONS


ORGANISATION MANAGEMENT

Head of the research group: Associated Professor MIKE FRANZ WAHL, mike.wahl@ttu.ee

The research group is focused on studies of strategic management and corporate governance, always turning special attention to knowledge, skills and values.

IN 2016

The focus was aimed at understanding ownership strategies for different corporate governance systems, and venture capitalists’ (VC) role in start-ups. Analysing firm cases from Estonia allows concluding that the strategic audit is useful for systematic development of ownership strategies, which in turn could be a realistic alternative for complete contracts. The use of strategic audit gives the owner an opportunity to analyse its own actions and behaviour, learning, knowledge management, and finally to clearly express his will in the form of an ownership strategy. Financial support is not the only thing venture capitalists (VC) provide to start-ups. The biggest difference between US and European start-ups is governmental funding at early stage in Europe, and different role and use of accelerators and the level of VC involvement.

SELECTED PUBLICATIONS


WORK ENVIRONMENT

Head of the research group: Professor PIIA TINT, piia.tint@ttu.ee

The Work Environment research group carries out research in the following research topics: safety management, improvement of the occupational health and safety in enterprises, risk assessment and measurements of occupational hazards (measurements of chemical agents and evaluation of exposure to electromagnetic fields); prevention of musculoskeletal disorders, assessment of the costs related to occupational accidents, modern forms of work environment (telework, aging workforce) and possible health risks.

The research is cross-disciplinary focusing on inter-sectoral linkages in academic research on modern safety management.

All the research projects are related to essential problems in Estonia and EU, such as- lack of qualified workforce, aging of workforce, an increase of musculoskeletal disorders and occupational accidents. Establishing a safe working environment that supports productivity is the key factor in ensuring economic growth in Estonia.

IN 2016

A comparison of the causes of the genesis of musculoskeletal disorders in office and garment industry workers and the manifestation of disease symptoms was performed. As a result, a model for the prevention of work-related musculoskeletal overload diseases in the upper extremities was developed.

The results of the safety culture research in Estonian small and medium-sized enterprises demonstrated existence of and differences between real safety culture and formal safety culture. The study has also revealed that the real safety culture in Estonian enterprises does not support safe behaviour and safe performance.

The research of worker participation in the management of occupational safety and health provided a better understanding of the role and effectiveness of the involvement of workers and their representatives in workplace health and safety arrangements in Estonia and in Europe, and assessed how to improve and enhance this engagement in the rapidly changing workplace environments experienced in the member states of the EU. In organizations, where senior manager is committed to safety and the issues of occupational health and safety are discussed at the management level, the work environment is safe, health risks are acknowledged, reduced and managed and employees are committed to work and motivated. The research complemented quantitative findings obtained from previous studies with detailed secondary information exploring the ways in which worker participation is organised, the rea-
sons and motivations behind it, the contexts in which it is successful and the role of health and safety representatives, inter alia, by providing information about how worker participation in OHS is shaped by the context in which establishments operate (e.g. national, economic, job-related etc.).

SELECTED PUBLICATIONS


ENVIRONMENTAL ECONOMICS

Head of the research group: Professor ÜLLAS EHLRICH, ullah.ehrlich@ttu.ee

An important research direction involves the analysis of environmental taxes and the policy debate about taxing externalities, as well as environmental trade-offs via valuation studies. Current research investigates how taxes support the goals they are expected to achieve. Estonia provides an interesting case as environmental taxes have special features, including revenue earmarking and long-term agreements with stakeholders concerning increases in the tax rates. Via research there are ties to international valuation studies of the Baltic Sea Region.

IN 2016

The research on the identification of economic value and the monetary equivalent of protected biological species and ecosystem services using the contingent valuation method (CVM) has continued. The group members also examined the possibilities of using the outcomes of CVM as an input for social cost-benefit analyses, which is important for economic justification of nature protection.

In the framework of the topic “The economic impact of the use of oil shale until 2050” environmental charges and their impact on the sustainability of the Estonian oil shale sector were investigated. The knowledge gained in this study was of great practical value in the elaboration of the draft of amendments to the “Environmental Charges Act” passed by the Government (in 2016). The role of research and development in sustainability of production of non-conventional fuels was also examined.

The economic impact of nature-based tourism in Estonia was analysed. In addition, demand and willingness to pay for Estonian nature-based tourism products, and also the potential of developing nature-based tourism enterprises will be surveyed. Adequate assessment of the economic impact of nature-based tourism forms the basis for governmental interests in making investments. Through the latter, more economic activity can be brought to the remote areas. Comparison with Scandinavian countries, where the nature-based tourism sector is well ahead, will provide a benchmark for Estonian nature-based tourism development.

SELECTED PUBLICATIONS


ESTONIAN MARITIME ACADEMY

Photo: The maritime focused Simulator Centre.
www.ttu.ee/institutes/estonian-maritime-academy/maritime-training-centre/bridge-simulator/
TTU photo archive
ESTONIAN MARITIME ACADEMY

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MAIN FIGURES 2016 (as of Jan. 01, 2017)
- Academic staff, total 65
- Scientific publications, total 7
RESEARCH PROJECTS

The research projects are coordinated by Research and Development Centre of Estonian Maritime Academy.

In 2016, the following studies were carried out:

ECONOMIC IMPACT STUDY OF THE MARITIME SECTOR

Head of the study: Lecturer TÔNIS HUNT, tonis.hunt@ttu.ee

The aim of the economic impact study of the maritime sector was to define the sector and chart the activities of the businesses in the maritime sector and thereby to assess the current situation and future potential of the maritime sector. A practical and complete set of recommendations has been composed for the politicians, which is important for the development of the maritime sector in Estonia. The economic impact study of the maritime sector is the first step of a study focusing on specific branches of the sector and finding the solutions to the problems within each branch.

MANDATORY ACTIONS TO RATIFY INTERNATIONAL CONVENTION ON STANDARDS OF TRAINING, CERTIFICATION AND WATCHKEEPING FOR FISHING VESSEL PERSONELL (STCW-F) AND CAPE TOWN AGREEMENT 2012 (SFV PROTOCOL 93) AND TO ASSESS ECONOMIC AND SOCIAL IMPACTS IN ESTONIA

Head of the study: Lecturer EHA MERIRAND, eha.merirand@ttu.ee

The study was carried out in order to assess the influence of implementing the Cape Town Agreement and the ratification of the STCW-F Convention in Estonia. The aim was to identify how the Cape Town Agreement and the ratification of the STCW-F Convention affects personnel in the fisheries sector by analysing economic and social aspects and what actions need to be performed to implement the Agreement and Convention in Estonia. The aim of the study was to determine the economic and social impacts of changes required in order to implement Cape Town Agreement and STCW-F Convention; to identify what are the actions taken by the influenced target groups; to evaluate the social impact on influenced target groups; to ascertain and evaluate the impacts of the implementation of the Convention and Agreement on the human and natural environment, national security, foreign relation of the country and regional development; to map the competences of different governmental bodies regarding the Agreement and Convention and to evaluate the costs and benefits associated to the implementation of STCW-F Convention.
STUDY OF THE ALUMNI OF ESTONIAN MARITIME EDUCATION INSTITUTIONS

Head of the study: Director for Development MADLI KOPTI, madli.kopti@ttu.ee

The aims of the survey were to assess the satisfaction of the alumni with maritime education institutions, to analyse different possibilities for maritime education, to draw up an overview of the career opportunities of maritime education alumni and to get an overview of people’s willingness who work in the maritime sector, to contribute to the development of maritime education. The results of this survey will be used as one of the inputs to develop the Concept of Estonian Maritime Education.

SELECTED PUBLICATIONS:
SMALL CRAFT COMPETENCE CENTRE

**Head of the centre:** ANNI HARTIKAINEN, anni.hartikainen@ttu.ee

The objective of SCC is to develop engineering knowhow and to transfer it in businesses. The Centre provides consultation and model testing services to the small craft and maritime sectors, carries out tests of and develops materials to be used in seawater and maritime climate as well as provides services in the design and test-production of electronics systems.

The main function of the Competence Centre is attracting and accumulating professional know-how in small craft engineering. Next to the small craft design and optimisation, these measures also include application of electronic systems and material technologies, training engineers, encouraging inter-sectoral and international cooperation and implementing a variety of soft development activities.

The two main R&D headings of the Centre are visioned as sustainability of the environment (e.g. application of organic and smart composite materials in seawater environment etc.) and efficient use of resources (e.g. optimization of vessel designs, their energy usage, etc.).

Material development is focused on the application of natural materials in lamination technology that can result in producing and usage of fully recoverable polymer composites in small craft engineering as well as in other sectors.

**IN 2016**

The towing tank of the SCC research infrastructure was launched and development services were provided to eighteen companies for 70 thousand euros that is seven times higher compared to 2015. A major part of the services rendered were a vessel design related hydrodynamic tests, analysis and development.

In cooperation with the TTÜ Department of Civil Engineering and Architecture, preparations were made to establish a research team on shipbuilding and hydrodynamics. Preparatory activities were started in the field of optimising vessel design concepts upon applying constructive appendages.