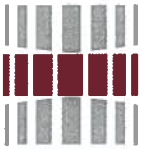

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TALLINNA TEHNIKAÜLIKOOL

Institute of Cybernetics at Tallinn University of Technology
Research Laboratory for Proactive Technologies, Tallinn University of Technology

CENS

Centre for Nonlinear Studies

Annual Report

2008

Tallinn, Estonia

Contents

Abstract

The Report reflects the state of the art and studies of CENS in 2008. This is the first year of renewed and enlarged activities involving analysis, synthesis and control of complex systems. Described are studies and results on: (i) dynamics of microstructured materials and solitons; (ii) water waves and coastal engineering; (iii) software development; (iv) fractality and econophysics; (v) general nonlinear wave problems; (vi) biophysics and cell energetics; (vii) optical nonlinearity and photoelasticity; (viii) nonlinear and robust control systems; (ix) proactive technologies. The Report presents the full list of programmes, projects and grants, and the full list of published papers, presentations at conferences, etc. The teaching activities are also listed. The Summary includes a Work Plan of CENS in 2008–2013. Some forthcoming activities in 2009 are described in the Annex.

Keywords: nonlinear dynamics, soft matter physics, microstructured solids, solitons, acoustodiagnostics, photoelasticity, cell energetics, water waves, extreme waves, coastal engineering, differential equations, nonlinear and robust control, correctness by design, proactive technology, interactive computing.

Sisukord

Lühikokkuvõte

Aruanne käsitleb Mittelineaarsete Protsesside Analüüsi Keskuse (CENS) tegevust aastal 2008. Uuenenud CENS haarab kompleksüsteemide analüüsi, sünteesi ja juhtimist. Põhitulemused on kirjeldatud järgmiste alateemade lõikes: (i) lainelevi mikrostruktuursetes materjalides ja solitonid; (ii) lained veepinnal ja rannikutehnika; (iii) tarkvara arendus; (iv) fraktaalsus ja ökonofüüsika; (v) mittelineaarne laineleviteooria; (vi) biofüüsika ja rakuenergeetika; (vii) optiline mittelineaarsus ja fotoelastsus; (viii) mittelineaarsed ja robustsed juhtimissüsteemid; (ix) proaktiivtehnoloogia. On antud ülevaade CENSi programmidest, projektidest ja grantidest ning esitatud publikatsioonide, konverentsiettekannete, külalisteadurite, seminaride jm nimekirjad, sh. ka ülevaade kraadiõppest. Aruande kokkuvõttes on esitatud CENSi tööplaan järgnevateks aastateks (2008–2013). Lisas on kirjeldatud paari olulisemat aspekti tegevusest aastal 2009.

Võtmesõnad:
mittelineaarne dünaamika, pehmisefüüsika, mikrostruktuuriga materjalid, solitonid, akustodiagnostika, fotoelastsus, rakuenergeetika, pinnalained, rannikutehnika, ekstreemlained, diferentsiaalvõrrandid, mittelineaarsed ja robustsed juhtimissüsteemid, korrektse projekteerimise meetodid, proaktiivtehnoloogia, interaktiivne arvutus.

1. Introduction

This Report is the tenth Annual Report of CENS, following the previous reports covering years 1999-2007. Compared with previous years, the main ideology of CENS was generalised and specified in order to reflect the dynamic world and the trends in science. This generalisation was supported by thematic and structural changes which are described in Section 2. Following the style of previous Reports, a short summary on research topics and structures is given in Section 2. Then in Section 3 an overview on current research in 2008 and co-operation projects is presented. Section 4 describes briefly the funding sources and in Section 5 publication records, lists of conferences, seminars, etc. are given. In Section 6 activities of CENS are described together with the lists of courses, graduate students, visitors, etc. The last Section 7 is devoted to conclusions and the Work Plan. The Annex gives some additional materials characterising the activities of CENS.

2. Overview on CENS

2.1 General

In order to use better the synergy between analysis, synthesis and control, and the corresponding basic funding schemes, the present CENS includes the following long-term block grants:

Nonlinear dynamics and complex systems (supervisor J.Engelbrecht)

- Complexity in nonlinear wave motion: solitonics and coherent wave fields, thermo-dynamical constraints and internal variables, anomalies of water waves including extreme waves;
- Complexity in biophysics: *in silico* modelling of cardiac contraction and cell energetics;
- Fractality in nature: multifractality, statistical topography, turbulent diffusion;
- Complexity of stress analysis.

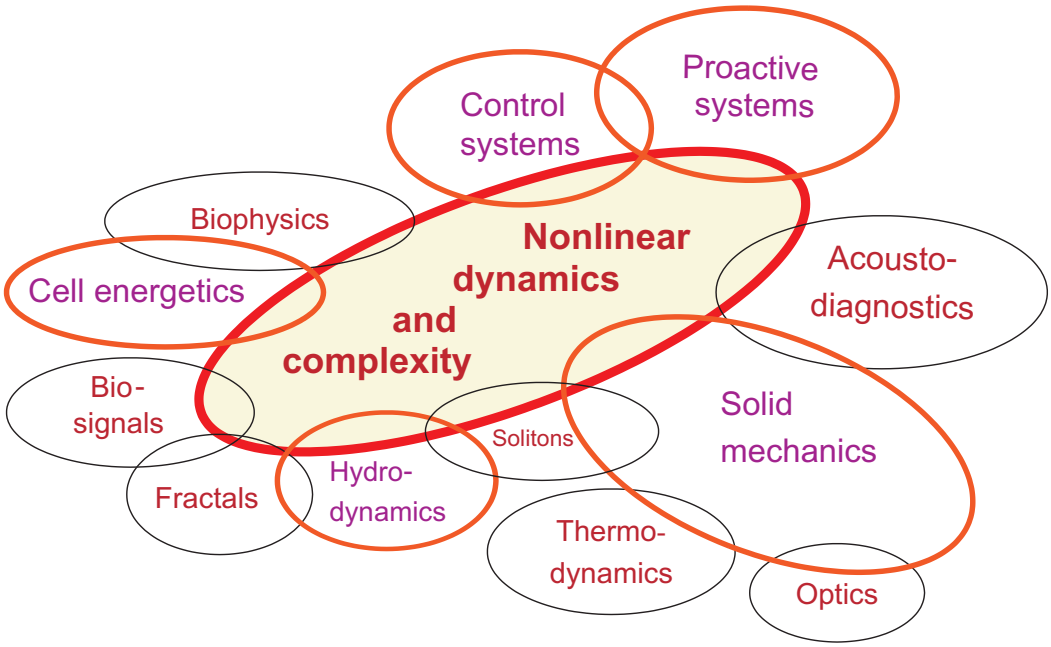
Synthesis of complex nonlinear control systems (supervisor Ü.Kotta)

- Nonlinear control theory – novel algebraic formalisms, catering for multiple time scales;
- Control at higher levels of decision making.

Proactivity and situation awareness (supervisor L.Mõtus)

- Complexity in software-intensive systems – emergent behaviour in proactive embedded systems, situation-aware interaction centred models of computation, time-counting systems with multiple metric times, holistic self-organizing systems.

The research fields are centered around nonlinear dynamics and complexity as shown below



Structurally CENS is based on the following departments and laboratories:

Institute of Cybernetics at Tallinn University of Technology:

Department of Mechanics and Applied Mathematics;

Laboratory of Photoelasticity;

Laboratory of Systems Biology;

Laboratory of Wave Engineering (founded in 2008, starting from Jan. 2009);

Department of Control Systems;

Tallinn University of Technology, Department of Computer Control:

Research Laboratory for Proactive Technologies.

The co-operation with previous partners (Biomedical Engineering Centre of the Tallinn UT and Chair of Geometry of University of Tartu) continues but their main activities are channeled differently.

2.2 More on organisation

The Work Plan of CENS "CENS 2008–2015. New Challenges in Complexity Studies" was drawn up in the beginning of 2008. In order to focus research groups, the following subthemes were distinguished:

- wave motion in solids;
- hydrodynamics and extreme waves;
- biophysics and cell energetics;
- fractality;
- nonlinear photo-elasticity;
- nonlinear control systems on time scales;
- emergent behaviour in proactive embedded systems.

The Work Plan is presented in Section 6.3. The official structures of the Tallinn UT and the Institute of Cybernetics at the Tallinn UT are described in Section 2.1. The present difference between the structures and research groups clearly demonstrates that research is ahead of structural changes. Recently, however, two Laboratories were launched in order to follow more clearly the actual research. Other structural changes are being prepared. These new Laboratories were: Laboratory of Wave Engineering; Laboratory for Proactive Technology.

Laboratory of Wave Engineering

The Wave Engineering (WE) Laboratory was formed in 2008, starting officially on 01.01.2009 to promote and provide a structure for research into water waves and coastal engineering within the Department of Mechanics and Applied Mathematics (http://cens.ioc.ee/cens/research-teams/waves-in-fluids/). The laboratory comprises three senior scientists, three PhD students, and one MSc student, assisted by an office secretary. Two PhD students from the Department of Mechanics, TUT, are associated with the laboratory.

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, runup 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.

Collaborative arrangements have been built with the University of Bergen, Norway, (hydrodynamic modelling), the University of Waikato, New Zealand, (coastal zone management) and James Cook University, Australia, (coastal processes and engineering). Currently, the laboratory is hosting Prof. Kevin Parnell (James Cook University), Dr. Tony Dolphin (University of Norwich), Dr. Tomas Torsvik (University of Bergen) and Ms Bryna Flaim (University of Waikato) as visiting scientists.

Research Laboratory for Proactive Technology

The laboratory (http://www.proactivity-lab.ee), established in 2007, focuses on theoretical and practical study of networked systems build from stationary and/or mobile software-intensive (proactive) components. Typical components are pervasive computing systems. The research is partitioned into three threads – modelling and verification of situation-aware interaction-centred computation, methods and technologies for acquiring situational information, and 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.

Staff of the laboratory includes 1 DSc, 8 PhD-s, 4 PhD students, plus a varying number of MSc level students and assistants. The researchers of the laboratory are closely cooperating with The Centre for ICT at Institute of Technology, University of Tartu in the areas of interaction-centred computation and multi-agent technologies; IB Krates (Estonian SME working internationally in the area of tools for, and development of embedded systems' software), Smartdust Solutions (Estonian SME working internationally in the area of wireless sensor networks).

3. Current results 2008

3.1 Institute of Cybernetics, Department of Mechanics and Applied Mathematics, Tallinn University of Technology

3.1.1 Dynamics of microstructured materials and solitons

Internal variables and microstructured materials
A unified framework for both dissipative and non-dissipative processes based on the canonical thermomechanics on the material manifold including weakly non-local dual internal variables enriched by an extra entropy flux is proposed for the use of internal variables in the description of the microstructure influence on the dynamic behavior of materials. In addition to the dissipative reaction-diffusion equation for a single internal variable of state, a hyperbolic evolution equation for the internal degree of freedom is also recovered in the non-dissipative case (A.Berezovski, J.Engelbrecht, G.A.Maugin).

Internal variables and generalized continuum theories
The formal structure of generalized continuum theories is recovered by means of the extension of canonical thermomechanics with dual weakly non-local internal variables. The canonical thermomechanics provides the best framework for such generalization. The Cosserat, micromorphic, and second gradient elasticity theory are considered as examples of the obtained formalization (A.Berezovski, J.Engelbrecht, G.A.Maugin).

One-dimensional microstructure dynamics
Dispersive wave propagation in solids with microstructure is discussed in the small-strain approximation and in the one-dimensional setting. It is shown that the generalizations of wave equation based on continualizations of discrete systems as well as on homogenization methods can be recovered in the framework of the internal variable theory in the case of non-dissipative processes (A.Berezovski, J.Engelbrecht, G.A.Maugin).

Numerical simulations of waves in microstructured solids
A linear microstructure model based on Mindlin theory is adopted and represented in the framework of the internal variable theory. Fully coupled systems of equations for macro-motion and microstructure evolution are represented in the form of conservation laws. A modification of wave propagation algorithm is used for numerical calculations. This modification is based on decomposition of wanted fields into average and excess parts and on accounting for source terms in the jump relations at boundaries between computational cells (A.Berezovski, M.Berezovski, J.Engelbrecht).

Solitary waves in Mindlin-type microstructured solids
Mindlin–Engelbrecht–Pastrone (MEP) model is used for describing the longitudinal deformation waves in microstructured solids. MEP models include Mindlin theory of continua with microstructure and the concept of wave hierarchies and they are able to take into account nonlinear and dispersive effects on the micro- as well as on the macrolevel. In 1D case Euler-Lagrange equations result in system of two equations of motions which couple macro-displacement and micro-deformation. By applying slaving principle the micro-deformation can be eliminated from the latter. This procedure results in a hierarchical wave equation of Boussinesq type (HB). In turn, by applying the asymptotic (reductive perturbation) method an evolution equation of Korteweg-de Vries type (PKdV) is derived from the HB equation (J.Engelbrecht and M.Randrüüt). All three model equations are integrated numerically under localised and/or harmonic initial conditions making use of pseudospectral method. The results are analysed in terms of space-time variables as well as spectral characteristics. The main goal is to determine domains in space of material parameters, where solitonic solutions emerge and approximated

models (HB and PKdV) can be applied (A.Salupere, K.Tamm and M.Randrüüt).

Solitary waves in granular materials — hierarchical KdV-type model
A hierarchical Korteweg–de Vries type evolution equation is applied for modelling solitary wave interactions in dilatant granular materials. The model equation is integrated numerically under localised initial conditions, consisting of two bell–shape initial excitations of different amplitudes. Interactions of solitary waves are analysed for four different solution types. Solitonic behaviour is detected for three solution types. In case of the fourth solution type, simultaneous emergence of solitary wave, tail and wave packet is observed and analysed (A.Salupere and L.Ilison).

Solitary deformation waves in a compressible hyperelastic rod
Propagation of axisymmetric deformation waves in circular cylindrical rods of compressible hyperelastic material is studied. Corresponding model equation is derived by Hui-Hui Dai and it describes propagation of waves of the finite wave-length taking into account the coupling effect of the material nonlinearity and the geometric size of the rod. Numerical simulations are carried out over a wide range of material parameters for localised initial conditions. The analysis of the time-space behaviour of solutions demonstrate that in some domains of space of material parameters single solitary wave solutions or trains of interacting solitons can be emerged from the initial localised pulses (A.Salupere and M.Vallikivi).

Description of twist waves in liquid crystals using mesoscopic continuum physics
Mesoscopic continuum physics introduces variables describing the microstructure – like orientation of crystals – into the domain of the fields, thus treating them equivalently to space. The theory of mesoscopic continuum physics has been reformulated, resulting in more compact equations, which are easier to understand. In this new formulation the balance of spin shows up naturally as component equations of the balance of momentum, this is an advantage over the standard formulation, in which it is postulated separately. Starting from this, a wave equation for twist waves has been derived on the mesoscopic space. Twist waves are one of the fundamental modes of orientation waves in liquid crystals (H.Herrmann).

3.1.2 Water waves

Extreme wave conditions in the Baltic Proper and in the Gulf of Finland during windstorm Gudrun
Wave conditions in the northern Baltic Proper during windstorm Erwin/Gudrun (January 7–9 2005, one of the strongest storms in the Nordic Region of Europe during the last decades that caused widespread property damage, exceptionally high storm surge levels, and the loss of 18 lives) are analysed based on in situ measurements in three locations and output of operational wave models from the German Weather Forecast Service, the Danish Meteorological Institute and the Finnish Institute of Marine Research. The measured significant wave height reached 7.2 m in the northern Baltic Proper and 4.5 m in the Gulf of Finland. Extremely rough seas occurred in the north-eastern region of the Baltic Sea Proper. The roughest wave conditions, estimated from the comparison of the forecast and measured data, occurred remote from the sensors, off the coasts of Saaremaa and Latvia where the significant wave height was about 9.5 m. Peak periods exceeded 12 s in a large part of the northern Baltic Proper and in the central part of the Gulf of Finland. Despite several atypical features of this storm, the reaction of water masses was reasonably forecast 48-54 hours ahead and accurately reproduced in 24–36 hour forecasts. The lessons learned from this event led to re-launching of routine operational oceanographic services in Estonia and were used in regular student courses in the Tallinn University of Technology and the Estonian Marine Academy a few weeks after the events (T.Soomere; in cooperation with

A.Behrens, GKSS, L.Tuomi, FIMR, J.W.Nielsen, DMI, T.Healy, Waikato).

Extremes and decadal variations of the northern Baltic Sea wave conditions
Average wave conditions, their seasonal cycle and decadal variations, and extreme wave storms in the northern Baltic Sea are studied based on long-term time series from Almagrundet (1978–2003) and Vilsandi (1954–2005), and wave statistics from the middle of the northern Baltic Proper. The typical wave periods are 3–4 s in coastal areas and 4–6 s on the open sea. The monthly mean wave height varies from about 0.4 (0.5) m in April–July to 0.8 (1.3-1.4) m in January at Vilsandi (Almagrundet). The annual mean wave height varied insignificantly in the 1960s–1970s, considerably increased in the 1980s, was at highest in the mid–1990s, and rapidly decreases in 1998–2005. Significant wave heights $H_S \geq 4$ m occur with a probability of about 1%. Extreme wave conditions with $H_S \geq 7$ wave heights over 7 m have been registered five times since 1978. The records overlook 2–3 such cases (T.Soomere).

Escalating extremes over descending trends of the northern Baltic Proper wave fields
Interannual variations of average wave conditions and extreme wave storms in the northern Baltic Sea are studied based on the above data, and simulations of wave properties in cyclone Gudrun in January 2005. The frequency of extreme wave conditions ($H_S \geq 7m$) has not changed significantly since the end of the 1970s. The overall recorded wave height maximum H_S between 1978–2005 is 7.8 m. The estimated maximum H_S in cyclone Gudrun was 9.5 m (T.Soomere; in cooperation with T.Healy, Waikato).

Simulation of patterns of wakes from high-speed ferries in Tallinn Bay
Spatial patterns and far field properties of the long-wave part of wakes of fast ferries in Tallinn Bay were analysed with the use of the Boussinesq-type shallow-water model COULWAVE forced by realistic ship motions. The calculated heights of ship waves exhibit substantial spatial variability. The largest waves were created when the ship sailing to Tallinn entered into supercritical regime when moving over the coastal slope. The maximum wave height eventually reached 3 m whereas along other sections of the track the wave height was about 1 m. The highest waves hit the area of Pirita Beach that apparently has much larger ship wave loads than the adjacent sections of the Viimsi Peninsula (T.Torsvik, T.Soomere).

Coastal processes managed retreat – is it really an option for mitigation of chronic erosion and storm surge flooding
Managed retreat on open-duned coasts subject to traditional low density individual dwelling subdivisional development is technically feasible. It is not feasible for diked coasts of the Netherlands and Germany, or for high rise urban beaches such as Miami. Conceptually, managed retreat can occur both as a gradual planned process or as catastrophic abandonment (as occurred in Cyclone Katrina). While the concept of managed retreat is often listed as an option it is rarely implemented on community scale. This would appear to be because it is regarded as economically and politically unacceptable. Two examples from New Zealand are presented. The first is the Waihi Beach seawall, presently a case before the Environment Court, in which the affected landowners wish to be protected by public funding of rebuilding the seawall, and are resisting the concept of a backstop wall. A second is the vision for the long term management of the Coromandel beaches by the regional council which encompasses managed retreat and implementation of "backstop walls"on private rather than public land. In some cases land acquisition is expected in the future (T.Soomere; in cooperation with T.Healy, Waikato).

Shifts in early spring wind regime in North-East Europe (1955–2007)
Changes to the winter-to-spring switch-time of the upper air flow regime at the 850 and 500 hPa levels over the north-eastern Baltic Sea are analyzed based on a data set extending from 1955 to 2007. The long-term variation of the air flow in early spring (March) exhibits multiple

regime shifts. The shifts are extracted by means of a vector analysis of the monthly mean air flow and using statistical shift detection technology. In the middle of the 1960s the average air flow turned from NW (WNW) to W (WSW) at the 500 (850) hPa level. The original regime was restored in the mid-1990s. The regime shifts in the average air flow in March can be interpreted as changes in the transition time from winter to summer circulation type (Climate of the Past, T.Soomere, in cooperation with S.Keevallik).

Exact travelling wave solutions in strongly inhomogeneous media
Approximate travelling wave solutions to linear one-dimensional wave equations with varying coefficients (that occurs in inhomogeneous medium) are usually found with use of the asymptotic procedures such as the WKB approach. For certain conditions put on the coefficients, this procedure leads to exact solutions. We show that such exact travelling wave solutions exist for a limited class of strongly inhomogeneous media and prove the existence and uniqueness of such waves. With the use of the obtained solutions, the solution of the relevant Cauchy problem is expressed in elementary functions. This approach enables detailed and straightforward analysis of the processes of wave transformation and reflection in a specific type of strongly inhomogeneous media (I.Didenkulova, T.Soomere, in cooperation with E.Pelinovsky).

Steepness and spectrum of nonlinear shallow water waves
The process of the nonlinear shallow water wave transformation in a basin of a constant depth is studied. Characteristics of the first breaking of the wave are analyzed in details. The Fourier spectrum and steepness of the nonlinear wave are calculated. It is shown that the spectral amplitudes can be expressed using the wave front steepness, which allows the practical estimations (I.Didenkulova, in cooperation with N.Zahibo, E.Pelinovsky and A.Kurkin).

Computation of realistic solitary wave runup on non-plane beach
Solitary wave runup on a non-plane beach is studied analytically and numerically. For the theoretical approach, nonlinear shallow-water theory is applied to obtain the analytical solution for the simplified bottom geometry, such as an inclined channel whose cross-slope shape is parabolic. It generalizes Carrier-Greenspan approach for long wave runup on the inclined plane beach that is currently used now. For the numerical study, the Reynolds Averaged Navier-Stokes (RANS) system is applied to study soliton runup on an inclined beach and the detailed characteristics of the wave processes (water displacement, velocity field, turbulent kinetic energy, energy dissipation) are analyzed. It is theoretically and numerically proved that the existence of a parabolic cross-slope channel on the plane beach causes runup intensification, which is often observed in post-tsunami field surveys (I.Didenkulova, in cooperation with H.Choi, E.Pelinovsky, D.C.Kim, and S.B.Woo).

Run-up of long waves on a beach: the influence of the incident wave form
The influence of the incident wave form on the extreme (maximal) characteristics of a wave at a beach (run-up and draw-down heights, run-up and draw-down velocities, and the breaking parameter) is studied. It is suggested to use in the calculations the definition of wavelength at a level of 2/3 of the maximal height, which to a certain degree correlates with the definition of the significant wavelength accepted in oceanology. Such a definition allows us to unify the relations for extreme run-up characteristics so that the influence of the incident wave form becomes insignificant. The obtained universal relations can be used for the estimates of runup characteristics when the exact information about the form of the incident wave is not available (I.I.Didenkulova and E.N.Pelinovsky).

Runup of long irregular waves on plane
Runup of irregular waves, modeled as superposition of Furrier harmonics with random phases, is studied in frames of nonlinear shallow water theory. The possibility of appearance of freak

waves on a beach is analyzed. The distribution functions of runup characteristics are computed. An incident wave represents an irregular sea state with Gaussian spectrum. The asymptotic of probability functions in the range of large amplitudes for estimation of freak wave formation in the shore is studied. It is shown that average runup height of waves with wide spectrum is higher than that of waves with narrow spectrum beach (I.Didenkulova, E.Pelinovsky and A.Sergeeva).

Practical oceanography:
Progress in knowledge of the physical oceanography of the Gulf of Finland 1997–2007
The main findings of studies of the physical oceanography of the Gulf of Finland (GoF) during 1997–2007 are reviewed. Only relevant updates published in international peer-reviewed research papers and monographs are discussed, bearing in mind that a comprehensive overview of the studies up to the mid-1990s is available. We start the discussion with updates on the basic hydrographical and stratification conditions, and progress in the understanding of atmospheric forcing and air-sea interaction. Advances in the knowledge of basin-scale and mesoscale dynamics are summarised next. Progress in circulation and water exchange dynamics has been achieved mostly by means of numerical studies. While the basic properties of circulation patterns in the gulf have been known for a century, new tools and characteristics such as water age, renewal index, and high-resolution simulations have substantially enriched our knowledge of processes in the GoF during the last decade. We present the first overview of both status and advances in optical studies in this area. Awareness in this discipline has been significantly improved as a result of in situ measurements. Our understanding of the short- and long-term behaviour of the sea level as well as knowledge of the properties of both naturally and anthropogenically induced surface waves have expanded considerably during these ten years. Developments in understanding the ice conditions of the GoF complete the overview, together with a short discussion of the gulf's future, including the response to climate change. Suggestions for future work are outlined (T.Soomere, in cooperation with K.Myrberg, M.Leppäranta and A.Nekrasov).

Extreme Waves Generated by Cyclones in Guadeloupe
Cyclones produce some harm by terrific wind speed, abnormal precipitations, and sea motion. Historically, storm surge inundation has been the most destructive and murderous. The extreme waves caused by cyclones on the coast of Guadeloupe for a whole historic period are discussed. The first documented sea damage during hurricane passage in Guadeloupe occurred in 1642. Data of extreme waves induced by hurricanes from 1928 to 2007 in Guadeloupe are collected and discussed. The heights of extreme waves for Caribbean and Atlantic coasts are compared; the most dangerous regions are also evaluated (I.Didenkulova, in cooperation with N.Zahibo and I.Nikolkina).

3.1.3 Software development

The program "F2PY Fortran to Python Interface Generator"(http://www.f2py.org/) is being developed. The aim of F2PY is to provide an automatic connection between the high-level Python scripting language and high-performance Fortran/C libraries and programs.

The SciPy package (http://www.scipy.org/) that gathers a variety of high level science and engineering modules for Python is developed (P.Peterson and others).

The SympyCore package (http://sympycore.googlecode.com/) that provides an efficient pure Python Computer Algebra System is developed (P.Peterson and F.Johansson).

A project "Microscope"has been started to develop a C++ application for driving different experiment protocols on flourecense and confocal microscopes (A.Illaste, P.Peterson, M.Vendelin).

3.1.4 Fractality and econophysics

Stochastic processes
In collaboration with the Akhiezer Institute for Theoretical Physics. National Science Center Kharkov Institute of Physics and Technology, we have studied the so-called CTRW (continuous time random walk) processes. In particular, we demonstrated that in the case of quenched disorder, the density field of the diffusing particles will be multifractal (we derived analytically the structure function scaling exponents); and in contrast to the prior wide-spread belief, cannot be described by sub-diffusion equations with fractional derivatives.

We also established the connection between anomalous scaling in the case of ACTRW (aging continuous time random walk) and in the case of experimental time-averaging of CTRW-like processes. Furthermore, we described a new scenario leading to the same type of anomalos scaling, when the diffusing particles are provided with appropriate initial seeds (J.Kalda, M.Säkki).

Statistical topography
The statistical topography of polymer films has been studied in cooperation with the TUT Institute of Material Sciences (Dr. Ü.Lille). We have revealed the presence of a correlated percolation network in polymeric PEDT/PSS complex and studied the effective Hurst exponent ($H < 0$) as a function of the system parameters (J.Kalda, M.Kree).

Turbulent diffusion
Using the one-dimensional (1D) model of passive scalar turbulence, we have studied the origin of the small-scale anisotropy of passive scalar turbulence. In particular, we have derived analytically the scaling exponent for the third order structure function; the result (approximately 1.1) is in a good agreement with the experimental data.

We have studied numerically (using the 1D model of the passive scalar turbulence), the evolution of tracer fields in a fully developed turbulence in the presence of a point source. The scaling laws of the moments of the tracer density are in a good agreement with the experimental results (obtained at IRPhE, University of Marseille).

During previous years, we have studied the evolution and scaling laws of material lines in fully developed turbulence. During last year, we have extended our numerical studies to a broader range of the velocity field smoothness exponents, now including values $\xi \leq 1$. Our results show that in the case of passive scalar turbulence, the reconnection of isodensity lines plays a fundamental role: the fractal dimensionalities of the material lines and isodensity lines are clearly different for almost all the values of the smoothness exponent, and are equal for the Kolmogorov value $\xi = 4/3$ only by a coincidence (J.Kalda, M.Kree, A.Morozenko).

Econophysics
The super-universal distribution of low-variability periods has been tested using various financial time-series. The results confirm our theoretical expectations and reveal one source of universality in the dynamics of financial markets. It is also useful for the portfolio risk analysis (R.Kitt, M.Säkki, J.Kalda) .

3.1.5 General nonlinear wave theory

Acoustodiagnostics of inhomogeneous and prestressed solids

The rapid advancements in technology afford to develop effective and versatile materials with variable in space and time properties. Considerable interest is generated in recent years on man-made materials like composite materials called functionally graded materials (FGMs). Many techniques have been developed for fabricating various FGMs, in which the material properties change considerably and continuously in the thickness direction. Utilization of ultrasonic waves is one of the very promising mean for characterization of FGMs.

Investigation of inverse problems to identify FGMs on the basis of wave propagation data resorting to the solutions of direct problems was carried on. This year special attention was focused to materials with exponentially variable properties. Two problems were studied in detail:

– counter-propagation and interaction of harmonic waves in a nonlinear elastic specimen made of FGM with exponentially considerably changing properties;
– nonlinear propagation and reflection of a burst in nonlinear elastic specimen made of FGM with exponentially weakly changing properties.

Due to the complexity of the analytical basis the first problem was solved numerically using the symbolic manipulation software Maple. The necessary algorithms and programmes were composed and numerous numerical experiments were implemented. The main attention was paid to the oscillations on the parallel boundaries of the specimen (structural element). It was noticed that the interaction of counterpropagating waves is very sensitive to the variation of material properties and to the values of the parameters of wave excitation. Important from the point of view of nondestructive testing is that the effects caused by nonlinearity are much less than the effects caused by material inhomogeneity. Consequently, on the basis of boundary oscillation profile data evoked by ultrasonic counterpropagating waves in the specimens made of FGM, it is possible to propose a method for qualitative nondestructive characterization of FGMs with essentially changing continuous properties. This method enables to distinguish specimens made by

– homogeneous material;
– material with symmetrically, distributed properties;
– material with asymmetrically distributed properties and also to distinguish the most relevant property of the material responsible for inhomogeneity.

The second problem is solved analytically making use of the small inhomogeneity and the perturbation technique. The analytical solution is derived and propagation and reflection of harmonic burst in exponentially graded material is studied. The dependence of harmonic's amplitude, phase shift and phase velocity on the excitation frequency and material inhomogeneity is clarified. Interesting phenomenon - reversal of nonlinear effects after reflection from a free boundary is observed. The obtained results may be useful in elaboration of algorithms for ultrasonic nondestructive testing of FGM (A.Ravasoo, A.Braunbrück).

Inverse problems

The identifiability of coefficients related to physical properties of microstructured bodies subject to Mindlin model by means of spectral decomposition of a general linear wave has been studied in one-dimensional case. It was shown that in the homogeneous case 4 coefficients of 5 are uniquely recoverable provided the wave is measured in a fixed point of the body over the time. The result is easily extendable to the piecewise homogeneous case, where the measurements of the wave in three points of each continuous part over time are used. In addition, the identifiability by means of group and phase velocities in the homogeneous case has been shown (J.Janno).

Piano hammer-string interaction – the studies of the string termination
The main goal is investigation of vibrations of the ideal flexible string, which one end is rigidly clamped, or coupled with a linear damped oscillator, and another one is terminated on the curved contact surface (cast iron frame). The vibrating string touches repeatedly this termination, and this, in turn, causes the modulation of fundamental frequency of the string, and the train of high frequency oscillations is generated. The problem is studied both analytically, and numerically. The effects of the contact nonlinearity and the shape of the contact surface on of the spectral structure of the string vibration are considered. The mathematical model of the string-frame interaction is also derived. The influence of the impact amplitude on the vibration spectra of struck string is estimated and discussed. It is shown that the power spectrum of the piano string vibrations grows up significantly and essentially reshapes with increasing of the amplitude of the hammer impact. It is demonstrated that the mechanism of the contact nonlinearity can generate the high frequency oscillations of the piano strings (A.Stulov).

3.1.6 Laboratory of Systems Biology

Biophysics and cell energetics
A series of experimental data point to the existence of profound diffusion restrictions of ADP/ATP in rat cardiomyocytes. This assumption is required to explain the measurements of kinetics of respiration, sarcoplasmatic reticulum loading with calcium, and kinetics of potassium ATP-sensitive channels. To be able to analyze and estimate the role of intracellular diffusion restrictions on bioenergetics, the intracellular diffusion coefficients of metabolites have to be determined. The aim of this work was to develop a practical method for determining of diffusion coefficients in anisotropic medium and to estimate the overall diffusion coefficients of fluorescently labeled ATP in rat cardiomyocytes. For that, we have extended raster image correlation spectroscopy protocols to be able to discriminate the anisotropy in diffusion coefficient tensor. Using this extended protocol, we estimated diffusion coefficients of ATP labeled with the fluorescent conjugate Alexa Fluor 647 (Alexa-ATP). In the analysis, we assumed that the diffusion tensor can be described by the two values: diffusion coefficient along the myofibril and across it. The average diffusion coefficients found for Alexa-ATP were as follows: $83\pm14\mu$m^2/s in longitudinal and $52\pm16\mu$m^2/s in transversal directions ($n = 8$, mean$\pm$SD). Those values are $\sim$2 (longitudinal) and $\sim$3.5 (transversal) times smaller than the diffusion coefficient value estimated for surrounding solution. Such uneven reduction of average diffusion coefficient leads to anisotropic diffusion in the rat cardiomyocytes. While the source for such anisotropy is uncertain, we speculate that it may be induced by ordered pattern of intracellular structures in rat cardiomyocytes.

The specific causes of the diffusion restrictions are not known but intracellular structures are speculated to act as diffusion barriers. Based on the proximity of sarcoplasmic reticulum (SR) to mitochondria, we hypothesize that SR not only utilizes ATP but may also act as a diffusion barrier leading to functional coupling of ATPases and mitochondria. The diffusion barriers can be enhanced by cytoskeleton proteins localized near SR. With a 3D finite-element model, we attempted to explore SR and associated cytoskeleton proteins as the candidate for diffusion barrier. The geometry for the mathematical model was constructed using representative mitochondrial and SR structural organization from confocal and electron microscope images. Diffusion restrictions induced by SR and cytoskeleton proteins were varied with other model parameters to fit the set of experimental data obtained on permeabilized rat heart muscle fibers. There are many sets of model parameters that were able to reproduce all experiments considered in this work. However, in all the sets, the permeability of SR network and associated cytoskeleton proteins was very low indicating importance of cytoskeleton proteins in formation of diffusion restrictions (M.Vendelin).

3.1.7 Laboratory of Photoelasticity

Optical nonlinearity and photoelasticity
The aim of the investigations has been development of the theory and algorithms of integrated photoelasticity for the determination of three-dimensional stress fields.

In integrated photoelasticity often the integral Wertheim law is used. This law ignores the influence of the rotation of the principal stress axes. The integral Wertheim law has been generalized for the case when rotation of the principal stress axes can not be ignored. For that the optical retardation is expressed through the solution of a third-order differential equation, the coefficients of which depend on the stress distribution on the light ray. Numerical examples show that rotation of the principal stress axes may considerably influence the value of the characteristic phase retardation.

An approximate solution of the inverse problem of axisymmetric thermoelasticity, applicable for residual stress measurement in glass, has been found. By the measurement of residual stresses in axisymmetric glass articles with integrated photoelasticity the axial stress and shear stress are determined directly from the measurement data. For determining also the radial and circumferential stress, equations of equilibrium and those of axisymmetric thermoelasticity is used. However, solution of the inverse problem of the equations of thermoelasticity is not unique. Using the perturbation method it is shown that if stress gradient in axial direction is constant, a unique solution of the problem is obtained.

A new method for complete determination of the axisymmetric residual stress field in glass has been elaborated. It is shown that the stress function for an axisymmetric thermal stress field can be determined on the basis of experimental data, obtained with integrated photoelasticity. Knowledge of the stress function permits one to calculate all the stress components as well as the temperature field in the test object (H.Aben, L.Ainola, J.Anton, A.Errapart).

3.2. Institute of Cybernetics: Control Systems Department

Nonlinear control systems on time scales
The notion of transfer equivalence of nonlinear control systems, described by input-output (i/o) equations, has been extended for nonlinear delta-differential equations on homogeneous time scale. The notion is based on the concepts of system reduction and irreducibility. A practical criterion for checking system irreducibility is given that requires to find the sequence of subspace of differential one-forms, associated to control system. The notion of transfer equivalence for nonlinear i/o delta differential equation plays a crucial role in the solution of the realization problem. Namely, the realization of the i/o equation in the state-space form is accessible (controllable) if and only if one starts from the irreducible i/o equation. The important point is that the irreducibility condition is formulated in terms of the same sequence of subspaces appearing in the realizability condition, the only difference being that now one has to compute more elements in this sequence. Though checking the irreduciblity property is not complicated and can be always done, finding the reduced (or irreducible) equation requires to integrate the differential one-forms that may be sometimes difficult to do (Ü.Kotta, M.Wyrwas).

Transfer function approach to the model matching problem of nonlinear control systems
The mainstream for the analysis and synthesis of nonlinear control systems is the so-called state space approach. The Laplace transform of a nonlinear differential equation is non tractable and transfer function approach was not developed until recently. We have demonstrated that one may use the transfer function formalism in the nonlinear case to recast and solve the model matching problem for nonlinear system. The model matching is a typical design problem in the sense that it plays a role in various other problems like the input-output linearization and the (disturbance) decoupling. In the model matching problem one is looking for the compensator

that guarantees the equality of the transfer functions of the compensated system and that of the prespecified model. Our problem statement and solution in terms of transfer functions are more general than the existing results since neither the control system itself, nor the model and the compensator are required to be realizable in the state space form. In particular, this gives a chance to find realizable compensators for nonlinear systems not having the state space realization. We have addressed both feedforward and feedback compensators. In case of a feedforward compensator we show that, in contrast what happens in the linear case, a class of nonlinear systems for which the solution exists, is quite restricted (Ü.Kotta).

Transformation the nonlinear system into the observer form: simplification and extension
We have addressed the problem of transforming the single-input single-output discrete-time system into the nonlinear observer form using both the state and output transformations. The necessary and sufficient solvability conditions were found in terms of exterior derivatives and exterior products of differential forms, associated to the input-output equation of the control system (T.Mullari, Ü.Kotta).

On classical state space realizability of quadratic input-output differential equations
Constraints on the parameters of the quadratic i/o model are suggested that lead to realizable models. The complete list of 2nd and 3rd order realizable i/o quadratic models is given and two subclasses of the arbitrary order realizable quadratic systems are suggested. Our conditions rely basically upon the property that certain combinations of coefficients of the equation are zero or not. We also gave explicit state equations corresponding to realizable 2nd order system and for one realizable subclass of equations (Ü.Kotta, P.Kotta, M.Tõnso).

Neural-networks-based ANARX models
Previously it was demonstrated that ANARX type models can be applied with in classical and adaptive control techniques. Continuing this research direction, this year earlier results were generalized for the multi-input and multi-output case, and also new feedback computation technique was proposed. Additionally, preliminary studies on possibility to apply neural networks based NARX model for development of built-in self-test component of analogue electronic circuit has been conducted (J.Belikov, S.Nõmm).

webMathematica implementations
The package NLControl, developed in our department during the last ten years within Mathematica environment, has been made partially available over the internet using webMathematica tools. The package contains functions that assist the solution of different modelling, analysis and synthesis problems for nonlinear control systems, described either by i/o or state equations (H.Rennik, M.Tõnso, Ü.Kotta, V.Kaparin, J.Belikov).

Robust control via reflection axes
In the field of robust control of discrete-time systems the reflection coefficient approach has been extended into a new direction based on the stable reflection axes description. The main advantage of the reflection axes polytope over the reflection vector polytope is that it allows much more freedom in the reflection coefficient assign, since there is practically no restrictions in the choice of the nominal system. The advantage of the new approach becomes evident especially in the case when the initial polynomial is chosen so that the reflection vector polytope is unstable. Using the stable reflection axes approach, the problem of robust output controller synthesis has been solved. Within this approach, the initial polynomial, associated with the nominal system, defines the polytope, necessary for controller design. The effect of the number and direction of the reflection axes on the closed-loop system pole placement has been studied. In case the initial polynomial is chosen so that the reflection vector polytope is stable, the both approaches yield the same controller (Ü.Nurges).

Robot scrub nurse
Joint research project with Tokyo Denki University aims development of the robot to replace human scrub nurse during laparoscopic surgery. While last year we demonstrated neural networks based ANARX (Additive Nonlinear Auto Regressive Exogenous) models applicability to recognize certain human hand motions, this year statistical methods, self organized maps and polynomial approximations were applied for the same purpose (S.Nõmm, J.Vain).

High-level control methods for decision procedures applicable in model-based testing
Model-based testing problem can be considered as a discrete control problem where the system under test (SUT) is driven towards the test goal using message passing. The test goal is specified using pre-orders of sub-goals. During the test run sub-goals guide the SUT towards the goal state. Concrete results achieved during the year 2008 include the pilot implementation of model-based testing system for a web-based distributed application, for a robot system and for ELIKO's street lighting control system. As a supporting technique for model based testing the compositional modeling methodology has been developed for IP Multimedia subsystem. All applications have served as necessary case-studies for further development of reactive planning testing methods and test generation algorithms (J.Ernits).

Model construction techniques
An automated learning algorithm for learning interactions of input-output observable agent system has been proposed. The algorithm generates a composition of extended timed automata from the timed traces of observable interaction events. Each component automaton in the model represents an observable input-output behavior of the agent. The method guarantees the bisimilarity between the timed traces of the learning set and the traces generated by the model (J.Vain).

The models constructed (using either compositional or automated model learning techniques) together with the test goal specification are necessary inputs for the reactive planning tester (RPT) synthesis algorithm. The RPT synthesis algorithm proposed in 2007 has been extended with approximating gain functions that considerably reduce the computational complexity of the tester programs. The learning and RPT synthesis methods have been implemented using logic constraint programming technique. In cooperation with EU FP6 project ROBOSWARM the distributed coordination algorithm of robot agents has been developed and its self-stabilization conditions proved formally using model checking method (J.Vain).

3.3 Research Laboratory of Proactive Technologies, Tallinn University of Technology

Elaboration and modifying of scientific theories, or discovering new interactions between the existing theories, is an inner mechanism that invokes scientific progress. The evolution of science is triggered as usually - by feedback from the not quite successful attempts of applying the existing theories for explaining natural phenomena, or to synthesising new artefacts.

Here the main results are briefly described (for details see http://www.proactivity-lab.ee). The conceptual basis for the future research has been elaborated which focuses on practical difficulties and paradoxes hindering rapid dissemination of pervasive computing systems, with special emphasis on integration and networking of component-based stand-alone systems caused phenomena. The key to resolution of observed difficulties lies, according to our belief, in better understanding the essence of the underlying computational processes, in providing the computational processes with adequate ambient information, and in enhancing self-X capabilities of the synthesised systems.

In particular, this summary describes our first, and in some cases indirect, attempts to address well-known difficulties observed in everyday life, and related to:

- verifying behaviour of real-time systems since its beginning (in 1950-es);
- explaining unexpected behaviour in complex systems, e.g. multi-agent systems;
- forecasting and controlling behaviour of networked pervasive computing systems (and real-time systems).

These difficulties have been amplified by persistently more stringent user requirements to new computer applications which the researchers'/designers' strive to satisfy by enhancing proactive and self-X capabilities in the designed systems. Self-X capabilities are often accompanied by increased autonomy of system's components that in its turn fosters the temptation and necessity to apply dynamically changing interactions between autonomous components, and to build proactive behaviour into autonomous components.

The results obtained in 2008 leave us with the following statements on which to build the future research:

- the new pervasive computing systems violate, strictly speaking, the axioms and restrictions imposed by Turing computing paradigm, hence the Turing computing paradigm based models provide too approximate description of systems' behaviour;
- the previous statement matches with the observations pointed out at the events of Grand Challenges for Computing Research (e.g. Stepney et al 2004), that leads us to search a solution within non-classical computation paradigms - in our case within situation-aware interaction centred models of computation;
- simultaneous and interacting research threads (models of computation and proactive models of applications, proactivity, autonomy and situation-awareness of systems, and technological platforms for implementation) – as practiced in the lab – have turned out to be fruitful and symbiotic, although not very easy to coordinate and to synchronise;
- systems comprising of autonomous (and may be proactive) components with dynamic structure of interactions have secured their position among novel computer applications and the related impacts and unsolved problems cannot be overlooked;
- autonomy and proactivity in artificial (as well as natural) systems assume the existence of dynamic structure of inter-component interactions and inevitably cause the level of emergent behaviour that cannot any more be neglected;
- for (partial) control of emergent behaviour one needs to understand the essence of the underlying computations - Turing machine paradigm cannot explain the computations in networked pervasive computing systems with sufficient details, and completely neglects many essential features;
- properties of the pilot multi-stream interaction machine (as a case study of a tool for reasoning about interaction-centred computation) look promising for detection of many dynamically emerging features and enables to embed into the computing system instruments (e.g. mediated interactions) for partially controlling the emergent behaviour;
- the experiments with detection and partial control of the emergent behaviour in artificial systems will provide better insight into the essence of emergent behaviour observed in the natural and/or social systems.

The Lab for Proactive Technologies has started a research programme that eventually will lead (hopefully) to symbiosis of computer science, systems science and complexity science with minor influence from artificial intelligence, artificial life. Such symbiosis provides the theoretical

basis for, and practical capability to design artificial, natural, and social systems; to develop methods and tools for analysing the behaviour of such systems, and ability to partially control the emergent behaviour in such systems. Simultaneously an eye is kept on the progress of technological platforms for collecting situational information, for communication between nodes of ad hoc networks, smart interfacing of nodes with different ontology, and computing in the nodes and in the network (L.Mõtus, et al.).

3.4 Research within international programmes

3.4.1 CENS–CMA Co-operation of Estonian and Norwegian Scientific Centres within Mathematics and its Applications. Contract: N 013909 (MTKO-CT-2004-013909).
PI: Prof. J.Engelbrecht;
Project manager: Dr. E.Quak.
The following researchers have used this project:
Prof. Tarmo Soomere (Tallinn) – senior researcher at CMA;
Prof. Andrus Salupere (Tallinn) – senior researcher at CMA;
Dr. Arvi Ravasoo (Tallinn) – senior researcher at CMA;
Dr. Jaan Kalda (Tallinn) – senior researcher at CMA;
Dr. Anatoli Stulov (Tallinn) – senior researcher at CMA;
Dr. Arkadi Berezovski (Tallinn) – senior researcher at CMA;
Dr. Andres Braunbrück (Tallinn) – post-doc at CMA;
Dr. Maksim Säkki (Tallinn) – post-doc at CMA;
Dr. Heiko Herrmann (Berlin) – post-doc at CENS;
Dr. Tomas Torsvik (Bergen) – post-doc at CENS;
Prof. K.Parnell (Australia) – senior researcher at CENS;
Dr. T.Dolphin (UK) – senior researcher at CENS;
Dr. C.Papenfuss (Berlin) – senior researcher at CENS;
D.Kurennoy – researcher at CENS.

3.4.2 FP-6, Complexity – NET.

Complexity - NET unites partners from the UK (coordinator), Belgium, Denmark, Estonia, Greece, Hungary, Ireland, Italy, the Netherlands, Portugal, Spain with France and Germany as observers. Estonian representatives are J.Engelbrecht (CENS), L.Mõtus (CDC) and A.Pöitel (Foreign Dept. of the Estonian Academy of Sciences).

According to the rules of ERA-NETs, the coordination of national activities is supported that helps to plan further research.

3.4.3 FP-6, EU IST Network of Excellence AIM@SHAPE on shape modelling. Contract IST-506766. Dr. E.Quak, Senior Fellow of the CENS-CMA project, is the Technical Manager of this Network of Excellence.

3.4.4 Project EstSpline "Educations, Scientific and Technological Aspects of Splines. FP7-PEOPLE-2-2-ERG224819. PI: Dr. E.Quak.

3.4.5 FP-6, Marie Curie Research and Training Network SEAMOCS "Applied stochastic models for ocean engineering, climate and safe transportation" (2005–2009). Contract MRTN-CT-2005-019374.

Main contractor: Lund University. The CENS group of water waves is leader of the work package 3 "Models on local scale". The responsible scientist is Prof. T.Soomere.

The partners are: University of Sheffield, Université Paul Sabatier (Toulouse), Katholieke

Universiteit Leuven, Chalmers Technical University (Göteborg), Royal Netherlands Meteorological Institute (De Bilt), Swedish Meteorological and Hydrological Institute (Norrköping), Det Norske Veritas (Norway, Oslo).

The following young researchers were recruited in the framework of SEAMOCS: 1. Dr. I.Didenkulova (Nižni Novgorod); 2. L.Kelpšaite (Klaipeda); 3. D.Kurennoy (St. Petersburg); 4. N.Delpeche (Trinidad and Tobago).

3.4.6 NordPlus Neighbour Nordic–Baltic–Russian network. Cooperation within education and research (2005–2008) **"Boundary Layer Phenomena over Partially Ice Covered Arctic Seas: Impact on Weather, Climate, Ecology and Sustainable Economy"**
Participants: Marie Curie Chair of Boundary-layer Physics, Division of Atmospheric Sciences, Dept. of Physical Sciences, Univ. of Helsinki, Finland (Prof. S.Zilitinkevich), Nansen Environ. Remote Sensing Centre, Bergen, Norway (I.Ezau), Wind Energy Dept., Risø National Laboratory, Denmark (Prof. S.E.Larsen), Danish Meteorological Institute, Copenhagen, Denmark (Dr. A.Baklanov), Nils Bohr Institute, University of Copenhagen, Denmark (Dr. P.D.Ditlevsen), Dept. of Meteorology, Stockholm University, Sweden (Prof. M.Tjernström), Arctic and Antarctic Research Institute, St. Peterburg, Russia (Dr. A.Korablev), Russian Hydrometeorological State University, St. Peterburg, Russia (Dr. S.Tyuryakov), Nansen Internat. Environ. Remote Sensing Centre, St.Petersburg, Russia (Dr. S.Kuzmina), Laboratory of Mathematical Modelling, University of Latvia, Riga, Latvia (Dr. J.Rimshans).

3.4.7 INNOVE (Estonia) project 1.0101–0208 "Inviting foreign experts in the framework of launching teaching of port and coastal engineering in Tallinn University of Technology" (2005–2008) financed from EU structural funds. Project leader – Prof. T.Soomere.

3.4.8 FP7, FET (Future and Emerging Technologies), CA (Coordination Action) GSD "Global System Dynamics and Policies: simulation and visualisation technologies", led by University College London (United Kingdom); partners: Utrecht University (Netherlands), Max Planck Institute of Meteorology (Germany), European Climate Forum e.V. (Germany), Chalmers Tekniska Hoegskola AB (Sweden), Unit for Research into Changing Institutions (United Kingdom), IMCS Intercollege Ltd. (Cyprus), Universidad de Alcala (Spain), Ecole des Hautes Etudes en Sciences Sociales (France), Potsdam lnstitute for Climate Impact Research (Germany). Prof. T.Soomere.

3.4.9 EEA grant EMP41 "Shoaling and runup of long waves generated by high-speed ferries"(2008–2010): Collaboration between Irina Didenkulova and (i) Univ. of Bergen: Tomas Torsvik, (ii) Dept. of Mathematics, Univ. of Oslo: Prof. Geir Pedersen, and (iii) Inst. of Applied physics: Prof. E.N.Pelinovsky.

3.4.10 ProVention Consortium Research and Action Grants (USA) "Tsunamis in Russian Lakes and Rivers"No 3019. (I.Didenkulova, E.Pelinovsky, 2007–2008). INTAS grant for studies of long-wave runup on a beach (Dr. I.Didekulova, 2007–2008).

3.4.11. Submission and winning of pan-Baltic BONUS-169 project BalticWay: The potential of currents for environmental management of the Baltic Sea maritime industry (expected to start from 01.01.2009; coordinator T.Soomere).
Together with Swedish Meteorological and Hydrological Institute (Norrköping), Laser Diagnostic Instruments (Tallinn), Danish Meteorological Institute, Department of Meteorology, Univ. of Stockholm, Institute for Coastal Research, GKSS Geesthacht, Finnish Institute of

Marine Research, and Leibniz Institute of Marine Sciences at the University of Kiel.

3.4.12 Estonian-Polish joint research project "Equivalence and reducibility of nonlinear control systems on time scales" (2007–2009), PI: Ü.Kotta. Partners: Tallinn University of Technology (Estonia); Bialystok Technical University, Institute of Mathematics and Physics (Poland).

3.4.13 NOE Euron European Robotic Network, Estonian coordinator: J.Vain. Euron has 210 members in 28 countries. (for list of members please see http://www.euron.org/members/index).

3.4.14 Project "Knowledge Environment for Interacting ROBOt SWARMs"(2006–2009), PI: J.Vain. Project coordinator: Tallinn University of Technology (Estonia). Project partners: ELIKO Competence Centre in Electronics-, Info- and Communication Technologies (Estonia); FATRONIK (Spain); INRIA (The French National Institute for Research in Computer Science and Control) (France); TKK (Helsinki University of Technology, Laboratory of Software Technology) (Finland); University of Oulu (Finland); KTH (Royal institute of Technology in Stockholm, Department of Microelectronics and Information Technology) (Sweden); IdMind (Portugal); UGDIST (University of Genoa, Department of Communication, Computer and System Sciences) (Italy).

3.4.15 EU ICT Coordination Action FOCUSK3D on 3D shapes and semantics. Task Leader: E.Quak.

3.4.16 Special Interest Group on Geometric Modeling, CAD, Evolving Interfaces and Surfaces of the European Consortium for Mathematics in Industry (ECMI), contact point: E.Quak.

3.4.17 ITEA project 05018 Title: Gene-Auto: Automatic Software Code Generation for Real-time Embedded Systems, duration of the project 01.01.2006 – 31.12.2008.
P.I. in Estonia: T.Naks (ProLab); P.I. in TUT: L.Mõtus (ProLab).
Partners: Continental Automotive France SAS, Airbus France, EADS Astrium SAS (France), Barco Avionics (Belgium), Israel Aircraft Industries, Tallinn University of Technology (Estonia), FRIA (Federation of Research in Computer Science and Control Theory, France), INRIA Rocquencourt (National Institute for Research in Computer Science and Control, France), IB Krates (Estonia), Cril Technology (France), Thales Alenia Space (France).

3.4.18 COST – European Cooperation in Science and Technology
COST action 295 – Dynamic Communication Networks: Foundations and Algorithms
Members of the management committee – M.Meriste and L.Mõtus (ProLab);
J.-S.Preden participated in the work of the Action 295.

3.4.19 COST action IC0603 – Antenna Systems & Sensors for Information Society Technologies (ASSIST). Member of the management committee is J.-S.Preden (ProLab).
Objectives: Cooperation towards a deeper understanding of antenna operation in new complex environments and for the corresponding development of adequate modelling and measuring tools are the main scientific objective of the action. Whereas traditional antenna areas still demand research, new unforeseen and challenging problems are appearing - e.g. antennas in consumer electronics, health care, biology, radio astronomy, earth sciences, and earth resources monitoring.

3.4.20 NATO RTO Task Groups: **SCI-TG-181** "Design Considerations and Technologies for Air Defence Systems", Participant L.Mõtus.
SCI-ET-206 "System Design Considerations and Technologies for Safe High-Tempo Operations in Degraded Visual Environments", Participants: M.Meriste and J.-S.Preden.

3.4.21 Nordforsk Research Network "Analysis and Applications"(grant 080151).
Participants from Norway, Denmark, Sweden, Finland, Estonia, Russia. PI: A.Salupere.

4. Funding

4.1 Target funding through the Ministry of Education and Research

1. Block grant SF0322521s03 "Nonlinear dynamics and stress analysis",
   PI: J.Engelbrecht.
2. Block grant SF0140018s08 "Synthesis of complex nonlinear systems", PI: Ü.Kotta.
3. Block grant SF0140113As08 "Proactivity and situation awareness", PI: L.Mõtus.

4.2 Estonian grants (Estonian Science Foundation)

1. H.Aben, ETF grant 6881, "Photoelastic tomography", (2006–2008).
2. A.Berezovski, ETF grant 7037, "Multiscale dynamics in microstructured solids", (2007–2010).
3. P.Peterson, ETF grant 5767, "Extreme waves: analysis of free surface models", (2004–2008).
4. J.Kalda, ETF grant 6121, "Scale-invariant geometrical properties of turbulent diffusion", (2005–2008).
5. T.Soomere, ETF grant 7000, "Real time optical measurements and modelling of wave-induced resuspension of bottom sediments", (2007–2010) (together with Ants Erm, Marine Systems Institute).
6. T.Soomere, ETF grant 7413, "Spatial and temporal variability of the Baltic Sea wave fields in changing climatic conditions", (2007–2010).
7. J.Janno, A.Ravasoo, ETF grant 6018, "Inverse problems for inhomogeneous and microstructured material identification", (2005–2008).
8. A.Salupere, ETF grant 7035, "Deformation waves in microstructured solids — multiscale models", (2007–2010).
9. Ü.Kotta, ETF grant 6922, "Control systems on time scales", (2007–2010).
10. S.Nõmm, ETF grant 6884, "Identifiability and Identification of NARX models (My First Grant)", (2006–2009).
11. J.Vain, ETF grant 7667, "Synthesis of model-based reactive planners for nondeterministic and distributed systems", (2008–2011).

12. M.Vendelin, ETF grant 7344, “Mechanoenergetics of an isolated single cardiomyocyte”, (2008–2011).

13. I.Didenkulova, EEA grant EMP41, “Shoaling and runup of long waves generated by high-speed ferries”, (2008–2010).

14. L.Mõtus, ETF grant 6182, “Research of multi-agent systems in heterogeneous environment with dynamic structure”, (2005–2008).

15. E.Rüstern, ETF grant 6837, “Robust methods for complex systems control: and integrated approach”, (2006–2009).

16. A.Udal, ETF grant 6914, “Modelling of semiconductor quantum well nanostructures and carbon nano-tubes”, (2007–2009).

17. R.Savimaa, ETF grant 7693, “Modelling of time-sensitive processes and emergent behaviour in multi-functional and virtual organisations”, (2008–2011).

4.3 International grants (see also 3.4)

1. H.Herrmann, Feodor Lynen fellowship of the German Alexander von Humboldt foundation (initially awarded 2008–2009).

2. S.Nõmm, INNOVE project “International Postdoctoral fellowship in the Institute of Cybernetics”, (2005–2008).

3. Dr. M.Vendelin. Wellcome Trust Grant: Analysis of structural and functional aspects of compartmentation of adenine nucleotides in heart muscle cells.
   Senior researchers in this project: Dr. R.Birkedal and Dr. P.Peterson.

4.4 Additional funding

1. Institute of Cybernetics at TTU – basic funding.

2. EAS funding scheme “Eureka ITEA D-MINT”(2008–2009), PI: Juhan-Peep Ernits.

4.5 National contracts

1. Contract N 8068 “Neural Networks for HVAC applications” between Tallinn University of Technology and OÜ Yoga to develop an algorithm for building climate control.
   P.I.: E.Petlenkov (ProLab); participant J.Belikov.

2. Network enabled capabilities (NEC) and ad hoc networks. P.I.: J.-S.Preden and M.Meriste (ProLab). Project partner: Institute of Technology (University of Tartu).

3. ELIKO competence centre – Smart space project. P.I.: J.-S.Preden, R.Pahtma (ProLab). Project partners: Smartdust Solutions, Eliko competence centre.

4. Power-line monitoring devices (ProLab). Partners: Smartdust Solutions, TUT Department of Electrical Engineering.

4.6 Supportive grants (travel, etc.)

1. SA Archimedes Kristjan Jaak travel grants for attending International Conference Cybernetics and Informatics, Zdiar, Slovakia, (V.Kaparin, J.Belikov).
2. SA Archimedes Kristjan Jaak travel grant for attending 17th IFAC World Congress, 24 295 EEK, (S.Nõmm).
3. EITSA travel grant for attending International Conference on Automation, Robotics, Control and Vision 2008, (Ü.Nurges).
4. EITSA travel grant for attending 2008 IEEE World Congress on Computational Intelligence, (S.Nõmm).
5. European Embedded Control Institute grants for attending HYCON-EECI Graduate School on Control 18.01.2009–7.02.2009, (V.Kaparin, J.Belikov).
6. Estonian Railway Scholarship from Tallinn UT, (M.Randrüüt).
7. Tiina Mõis scholarship from Tallinn UT, (M.Randrüüt).
8. A.Ots Scholarship for studies in the Chalmers University, Gothenburg, (M.Vallikivi).
9. IEEE Swarm Intelligence Symposium 2008 Student Travel Grant awarded by IEEE Computational Intelligence Society, (T.Lints).
10. ICT PhD student scholarship from Estonian Information Technology Foundation, (T.Lints).
11. A travel and accommodation bursary awarded by the organisers of A-LIFE XI (ProtoLife), (T.Lints).
12. Participation in EU-China Summer School on "Internet, Science, and Society" was sponsored by the Estonian Doctoral School in ICT, (T.Lints).
13. University of Turin grant to attend the conference MECAMAT 2008, (M.Randrüüt).

5. Publicity of Results

5.1 Research Reports

1.	Mech 291/08	L.Ilison, A.Salupere. Interactions of solitary waves in hierarchical KdV-type system.
2.	Mech 292/08	A.Stulov, D.Kartofelev. Modeling of the string with nonlinear contact conditions.
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5.2.4 Submitted papers

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2. A.Berezovski, J.Engelbrecht, G.A.Maugin. Internal variables and generalized continuum theories. Proc. of IUTAM Symposium on Progress in the Theory and Numerics of Configurational Mechanics, Friedrich-Alexander-University, Erlangen-Nuremberg, Germany, October 20–24, 2008, (submitted).

3. A.Berezovski, J.Engelbrecht, G.A.Maugin. One-dimensional microstructure dynamics. Proc. of 11th EUROMECH-MECAMAT Conf.: Mechanics of microstructured solids: cellular materials, fibre reinforced solids and soft tissues. Torino, Italy, March 10–14, 2008, (submitted).

4. A.Berezovski, M.Berezovski, J.Engelbrecht. Waves in inhomogeneous solids.
   - In: E.Quak (Ed.): Applied Wave Mathematics, Springer (Lecture Notes).

5. J.Belikov, E.Petlenkov. Calculation of the control signal in MIMO NN-based ANARX models: Analytical approach. In: Proc. of the 10th Intern. Conf. on Control, Automation, Robotics and Vision, Hanoi, Vietnam, December 2008, (accepted).

6. I.Didenkulova, E.Pelinovsky, and T.Soomere. Long Wave Dynamics along a Convex Bottom. Journal of Geophysical Research – Oceans, (submitted).

7. I.Didenkulova. Nonlinear Long-Wave Deformation and Runup in a Basin of Varying Depth. Nonlinear Processes in Geophysics, (submitted).

8. I.I.Didenkulova, E.N.Pelinovsky. Tsunami-like events in Russian inland waters. Theoretical and Applied Hydrophysics, (submitted).

9. I.Didenkulova. New Trends in the Analytical Theory of Long Wave Runup. - In: E.Quak (Ed.): Applied Wave Mathematics, Springer (Lecture Notes).

10. J.Engelbrecht. Nonlinear Deformation Waves. - In: E.Quak (Ed.): Applied Wave Mathematics, Springer (Lecture Notes).

11. J.Engelbrecht, A.Ravasoo, J.Janno. Nonlinear acoustic NDE - qualitative and quantitative effects. - Materials and Manufacturing Processes, 20 p., (submitted).

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14. L.Ilison, A.Salupere. Propagation of sech2-type solitary waves in hierarchical KdV-type systems, Mathematics and Computers in Simulation, (submitted).

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16. J.Janno, K.Kasemets. A positivity principle for parabolic integro-differential equations and inverse problems with final overdetermination, (submitted).

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18. J.Kalda. Efficient method of finding scaling exponents from finite-size Monte-Carlo simulations, Physica A, http://arxiv.org/abs/0804.1911, (submitted).

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5.2.5 Popular science / Science policy

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5.3 Conferences

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2. 11th EUROMECH-MECAMAT Conference: Mechanics of microstructured solids: cellular materials, fibre reinforced solids and soft tissues. 10–14 March 2008, Torino, Italy.
   J.Engelbrecht, M.Randrüüt, A.Salupere. On modelling wave motion in microstructured solids.
   A.Berezovski, J.Engelbrecht, G.A.Maugin. One-dimensional microstructure dynamics.
   A.Salupere, L.Ilison. Numerical simulation of interaction of solitons and solitary waves in granular materials.

3. International Conference on Applied Mathematics: Modeling, Analysis and Computation, 1–5 June 2008, City University of Hong Kong.
   A.Berezovski. Macroscopic Dynamics of Phase-Transition Front and Straight Brittle Crack.

4. Fifth International Conference of Applied Mathematics and Computing, Plovdiv, 12–18 August 2008, Bulgaria.
   A.Berezovski. Thermodynamics of finite volumes.

5. IUTAM Symposium on Progress in the Theory and Numerics of Configurational Mechanics, Friedrich-Alexander-University, Erlangen-Nuremberg, 20–24 October 2008, Germany.
   A.Berezovski, J.Engelbrecht, G.A.Maugin. Internal variables and generalized continuum theories.

6. 18th International Symposium on Nonlinear Acoustics, 7–10 July 2008, Stockholm, Sweden.
   A.Braunbrück. Harmonic burst in inhomogeneous material.

7. XXII International Congress of Theoretical and Applied Mechanics ICTAM 2008, 24–29 August 2008, Adelaide, Australia.
   J.Engelbrecht, A.Berezovski, G.A.Maugin. Internal variables and microstructures materials.

A.Salupere, M.Randrüüt, K.Tamm. Emergence of soliton trains in microstructured materials.

8. International Conference on Multi-Functional Materials and Structures. 28–31 July 2008, Hong Kong.
   J.Engelbrecht. Nonlinear acoustic NDE - qualitative and quantitative effects.

9. 4-th International Conference Inverse Problems: Modelling and Simulation, 26–30 May 2008, Fethiye.
   J.Janno. Inverse problems for microstructured materials.

10. 13-th International Conference on Mathematical Modelling and Analysis and 3-rd Int. Conf. on Approximation Methods and Orthogonal Expansions, 4–7 June 2008, Kääriku.
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11. International Conference "Direct, Inverse and Control Problems for PDE's"- DICOP, 22–26 August 2008, Cortona.
    J.Janno. A positivity principle for parabolic integro-differential equations and final overdetermination.

12. Conference "Faculty of Science in TUT - 6 years of development", 19 September 2008, Tallinn.
    J.Janno. Inverse problems for microstructured materials.

13. Chaotic Modeling and Simulation International Conference (CHAOS2008), 3–6 June 2008, Chania Crete Greece.
    J.Kalda. The processes responsible for the extreme intermittency by turbulent mixing.

14. 52nd Annual Meeting of Biophysical Society, February 2008, Long Beach, LA, USA.
    M.Vendelin. 3D reaction-diffusion model of interaction between mitochondria and sarcoplasmic reticulum/cytoskeleton proteins in heart muscle cells.
    A.Illaste. Mathematical model of mitochondrial energy metabolism.
    R.Birkedal. Expression and localization of ryanodine receptors in rainbow trout cardiomyocytes: individual variation, but no effect of temperature acclimation.

15. The 34th Conference "Applications of Mathematics in Engineering and Economics" (AMEE'08), 6–12 June 2008, Sozopol, Bulgaria (invited lecture).
    A.Salupere. Numerical simulation of propagation of solitary waves and solitons in microstructured solids.

16. 18th International Symposium on Nonlinear Acoustics (ISNA 18) 07–10 July 2008, Stockholm, Sweden.
    A.Stulov, D.Kartofelev. Vibration of the string with nonlinear contact condition.

17. Workshop "Industry Challenges in Geometric Modeling", CAD and Simulation 13–14 March 2008, Darmstadt, Germany.
    E.Quak. The FOCUS K3D on 3D shapes and semantics.

18. Workshop Approximations methoden und Schnelle Algorithmen, Hasenwinkel (Mecklenburg) , 4–9 June, Germany.
    E.Quak. Meeresautobahnen für die Ostsee.

19. CIB International Conference in Building Education and Research "Building Resilience", 11–15 February 2008, Heritance Kandalama, Sri Lanka.

T.Soomere. Extreme wave and water level conditions in the Baltic Sea in January 2005 and their reflection in teaching of coastal engineering.

20. Winter School "Nonlinear waves 2008". 1–7 March 2008, Nizhny Novgorod, Russia.
    I.Didenkulova. Estimates of long-wave runup characteristics on a beach.

21. Joint MoRST (Ministry of Research, Science & Technology) - DfG (Deutsche Forschungsgemeinschaft) International workshop on "Future of Environmentally Sustainable Coastal Marine Development"Oceanside Hotel, Mt Maunganui, 26–27 March 2008, New Zealand.
    T.Soomere. Coastal marine hazard and sustainable development.

22. Conference "Sea and coastal research 2008". 9–11 April 2008, Palanga, Lithuania.
    L.Kelpšaite. Closure depth at the Lithuanian coast.

23. Solutions to Coastal Disasters 2008 Conference, American Society of Civil Engineers (ASCE), 13–16 April 2008, Turtle Bay Resort on Oahu, Hawaii.
    T.Soomere, T.Healy. Escalating extremes over descending trends of the northern Baltic Sea wave fields.
    T.Soomere, T.Healy. Managed retreat - is it really an option for mitigation of chronic erosion and storm surge flooding.
    I.Didenkulova, E.Pelinovsky, T.Soomere. Influence of the initial wave shape on tsunami wave runup characteristics.

24. Conference of science policy "Science – deaf or sound", 28 Aprill, 2008, Tallinn, Estonia.
    J.Engelbrecht and T.Soomere: took part in the panel discussion.

25. Workshop on "Risk assessment and environmental security in the baltic sea region", Lithuanian Academy of Sciences, 6–7 May 2008, Vilnius, Lithuania.
    L.Kelpšaite. Risk assessment and environmental security in the Baltic Sea region.

26. US-EU-Baltic 2008 International Symposium, 27–29 May 2008, Tallinn, Estonia.
    I.Didenkulova. Analysis of tide-gauge records and their spectra of tsunami waves and background oscillations.
    L.Kelpšaite. Wave climate variability in the Tallinn area.
    I.Zaitseva, T.Soomere. On long - term variations of the wave conditions in the Northern Baltic Sea.

27. Summer school on environmental dynamics "Climate forcings and global patterns", Istituto Veneto di Scienze Lettere ed Arti, Palazzo Cavalli Franchetti, 13–20 June 2008, Venice, Italy.
    L.Kelpšaite and D.Kurennoy. Climate forcings and global patterns.

28. Conference on Marine Problems and Specific Solutions, COMPASS 2008, 15–18 June 2008, Maldives.
    I.Didenkulova, E.Pelinovsky. Some Analytical Solutions in Tsunami Wave Runup Theory.

29. EC project meeting "Voluntary Activities towards improved Civil Protection in Europe", 12 June 2008, Roskilde, Denmark.
    T.Soomere. Small variations of forcing leading to substantial increase of the risk of coastal marine hazards.

30. EASAC: European Academies Science Advisory Council workshop, 16–17 June 2008, Prague.
    T.Soomere. Environmental aspects of NordStream: developments and challenges.

31. International Conference (school-seminar) on the Dynamics of Coastal Zone of Non-tidal Seas, June 30 – July 5, 2008, Baltiysk, Russia.
    L.Kelpšaite. Value of the depth of closure at the different Lithuanian sea coast points.
    D.Kurennoy, D.Ryabchuk. The lithodynamic modeling of the Eastern part of the Gulf of Finland, Kurort area, Sant-Petersburg.

32. The European Consortium For Mathematics In Industry Conference University College London, 30 June – 4 July 2008, London.
    T.Soomere. Complexity of climate changes in small scale: experience from the Baltic Sea. (for the kick-off meeting of the FP7 project GSD, held jointly with the ECMI).

33. SIAM Conference on Nonlinear Waves and Coherent Structures, 21–24 July 2008, Universita di Roma "La Sapienza".
    T.Torsvik, T.Soomere. Simulation of high-speed ferry wakes in Tallinn Bay.
    I.Didenkulova, E.Pelinovsky. Travelling waves in strongly inhomogeneous media: propagation and transformation.

34. 33th International Geological Congress, 6–14 August 2008, Oslo.
    T.Soomere, A.Kask, T.Healy. Sediment transport patterns and rapid estimates of net loss of sediments for "almost equilibrium"beaches of tideless embayed coasts.
    A.Kask, J.Kask, T.Soomere. Formation of sand deposits in Estonian coastal sea (poster).

35. 3rd International Student Conference "Biodiversity and functioning of aquatic ecosystems in the Baltic sea region". Klaipeda, Lithuania, on 9–13 October 2008.
    L.Kelpšaite. Wave regime variations at Lithuanian coast of the Baltic Sea.
    D.Kurennoy. Coastal processes in the Gulf of Finland.
    I.Zaitseva-Pärnaste (poster). Long-term variations of wave conditions in the northern Baltic Sea derived from visual observations from Vilsandi, Pakri and Narva-Jõesuu.
    A.Räämet (poster). On the variability of the Baltic Sea wave fields.

36. International Forum "Ethics and Science for the Enviroment", Torun, Poland, 12–14 October 2008.
    T.Soomere and E.Quak. Environmental concerns about building large-scale pipelines in the Baltic Sea.
    T.Soomere participated in the panel discussion.

37. Conference Rogue Waves 2008. 13–15 October 2008, Brest, France.
    I.Didenkulova. Runup of irregular waves on a plane beach.

38. DNVA–RSE Norway-Scotland Internal Waves Symposium, Oslo 14–15 October 2008. The Norwegian Academy of Science and Letters (DNVA) and The Royal Society of Edinburgh (RSE).
    T.Soomere participated.

39. SEAMOCS network meeting and conference on fatigue. 23–24 October 2008, Oslo.
    T.Soomere participated.
    I.Didenkulova. Wave runup.
    L.Kelpšaite and I.Zaitseva. Wave regime changes at the Baltic Sea eastern coast.
    D.Kurennoy. Variability in wake properties generated by high-speed ferries.

40. International Workshop "Caribbean Waves: Risk Evaluation of Natural Hazards in the Caribbean", 9–10 December 2008, Pointe-a-Pitre, Guadeloupe, FWI, Lesser Antilles.
I.Didenkulova. Runup of desctructive waves on a beach; chair of the "Storm surge"session.

41. European Academies Scientific Advisory Council (EASAC) Environmental Steering Panel meeting, 12 November 2008, Royal Society, London.
T.Soomere. Environmental concerns about building large-scale pipelines in the Baltic Sea.

42. Kybernetika a Informatika: Medzinarodna konferencia SSKI, 10–14 February, Zdiar, Slovakia.
J.Belikov, Ü.Kotta, T.Mullari, S.Nõmm, M.Tõnso. Discretization of continuous-time nonlinear control systems with computer algebra system Mathematica.
M.Halás, M.Huba, Ü.Kotta. Overview of transfer function formalism in nonlinear continuous-, discrete-time and time-delay systems.
V.Kaparin, Ü.Kotta, T.Mullari, M.Tõnso. Transformation of nonlinear control system into observer form with computer algebra system Mathematica.

43. IEEE World Congress on Computational Intelligence (WCCI2008), 1–6 June 2008, Hong Kong.
S.Nõmm, E.Petlenkov, J.Vain, F.Miyawaki. Application of self organizing Kohonen Map to detection of surgeon motions during endoscopic surgery.

44. American Control Conference 2008, 11–13 June, Seattle, Washington, USA.
S.Nõmm, M.Wyrwas. Dynamic output feedback linearization based adaptive control of nonlinear MIMO systems.
M.Wyrwas, D.Casagrande, Ü.Kotta, M.Tõnso. Transfer equivalence and reduction of nonlinear delta differential equations on homogeneous time scale.

45. 17th World Congress The International Federation of Automatic Control, 6–11 July 2008, Seoul, Korea.
Ü.Nurges, E.Rüstern. Robust pole placement via reflection axes polytopes.
Ü.Kotta, K.Schlacher. Possible non-integrability of observable space for discrete-time nonlinear control systems.
Ü.Kotta, M.Halás, C.H.Moog. Transfer function approach to the model matching problem of nonlinear systems.
S.Nõmm, E.Petlenkov, J.Vain, J.Belikov, F.Miyawaki, K.Yoshimitsu. Recognition of the surgeon's motions during endoscopic operation by statistics based algorithm and neural networks based ANARX models.

46. 10th IEEE International Conference on Automation, Control, Robotics and Vision ICARCV 2008, 17–20 December, Hanoi, Vietnam.
P.Kotta, Ü.Kotta, M.Halás. Irreducibility and reduction of nonlinear control systems: unification and extension via pseudo-linear algebra.
Ü.Kotta, A.Leibak, M.Halás. Non-commutative determinants in nonlinear control theory: preliminary ideas.

47. 2nd IEEE International Conference on Self-Adaptive and Self-Organizing Systems, SASO 2008, October 20–24 Venice, Italy.
J.Vain, T.Tammet, A.Kuusik, A.Puusepp. RFID-based Communication for a Self-Organizing Robot Swarm.

48. 11th International Biennial Baltic Electronics Conference, 6–8 October 2008, Tallinn, Estonia.
J.Vain, T.Tammet, A.Kuusik, E.Reilent. Software architecture for swarm mobile robots.
J.Vain, T.Tammet, A.Kuusik, S.Juurik. Towards scalable proofs of robot swarm dependability.
E.Petlenkov, A.Jutman, S.Nõmm, R.Ubar. Dynamics output feedback linearization based adaptive control of nonlinear MIMO systems.

49. International Mathematica User Conference 2008, Champaign, 23–25 October, IL, USA.
Ü.Kotta, P.Kotta. Mathematica assistance in proving theorems in nonlinear control.
M.Tõnso, J.Belikov, V.Kaparin, H.Rennik, Ü.Kotta. Modeling, analysis, and synthesis of nonlinear control systems with mathematica.
H.Rennik, M.Tõnso, Ü.Kotta. Solving problems for nonlinear control systems using webMathematic.

50. The 7th World Congress on Intelligent Control and Automation. 25–27 June 2008, Chongqing, China.
Ü.Kotta, M.Tõnso. Realization of discrete-time nonlinear input-output equations: polynomial approach.

51. 16th Mediterranean Conference on Control and Automation, 25–27 June 2008, Ajaccio, Corscia, France.
T.Mullari, Ü.Kotta. Transformation of nonlinear control systems into the observer form: necessary conditions.

52. EuroSciPy 2008 Conference, 26–27 July 2008, Leipzig, Germany.
P.Peterson. On providing a Computer Algebra System for Python.

53. The 13th Estonian Theory Days, 3–4 October 2008, Jõulumäe, Estonia.
P.Peterson. Scientific computations within Python: numerical and analytical tools.

54. Estonian Summer School on Computer and Systems Science.
T.Lints. My first steps towards general AI.

55. Estonian Winter School in Computer Science.
J.-S.Preden: Situation awareness of computing agents.
T.Lints. Defining Adaptivity – a short review.

56. 34th Estonian Spring School in Theoretical Biology: Laws of Biology.
T.Lints, participated.

57. 12th Estonian Computer Science Theory Days.
T.Lints, L.Mõtus.

58. EU-China Summer School on "Internet, Sciences, and Society", 1–4 June 2008, Warsaw, Poland.
T.Lints, participated.

59. 12th IASTED International Conference on Artificial Intelligence and Soft Computing 2008, 1–3 September, Palma De Mallorca, Spain.
T.Lints. Let AI Learn from Web 2.0. Tag Co-Occurrence based Text Categorization as an Example.

60. IEEE Swarm Intelligence Symposium, 21–23 September 2008, St. Louis, Missouri, USA.
T.Lints. FlockHeadz: Virtual Flock in a Room Used as a Controller.

61. Artificial Life XI: 11th International Conference on the Simulation and Synthesis of Living Systems, Winchester, UK.
T.Lints.

62. GPS/INS Multi-sensor Kalman filter navigation, 19–22 May 2008, Paris, France.
K.Rannat, participated.

63. 3rd International Workshop on Technologies for Search and Rescue, and other Emergency Marine Operations, 14–16 October 2008, Brest, France.
K.Rannat, R.Serg, participated.

64. ECO-NET Workshops in Brest, 8 July, 20–21 October; and Tallinn, 1 December 2008.
K.Rannat, participated.

65. International Seminar on Defence R&D, 26 September 2008, Tartu.
P.Uba, K.Rannat, P.Kukk. Meteo-data from GPS-signal.

66. 13th WSEAS International Conference on Applied Mathematics, 15–17 December 2008, Puerto de la Cruz, Spain.
K.Rannat. Thermohaline fields monitoring model.

67. ARIS Process Days, 5–6 November 2008, Stockholm, Sweden.
T.Kangilaski, participated.

68. IBM Rational Software Development Conference, 10–14 June 2008, Orlando, USA.
T.Kangilaski, participated.

69. Oracle Nordic Application Days, 12–13 March 2008, Stockholm, Sweden.
T.Kangilaski, participated.

70. ebIX Forum 2008, 16–17 April 2008, Tallinn.
T.Kangilaski, participated.

71. ARIS Process world Europe, 17–18 June 2008, Berlin, Germany.
T.Kangilaski, participated.

72. Model-based Testing in Street Lighting Case Study, D-Mint project Plenary meeting, 9 September 2008, Bilbao, Spain.
A.Kull, participated.

73. ITEA 2 Symposium, 21–22 October 2008, Rotterdam, the Netherlands.
T.Naks, J.-S.Preden, R.Pahtma, participated.

74. Wireless Applications for Machines and Systems, WAMS2008, November 18–19 2008, Ylivieska, Finland.
R.Pahtma, participated.

75. IADIS International Conference, April 9–11 2008, Algrave, Portugal.
T.Kangilaski. Implementing EU directive 2003/54/EC for Electricity Market in Estonia.
V.Kimlaychuk. SOA Integration Aspects for Large Companies.

76. 3rd International Conference on Performance Evaluation Methodologies 2008, 10–25 October, Athens, Greece.
A.Chechkin. Heavy tailed Levy random motions in super- and subharmonic potential wells.

5.4 Seminars

5.4.1 Tallinn Seminars on Mechanics (CENS)

1. 21.01 Dr. Andres Braunbrück: Harmonic burst in weakly inhomogeneous material.
2. 25.02 Dr. Marko Vendelin, Prof. Jüri Engelbrecht: Biological complex systems.
3. 3.03 Dr. Christina Papenfuss: Mesoscopic theory and application to the phase transitionbetween the nematic and isotropic phase of liquid cristals.
4. 21.04 Dmitri Kartofelev, Dr. Anatoli Stulov: Vibration of the string with nonlinear contact.
5. 5.05 Dr. Kevin Parnell (School of Earth and Environmental Sciences, James Cook University, Qeensland, Australia): Climate change, shoreline processes and indigeneous communities on reef islands of Torres strait, Northen Great Barrier Reef.
6. 12.05 Prof. Efim Pelinovsky (Department of Nonlinear Geophysical Processes, Institute of Applied Physics, Russian Academy of Sciences, Nizhny Novgorod:
   Unsteady and nonlinear dynamics of edge waves.
7. 15.05 Seminar on Complexity.
   Prof. Efim Pelinovsky (Nizhny Novgorod): Freak waves in physics: from ocean to astrophysics;
   Dr. Jaan Kalda: Turbulent mixing as a driving force for intermittency;
   Prof. Leo Mõtus: Transparency of interactions.
8. 17.05 Prof. Anastassos (Tassos) Bountis (University of Patras, Greece):
   Chaos and order in multidimensional Hamiltonian systems.
9. 19.05 Irina Didenkulova: Main mechanism of generation of extreme waves.
10. 20.05 Prof. Kari Suomi (University of Oulu): Durational and tonal interactions in Finnish.
11. 26.05 Prof. Peter Deuflhard (Zuze Institute, Berlin): The DFG Research Center MATHEON (Mathematics for Key Technologies) its mission and activities.
12. 30.05 Prof. Michael Stiassnie (TECHNION-Israel Institute of Technology, Haifa, Israel): Recurrent solutions of Alber's equation for random water-wave fields.
13. 6.06 Prof. Wojciech Sulisz (Institute of Hydroengineering at the Polish Academy of Sciences): On the modelling of the propagation of nonlinear wave trains and freak wave.
14. 15.06 Dr. H.Herrmann: Modern constitutive theory: 3. Mesoscopic continuum physics.
15. 16.06 Dr. Andras Szekeres (Budapest University of Technology and Economics):
    Levels of Interdisciplinarity (Iy) by Thermo-Hygro-Mechanics.
16. 19.06 Prof. E.E.Gdoutos (School of Engineering, Democritos University of Thrace, Creece): Failure of composite sandwich structures.
17. 14.08 Bryna Kathryn Flaim (Waikato University), New Zealand:
    The continental shelf as a repository for dredged sediment, northeast New Zealand.

18. 22.09 Dr. Els Heinsalu (KBFI): Subdiffusion in space-periodic force field.
19. 29.09 Dr. Tony Dolphin (Shore of Environmental Sciences, University of East Anglia, Norwich, United Kingdom): Shoreline variability behind segmented shore-parallel breakwaters in a meso-tidal environment.
20. 6.10 Merle Randrüüt: Deformation waves in microstructured materials: one-dimensional evolution equation.
21. 9.10 Dr. Bernd Fischer (Southamptoni University): Explaining verification conditions.
22. 13.10 Kert Tamm: Deformation waves in Mindlin-type microstructured materials.
23. 20.10 Tanel Peets: Modelling of diffusion in microstructured materials.
24. 27.10 Prof. Niels Olhoff (Department of Mechanical Engineering, Aalborg University): Topology optimization of continuum structures against vibration and noise.
25. 28.10 Prof. Jiri Plesek and Dusan Gabriel (Institute of Thermomechanics, Academy of Sciences of the Czech Republic): On wave dispersion in finite element meshes.
26. 10.11 Dr. Andres Udal (TUT): Quantum mechanical coordinate-momentum transforms and the Heisenberg's uncertainty as a classical Fourier signal processing problem: the philosophical and practical conclusions.
27. 17.11 Prof. Aleksei Chechkin: Levy flights: paradigm of non-brownian random motion.
28. 24.11 Dr. Arvi Ravasoo: NDT & FGM.
29. 1.12 Dr. Andres Braunbrück: Ultrasonic burst in exponentially graded materials.
30. 8.12 Prof. Aleksei Chechkin: Origin and properties of the kinetic equations with fractional derivatives.

5.4.1.1 Seminars of the Wave Engineering Group

1. 11.03 Dr. E.Quak: Discrete geometry.
2. 18.03 Dr. H.Herrmann: PUZZLE 2 (Computer from inside).
3. 25.03 D.Kurennoy: Introduction to my work.
4. 1.04 Dr. I.Didenkulova: New trends in the nonlinear theory of long wave runup on a beach.
5. 22.04 Dr. T.Soomere: Long waves experiment planning.
6. 29.04 D.Kurennoy: Morphological structure of Gulf of Finland.
7. 6.05 K.Parnell: Different experimental methods.
8. 13.05 Prof. E.Pelinovsky: Non linear wave theory.
9. 20.05 I.Zaitseva: On long-term variations of the wave conditions in the Northern Baltic Sea.
10. 27.05 L.Kelpšaite: What lives at Lithuanian coast?

11. 22.11 I.Zaitseva-Pärnaste: Seasonal and long-term variations of wave conditions in the northern Baltic Sea.

12. 27.11 L.Kelpšaite: Temporal changes in the relative importance of wind-wave and ship-wake energy: Tallinn Bay, the Baltic Sea.

13. 4.12 D.Kurennoy: Variability in wake properties generated by high-speed ferries.

5.4.1.2 Seminars of the Laboratory of Proactive Technologies

1. 19.09 L.Mõtus: Verification of embedded software - modules versus systems.

2. 2.10 V.Kimlaychuk: Shared knowledge security in agent network.

3. 9.10 J.Preden, M.Meriste: Network enabled capabilities and ad hoc networks.

4. 16.10 A.Riid: Error-free simplification of fuzzy systems.

5. 30.10 A.Udal: Quantum mechanical coordinate-momentum transforms and the Heisenberg's uncertainty as classical Fourier' signal processing problem.

6. 6.11 M.Meriste: Interactive digital map – a multi-agent system.
   R.Serg: Adapting futures: scalability for real-world computing.

7. 13.11 R.Pahtma: Intelligent dust and positioning of motes.

8. 20.11 T.Naks: Model based development and qualification of software process.

9. 27.11 J.Preden: Aspects of situation-awareness.

10. 4.12 R.Savimaa: Modelling time-sensitive behaviour in organisations – possibilities and practice.

11. 11.12 A.Kull: Model-based testing of Embedded Systems.

12. 18.12 A.Karpištštenko: Design of "Canvas"for networked systems.

5.4.2 Seminars outside the home Institute

1. A.Berezovski: Numerical simulation of wave and front motion in inhomogeneous solids Centre of Mathematics for Applications, CENS Guest Lectures, University of Oslo, 28.04.2008.

2. A.Stulov: Materials with memory: from solitary waves to music, CMA Guest Lecture, University of Oslo, 16.09.2008.

3. A.Braunbrück: Nonlinear wave propagation in inhomogeneous medium. TUT, Faculty of Civil Engineering, Institute of Mechanics. Open lecture to apply the position of part time assistant professor, 6.05.2008.

4. J.Kalda: The dynamics behind the extreme intermittency of turbulent mixing. CMA, University of Oslo, 5.02.2008.

5. J.Kalda: Turbulent mixing: the dynamics behind extreme intermittency. Institute of Physics, University of Oslo, 14.02.2008.

6. J.Kalda: The mechanism of creating extreme intermittency by turbulent mixing. 23.05.2008.

7. J.Kalda: Meeting of the representatives of the physics olympiads of small countries, Aarau, Switzerland, 26–27.05.2008.

8. Ü.Kotta: Studies on control in the Institute of Cybernetics at TUT, Slovak University of Technology, 8.09.2008.

9. Ü.Kotta: Construction of observers for nonlinear discrete-time control systems, Wuhan University, 1.07.2008.

10. J.Vain: Robot swarms and ROBOSWARM on ELIKO HEI seminar "Smarter house", Tallinn University of Technology, 22.05.2008.

11. M.Tõnso: Realization of nonlinear input-output equations using polynomial approach: preliminary ideas, Voore, Estonia, 25.04.2008.

12. J.Vain: Tutorial on Dependability, Nordic Network on Dependable Systems (NODES) Summer School, Nüpli, Otepää, Estonia, 28.08.2008.

13. I.Didenkulova: Travelling wave solution in the variable-coefficient wave equation. Universite des Antilles et de la Guyane, Guadeloupe, French West Indies, 31.01.2008.

14. T.Soomere: Earth and marine sciences. Annual conference of the Institute of Geology (in Estonian), Tallinn, 27.02.2008.

15. I.Didenkulova: New trends in the nonlinear theory of long wave runup on a beach. Department of Civil & Environmental Engineering, MIT, Cambridge, USA, 4.04.2008.

16. I.Didenkulova: Shoaling and runup of long waves generated by high-speed ferries. Department of Civil & Environmental Engineering, Cornell University, Ithaca, USA, 10.04.2008.

17. I.Didenkulova, delivered lecture on: Tsunami Problem in school N 13, Nizhny Novgorod, 5.03.2008.

18. T.Soomere, public lecture: Ferocious storms and high waves on Estonian coasts. Lakewood, (Estonian House), 18.04.2008.

19. T.Soomere, public lecture: Hiiumaa in the mercy of sea and waves? During the days of science organised by the Estonian Academy of Sciences, Hiiumaa, (in Estonian), 8–9.05.2008.

20. T.Soomere, public academic lecture of Estonian Academy of Sciences: Ferocious sea. nr. 47 (in Estonian), 10.09.2008.

21. T.Soomere, series of lectures to gymnasium pupils: Ferocious sea I: Tsunami. (in Estonian), 13.09.2008.

22. T.Soomere, series of lectures to gymnasium pupils: Ferocious sea II: Coastal flooding. (in Estonian), 21.09.2008.

23. T.Soomere, series of lectures to gymnasium pupils: Ferocious sea III: Freak waves. (in Estonian), 1.11.2008.

24. T.Soomere: Marine hazards for the City of Tallinn (in Estonian), and T.Dolphin: Measuring shorelines and coastal processes using digital cameras, to the Commission on Environment of the Council of the City of Tallinn, 3.11.2008.

25. T.Soomere: Coastal hazards for the City of Tallinn and City of Pärnu. (in Estonian), 6.11.2008.

26. T.Soomere, series of lectures to gymnasium pupils: Ferocious sea IV: Ferocious sea IV: Man-induced threats. (in Estonian), 9.11.2008.

27. I.Didenkulova: Extreme wave phenomenon, University of Antilles and Guyane, Guadeloupe, 12.11.2008.

28. T.Soomere, public lecture: Estonia in the mercy of wind and waves? Kapa Stuudium, Kohila, Tohisoo Mõis, 16.11.2008.

29. E.Quak: The EU FOCUS K3D Coordination Action: scope and goals Workshop Industry Challenges in Geometric Modeling, CAD and Simulation 2008, Darmstadt, Germany, 13.03.2008.

30. E.Quak: On the potential of reducing coastal pollution by a proper choice of the fairway. Workshop Approximationsmethoden und Schnelle Algorithmen, Hasenwinkel, (Mecklenburg), Germany, 6.06.2008.

31. E.Quak: The upcoming BONUS project BalticWay Annual IoC Workshop, Nelijärve, 18.10.2008.

32. E.Quak: Overview of EC research funding Invited lecture, Kick-off meeting of the EU Marie Curie Initial Training Network SAGA (Shapes, Geometry, Algebra), Castro Urdiales, Spain, 17.11.2008.

33. L.Mõtus, M.Meriste: Towards proactive computing systems. Final Workshop of the Estonian Centre of Excellence for Dependable Computing 2002–2007, Tallinn ,January 2008.

34. M.Meriste, L.Mõtus: Knowledge-based Estonia - proactive networking. Tallinn (in Estonian).

35. M.Meriste, J.-S.Preden: Interacting entities in dynamic networks. COST Action 295 regular workshop, Freiburg, February 2008.

36. M.Meriste: Intelligent building as a self-organising system (in Estonian).

37. M.Meriste: Interactive maps. German SME delegation visiting TU Institute of Technology, September 2008.

38. L.Mõtus: Proactive technologies and their applications. Seminar Intelligent Building 2, TUT, organized by IEEE Estonia.

39. A.Udal: Quantum mechanical coordinate-momentum transforms and the Heisenberg's uncertainty as a classical Fourier' signal processing problem: philosophical and practical conclusions. Center of Nonlinear Studies CENS (Inst. of Cybernetics TUT).

40. R.Pahtma: A Cricket based positioning system for the TUT Robotics Club robot. Robotex 2008.

6. Research and teaching activities

6.1. Meetings, events

6.1.1 CENS-CMA Workshop on Thermodynamics of slow and fast dynamical processes 17–18 March 2008, Tallinn, Estonia
Speakers: A.Berezovski (Tallinn), H.Herrmann (Tallinn), P.Van (Budapest), C.Papenfuss (Berlin).
Host institution: Centre for Nonlinear Studies, Institute of Cybernetics at Tallinn University of Technology
Schedule:

17 March	C.Papenfuss: Thermodynamic results on the relation between the heat flux and entropy flux.
	P.Van: Objective time derivatives in non-equilibrium thermodynamics.
18 March	A.Berezovski: Thermodynamics of finite volumes.
	H.Herrmann: Twist waves in liquid crystals, mesoscopic description.

Participants:
J.Engelbrecht, A.Salupere, A.Stulov, A.Ravasoo, M.Berezovski (Tallinn); L.Kelpšaite (Vilnius); I.Didenkulova (Nizhnii Novgorod).

The scope of the workshop was to discuss certain thermodynamics aspects of continuum mechanics arisen in the theory and different areas of applications. The similarity and difference between mesoscopic description and internal variables theory were clearly demonstrated. Theoretical results following from Liu technique and frame indifference principle were complemented by the use of thermodynamic notions in numerical calculations. The workshop was organized in the framework of EU Marie Curie Transfer of Knowledge project MTKD-CT-2004-013909 "Co-operation between Estonian and Norwegian Scientific Centres within Mathematics and its Applications".

6.1.2 Estonian Days of Mechanics. 15–16 September 2008, Tallinn, organised by A.Ravasoo. Altogether 24 talks, the overview presented by M.Kutser. (Estonian J. Eng., 2008, 14, 4, 345–347). During the meeting, the new Estonian National Committee of Mechanics was elected, chaired by A.Salupere. He will be also a contact person for the IUTAM.

6.1.3 Seminar on Complexity. 15 May 2008, Tallinn.
E.Pelinovsky (Nizhni Novgorod): Freak waves in physics: from ocean to astrophysics.
J.Kalda (CENS): Turbulent mixing as a driving force for intermittency.
L.Mõtus (CENS): Transparency of interactions.

6.1.4 8th Glass Stress Summer School, June 5–6. Together with Glasstress Ltd, Laboratory of Photoelasticity participated in organizing. Participants: Germany, Czech Republic and Estonia.

6.1.5 Laboratory of Wave Engineering, events

Measurements of properties and runup of ship-induced waves.

The wave engineering team organised a series of field works, targeted to measurements of properties of ship wakes in Tallinn Bay and runup features of of ship-induced long waves. A preliminary series of measurements, with a total duration of 4 weeks, took place at the eastern breakwater of Lennusadam, about 2 km from Linnahall and 3 km from the passenger harbour. The water surface time series was sampled at a frequency of 5 Hz with the use of a downward-looking echosounder. The main part of the field works was performed near and at the island of Aegna for 21 June – 20 July. The studies comprised measurements of runup heights, recording of beach profile changes, identification of ship's type, speed and distance to the study site, visual observations of the overall appearance of the ship wave systems, video recordings of the runup details, GPS-recordings of several tracks of fast ferries, numerical modelling of ship wake patters for realistic ship tracks, and studies of wave-induced changes of the optical properties of sea water.

The entire team, including PhD students at the Department of mechanics Andrus Räämet and Andres Kask, and several guests (Prof. Kevin Parnell, Prof. Efim Pelinovsky, Dr. Tony Dolphin, dr. Ants Erm, among others) took part in the planning and practical organisation of the experiment, performing field measurements (which involved about 60 person-days spent at site), analysis of the data and writing of reports. The first publication - an overview of the performed studies and the basic conclusions about the properties of ship wakes and their impact on the coast - has been submitted to Estonian Journal of Engineering (Parnell et al. 2008). Detailed comparison of numerical simulations and experimental data and analysis of variability in spatial patterns of long nonlinear waves from fast ferries is presented in the paper, submitted to Nonlinear Processes in Geophysics (Torsvik et al.). At the time of writing, three conference papers, partially or entirely based on the results of the experiment have been presented already, and five papers have been accepted for oral presentations at the 10th International Coastal Symposium (Lisbon, April 2009).

One-day course (23.05.2008) accompanied with a two-day field trip (21–22.05) to the North Estonian coasts was organised in cooperation with Dept. of mechanics, Tallinn University of Technology. The key lectures were given by Prof. Efim Pelinovsky and Prof. Kevin Parnell.

The actions were reflected in media (V.Veski, Maaleht 7.08.2008), see Section "Media outreach". All SEAMOCS team member participated.

3rd International Student Conference "Biodiversity and functioning of aquatic ecosystems in the Baltic sea region" (Loreta Kelpšaite) took place in Juodkrante, Klaipeda, Lithuania on 9–13 October 2008. The conference contained 48 students' presentations (22 oral and 26 poster). This multidisciplinary conference covered various aspects of marine environmental research: from molecular ecology of aquatic organisms, biodiversity and functioning of the plankton and benthos communities to the modeling of the ecosystem processes. Also the socio-economic and coastal zone management studies were presented. Students from 10 different countries (Belarus, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia, Sweden, Ukraine) take part at conference.

6.2 International cooperation

Institute of Cybernetics:

Within new collaborative agreements (signed in 2008):

– Akhiezer Institute for Theoretical Physics. National Science Center, Kharkov Institute of Physics and Technology.

– Institute of Thermomechanics, Czech Academy of Sciences, Prague, Czech Republic.

– Department of Mathematics, University of Patras, Patras, Greece.

Within existing agreements with the Department of Mathematics, University of Turin; Department of Mathematics of City University, Hong Kong; HAS-TUB Research Group for Continuum Mechanics; Hungarian Academy of Sciences; d'Alembert Institute, University Pierre and Marie Curie, Paris; Department of Mathematics, University of Messina.

Other types of ongoing international cooperation:

– Collaboration between I.Didenkulova and (i) Univ. Antilles Guyane: Prof. N.Zahibo, (ii) Dept. of Mathematics, Univ. of Oslo: Prof. J.Grue.

– Collaboration with the Finnish Marine Research Institute and University of Helsinki: Physical oceanography of the Gulf of Finland and the Baltic Sea (K.Myrberg, M.Leppäranta), Planetary Boundary Layers (S.Zilitinkevich).

– Collaboration with the GKSS Geesthacht (H.Günther): Pre-operational modelling of wave regime in the Gulf of Finland, Implementation of WaMoS in the Baltic Sea.

– Project "Stress field in locally plastically deformed glass". University of Southern Mayne (USA) and Marine Biology Laboratory, Woods Hole (USA).

– Laboratory of photoelasticity participates also in an informal research project "Modelling and experimental measurement of residuals stress in tempered glass panels". Other participants of the project are University of Valenciennes (France), Faunhofer ITWM (Germany) and Prelco Company (Canada).

– Laboratory of photoelasticity participates in an informal academic cooperation on the topic "Stress field in locally plastically deformed glass". Head of the team is Prof. C.R.Kurkjian from the University of Southern Mayne (USA). The third participant is Prof. R.Oldenbourg from the Marine Biology Laboratory, Woods Hole (USA).

Laboratory of Proactive Technologies: collaboration partners: Brown University; Ecole Nationale Supérieure d'Electrotechnique, d'Electronique, d'Informatique, d'Hydraulique et des Télécommunications (ENSEEIHT), Toulouse; Leeds University; Microsoft Research, Redmond; University of Lübeck; Vilnius University.

6.3 Teaching activities

6.3.1 CENS seminars for graduate students

1. Seminar in cell energetics – M.Vendelin.
2. Confocal microscopy – R.Birkendal.
3. Waves and coastal engineering – T.Soomere.
4. Microstructured solids – A.Berezovski, A.Salupere.

6.3.2 Courses:

1. J.Engelbrecht – courses in TUT:
   - Mathematical modelling
   - Nonlinear Dynamics
2. A.Salupere – courses in TUT:
   - Statics
   - Dynamics
   - Continuum Mechanics
   - Theory of Elasticity
   - Special Topics in Mechanics
   - Seminars and Special Seminars for MSc and PhD students
3. M.Randrüüt – courses in TUT:
   - Technical Mechanics
4. T.Peets – courses in TUT:
   - Dynamics
   - Mathematical modelling
5. M.Vendelin – courses in TUT:
   - Seminars and Special Seminars for MSc and PhD students
6. P.Peterson – courses in TUT:
   - Seminars and Special Seminars for MSc and PhD students
7. J.Janno – courses in TUT:
   - Mathematics for doctoral students II
   - Calculus
8. J.Kalda :
   - Training of the Estonian and Finnish teams for 39. International Physics Olympiad July 20–29 2008, Isfahan, Iran. Estonian students won one silver medal and two bronze medals
   - Participation in the organization of 4th Estonian–Finnish Olympiad 28–30 April, Tallinn
   - 6th Academic Olympiad in Physics 17 March 2008, University of Tartu
   - 55th Estonian Physics Olympiad 8–9 March 2008
9. T.Soomere: – courses in TUT:
   (assistents: I.Didenkulova, L.Kelpšaite and D.Kurennoy)
   - Wave dynamics
10. J.Vain, M.Kääramees, J.Ernits: – courses in TUT:
    - Preparation of Scientific Papers
11. E.Rüstern, Ü.Nurges, A.Riid: – courses in TUT:
    - Advanced Automatic Control Systems
12. E.Rüstern, Ü.Nurges: – courses in TUT:
    - Control of Dynamic Systems
    - Modelling of Dynamic Systems

13. J.Vain: – courses in TUT:
    - Advanced Topics in Computer Science
    - Formal Verification
    - Formal Methods in System Design
    - Special Course on Hybrid Systems

14. Ü.Kotta: – courses in TUT:
    - Nonlinear Control Systems and Computer Algebra I
    - Nonlinear Control Systems and Computer Algebra II
    - Algebraic Methods in Nonlinear Control Systems Theory
    - Computer Algebra in Nonlinear Control Systems Theory

15. S.Nõmm, M.Tõnso: – courses in TUT:
    - Algebraic Methods in Nonlinear Control Systems Theory
    - Computer Algebra in Nonlinear Control Systems Theory

16. S.Nõmm, Ü.Kotta, J.Vain: – courses in TUT:
    - Nonlinear Control Systems: Computational Aspects
    - Modern methods in nonlinear control systems and computer algebra systems

17. S.Nõmm: – courses in TUT:
    - Introduction to control systems on time scales

18. M.Wyrwas: – courses in Information and Communication Technologies Graduate School:
    - Nonlinear control systems on time scales

19. J.Vain: – courses Technical University of Denmark:
    - Model based testing and verification of embedded systems

20. R.Birkedal, P.Peterson: – course
    - Confocal microscopy

21. J.Belikov, V.Kaparin: – courses in Tallinn University:
    - Software for Mathematics

22. I.Didenkulova: – course at University of Antilles and Guyane
    - Numerical simulation of tsunami wave propagation based on computational codes TUNAMI and "NAMI-DANCE", 21.01–3.02

23. T.Naks and R.Savimaa: – lectures:
    - Introduction to Real-time Software Engineering

24. T.Naks supervision of course projects:
    - Real-time systems

25. L.Mõtus: – course:
    - Software dynamics
    - Multi-Agent Systems

26. L.Mõtus: – courses for PhD students for individual study, e.g.:
    - Artificial Intelligence and Real-time
    - Foundations of Multi-agent System

27. R.Serg: supervises practical exercises in Computer Networks

28. A.Udal: (together with E.Velmre, Department of Electronics) course:
    - Optoelectronics and Integrated Optics

6.3.3. Participation in other events, transfer of knowledge:

1. T.Soomere, visit to New Zealand, lectures to the University of Waikato, Environment Bay of Plenty, Canterbury University; participation in the field trip organized by Prof. Terry Healy etc.; March – April 2008.

2. I.Didenkulova, visit to Marseille, France to participate in the workshop accompanying the defence of PhD thesis "On the interaction of wind and rogue waves"by Julien Touboul and to take part in planning meeting on cooperation on wave dynamics in the Institut de Recherche sur les Phenomenes Hors-Equilibre (IRPHE) with Prof. Ch.Kharif, Prof. E.Pelinovsky, Prof. E.Barthelemy, Prof. V.Rey, Prof. D.Clamond, Prof. J.-P.Giovanangeli and Prof. M.Abid, November 22–26, 2007.

3. I.Didenkulova, visit to Lund, to the SEAMOCS partner Lund University, (December 20, 2007) During this visit she presented a seminar paper "Long waves in a coastal zone"and had very interesting and useful discussion with SEAMOCS coordinator Prof. Georg Lindgren and Prof. Krzysztof Podgorski about wave statistics after the seminar.

4. I.Didenkulova, visit to Bergen, December 21–27, 2007 to participate in a planning meeting with Prof. Jarle Berntsen and Dr. Tomas Torsvik (University of Bergen), where we discussed the possibility of applying for an EEA grant to finance collaboration between Estonia and Norway.

5. I.Didenkulova, visit to Pointe-a-Pitre, Guadeloupe to University of Antilles and Guyane, (January 7 – March 3, 2008) to participate in tsunami field surveys after 2004 and 2007 tsunamis in Guadeloupe and also to analyze real tide-gauge records of storm surges after Hurricane Dean of August 16–17, 2007. She also presented a seminar paper "Travelling wave solution in the variable-coefficient wave equation"at Universite des Antilles et de la Guyane, January 31, 2008 and adviced I.Nikolkina (MS student) in preparations of her MS thesis, in particular, in tsunami wave modeling and propagation of 2004 and 2007 tsunamis in Guadeloupe. January 21 – February 3 — training course in "Numerical simulation of tsunami wave propagation based on computational codes TUNAMI"and "NAMI-DANCE".

6. I.Didenkulova delivered lecture on Tsunami Problem in school N 13, Nizhny Novgorod, March 5.

7. I.Didenkulova, visit to Boston, USA to Massachusetts Institute of Technology, April 3–12, 2008. During this visit she presented a seminar paper "New trends in the nonlinear theory of long wave runup on a beach"(April 4) at the Department of Civil & Environmental Engineering and had a very interesting discussion with Professor Chiang C.Mei.

8. I.Didenkulova, visit to Bergen, August 18 – September 01, 2008 to participate in research program within joint EEA grant.

9. I.Didenkulova, participation in the local workshop, organized by Prof. E.Pelinovsky, on the program NAMI-DANCE, which is an improved version of the numerical code TUNAMI (September 19–26, 2008, Nizhny Novgorod, Russia). Also took part in the seminars by L.A.Ostrovsky and O.V.Rudenko "Some actual problems of nonlinear acoustics"(19 September 2008) and by A.P.Kiselev "Paraxial and exact localized solutions of the wave equation", 26 September 2008.

10. I.Didenkulova, visited to Pointe-a-Pitre, Guadeloupe to University of Antilles and Guyane in the framework of long-term collaboration. She participated in the analysis of field survey data of tsunami and storm surges and in the organization of the international workshop "Caribbean waves: risk evaluation of natural hazards in the Caribbean"on December 9–10, 2008 (10 November – 19 December 2008).

11. E.Quak. Kick-off Meeting EU FOCUS K3D Coordination Action Genova, Italy, March 3–5.

12. E.Quak. Workshop Industry Challenges in Geometric Modeling, CAD and Simulation 2008 Darmstadt, Germany, March 13–14.

13. E.Quak. Workshop Approximationsmethoden und Schnelle Algorithmen Hasenwinkel (Mecklenburg), Germany, June 6–8.

14. E.Quak. International Forum Ethics and Science for the Environment Contributions to the invited presentation by Tarmo Soomere (CENS), Environmental concerns about building large-scale pipelines in the Baltic Sea Torun, Poland, October 12–14.

15. E.Quak. Annual IoC Workshop Nelijärve, October 18.

16. E.Quak. Kick-off meeting of the EU Marie Curie Initial Training Network SAGA (Shapes, Geometry, Algebra) Castro Urdiales, Spain, November 17.

17. E.Quak. EU ICT Event 2008 Lyon, France, November 25–27.

18. E.Quak. Workshop 3D Physiological Human Zermatt, Switzerland, December 1–4.

19. J.-S.Preden. Microsoft Research at Redmond.

6.4. Visiting fellows

For shorter period

1. Dr. C.Papenfuss (Berlin), 15 February – 15 April 2008, (CENS-CMA).

2. Dr. P.Ván (Budapest). Exchange program between Estonian and Hungarian Academies of Sciences, 17–28 March 2008.

3. Dr. A.Chechkin, Akhiezer Institute for Theoretical Physics. National Science Center Kharkov Institute of Physics and Technology, 1 October – 31 December 2008, (CENS-CMA).

4. Dr. Miroslav Halas, Slovak University of Technology, Slovakia, 24 February – 5 March 2008.

5. Dr. Malgorzata Wyrwas, Bialystok Technical University, Poland, 1–11 January; 3–19 June 2008.

6. Prof. Zbigniew Bastosiewicz, Bialystok Technical University, Poland, 2–9 April 2008.

7. Dr. Ewa Pawluszewicz, Bialystok Technical University, Poland, 2–9 April 2008.

8. Dr. Tony Dolphin (Norwich, UK), visited the IoC team 26–30 June 2008 in the framework of of measurements of properties and runup of ship-induced waves, and from 22 September in the framework of joint coastal studies and wave research.

9. Dr. Tomas Torsvik (University of Bergen, Norway) visited the IoC team 26 October – 9 November 2008, in the framework of collaboration in fast ferry waves research.

10. Prof. Kevin Parnell (James Cook University, Australia), 21 April – 21 July 2008 (supported by the sister of Marie Curie TK project CENS-CMA), in the framework of measurements of properties and runup of ship-induced waves, and as one of the opponents to PhD thesis of I.Didenkulova.

11. Dr. Kai Myrberg (Helsinki), as a member of the scientific committee for the defence of PhD thesis of I.Didenkulova, 19–21 July 2008.

12. Prof. Geir Pedersen, as opponent and a member of the scientific committee for the defence of PhD thesis of I.Didenkulova, 19–21 July 2008.

13. Prof. Efim Pelinovsky, as co-supervisor of the PhD thesis of I.Didenkulova, 10–21 July and in the framework of the Intense course in extreme waves and coastal processes 8–24 May 2008 (supported by the INNOVE project 1.0101–0208).

14. Prof. Matti Leppäranta (Helsinki), and Dr. Kai Myrberg, two days in June 2008, cooperation in the analysis and overview of the progress in the physical oceanography of the Gulf of Finland

15. Prof. Miky Stiassnie (David Hacohen and Hillel Dan Chair of Civil Engineering Division of Environmental, Water and Agricultural Engineering TECHNION-Israel Institute of Technology, Haifa 32000, Israel), 29 May – 1 June 2008, seminar presentation and cooperation in extreme wave studies.

16. Prof. Wojciech Sulisz (Institute of Hydroengineering, Polish Academy of Sciences), 5–7 June 2008, seminar presentation and cooperation in extreme wave studies.

17. Prof. Alex Gammerman, (Professor of Computer Science, and Director of the Computer Learning Research Centre (CLRC), Royal Holloway, University of London.

18. Johannes Helander, Architect and Chief Scientist at Microsoft Innovation Center in Aachen, Germany.

19. Gabriel Jakobson, Chief Scientist, Altusys Corp; IEEE Communications Society, Board of Governors.

20. Dr. Andras Szekeres, Budapest University of Technology and Economics, 1–20 June 2008.

21. Prof. Jiři Plesek, Institute of Thermomechanics Acad. Sci. Czech Republic, 22–31 October 2008.

22. Dr. Gabriel Dusan, Institute of Thermomechanics Acad. Sci. Czech Republic, 22–31 October 2008.

For longer periods

1. H.Herrmann (postdoc Research Fellow CENS-CMA).

2. I.Didenkulova. Experienced Researcher supported by the Marie Curie RTN network SEAMOCS, 1 September 2007 – 31 October 2009.

3. L.Kelpšaite. Early Stage Researcher supported by the Marie Curie RTN network SEAMOCS, 15 November 2007 – 31 October 2009.
4. D.Kurennoy. Early Stage Researcher supported by the Marie Curie RTN network SEAMOCS, 15 November 2007 – 31 October 2009, for 1 Sept. 2008 – 30 April 2009 supported by Marie Curie TK network CENS-CMA.
5. N.Delpeche. Early Stage Researcher supported by the Marie Curie RTN network SEAMOCS, 1 October 2008 – 31 October 2009.
6. B.Rehak, 1 September 2007 – 30 June 2008.
7. J.Jakubiak, 18 February – 30 June 2008.

6.5 Graduate studies

Department of Mechanics and Applied Mathematics:

Promoted:

1. PhD:

J.Anton	Technology of integrated photoelasticity for residual stress measurement in glass articles of axisymmetric shape (supervisor H.Aben).
I.I.Didenkulova	Long wave dynamics in the coastal zone (supervisors T.Soomere, E.Pelinovsky).

In progress:

1. PhD:

M.Berezovski	Numerical simulation of front tracking in inhomogeneous solids (supervisor J.Engelbrecht).
T.Peets	Dispersion in microstructured solids (supervisor J.Engelbrecht).
M.Randrüüt	Evolution and existence of nonlinear waves in microstructured solids (supervisors J.Engelbrecht and A.Salupere).
A.Illaste	Mathematical model of mitochondrial energy metabolism (supervisor M.Vendelin).
D.Schryer	^{13}C impulse labeling studies with Saccharomyces cerevisiae (supervisor M.Vendelin).
M.Kalda	Mechanoenergetics of a single cardiomyocyte (supervisor M.Vendelin).
K.Veski	Heterogeneity of energetic parameters in cardiomyocytes (supervisor M.Vendelin).
M.Sepp	Estimation of diffusion restrictions in cardiomyocytes using kinetic measurements (supervisor M.Vendelin).
K.Tamm	Deformation waves in microstructured solids (supervisor A.Salupere).
L.Ilison	Solitons and solitary waves in KdV-type hierarchical systems (supervisor A.Salupere).
A.Räämet	Spatio-temporal variability of the Baltic Sea wave fields in changing climate conditions (supervisor T.Soomere).
L.Kelpšaite	Sediment transport and wave influence to the ecosystem behavior near the Lithuanian sea shore (supervisors A.Razinkovas, Coastal Research and Planning Institute, Klaipeda University, Lithuania, T.Soomere).

A.Kask	Natural and anthropogenic morphodynamics caused by litohydrodynamical processes in the Estonian coastal sea (supervisor T.Soomere).
D.Kurennoy	Wave climate changes in the Baltic Sea and their impact on coastal processes (supervisor T.Soomere).

2. MSc:

D.Kartofelev	Sound generation mechanisms in grand pianos (supervisor A.Stulov).
M.Vallikivi	Deformation waves in hyperelastic rods (supervisor A.Salupere).
I.Zaitseva-Pärnaste	Long-term variations of the northern Baltic Sea wave fields (supervisor T.Soomere).
M.Kree	Statictical topography of turbulent mixing (supervisor J.Kalda).

Marine Academy diploma theses:

Olga Tribštok	(supervisor I.Zaitseva-Pärnaste).
Katri Kartau	Evolution of Valgeranna Beach (supervisor T.Soomere).
Tanel Hall	Ship waves on Aegna (supervisors L.Kelpšaite, D.Kurennoy)

Control Systems Department:

Promoted:

1. MSc:

H.Rennik	Solving modeling, analysis and synthesis problems for nonlinear control systems using webMathematica (supervisor Ü.Kotta, cosupervisor M.Tõnso).
V.Kaparin	Nonlinear Control Systems with Computer Algebra System MATHEMATICA: Observability and Observer Forms (supervisor Ü.Kotta, cosupervisor M.Tõnso).
J.Belikov	Synthesis and identification of nonlinear discrete time models for model based control ((co)supervisor S.Nõmm, (co)supervisor E.Petlenkov).
K.Klenski	Optimal pickup and delivery task scheduling in m-crane systems with non-crossing constraint (supervisor J.Vain).
K.Haavik	Distributed testing case-study: SEB RWA & Disclosure Data Delivery (supervisor J.Vain).
L.Laasik	Method of solving asymmetric traveling salesman problem and its implementation (supervisor J.Vain).
J.Irve	Simulation of swarm-based cleaning task using indirect communication (supervisor J.Vain).

In progress:

1. MSc :

R.Piirat	J2EE based architecture patterns and their analysis (supervisor J.Vain).
A.Kanarbik	Distributed home automation system (supervisor J.Vain).

2. PhD:

M.Tõnso	Computer algebra tools for modelling, analysis and synthesis for nonlinear control systems (supervisor Ü.Kotta).
V.Kaparin	Transformation of the nonlinear state equations into the observer form (supervisor Ü.Kotta).
J.Belikov	Identification and control of complex nonlinear multi input multi output systems based on methods of artificial intelligence (supervisor E.Petlenkov).
A.Anier	Motion recognition via abstract interpretation (supervisor J.Vain).
M.Markvardt	Test data generation methods for input validation (supervisor J.Vain).

Laboratory for Proactive Technology:
In progress:

1. PhD:

T.Lints	Adaptivity.
A.Kull	Model-Based Testing of Reactive Systems.

6.6 Distinctions

Fellows:

1. V.Saks, J.Engelbrecht, E.Seppet, M.Vendelin – Estonian Science Award in Geo-Biosciences for "Molecular System Bioenergetics".
2. J.Kalda – N.Alumäe Lecture, Tallinn, 15 Sept., 2008.
3. H.Aben – Murray medal from the Society of Experimental Mechanics (lecture in 2010).

Students:

1. M.Randrüüt – Scholarship of Estonian Railways from Tallinn University of Technology.
2. M.Randrüüt – Scholarship of Tiina Mõis Foundation from Tallinn University of Technology.
3. J.Belikov – 3rd Prize in National Students Research Contest 2008 in natural and technical sciences (in MSc subgroup).
4. P.Kotta – Nominee of the best paper in International Conference on Control, Automation, Robotics and Vision 2008.

6.7 Other activities

6.7.1 Participation on programme committees, reviewing papers:

1. Nordic Workshop on Programming Theory NWPT2008, J.Vain.
2. IFIP Conference on Formal Techniques for Networked and Distributed Systems (FORTE), J.Vain.
3. IFAC Conference on Nonlinear Control Systems (NOLCOS), Ü.Kotta.

4. IFAC Conference on Control Systems Design, Ü.Kotta.
5. Industry Challenges in Geometric Modeling, CAD and Simulation 2008, E.Quak.
6. Conference IEEE Shape Modeling International 2008, E.Quak.
7. Workshop 3D Physiological Human, E.Quak.
8. IUTAM Symposium on Cellular, Molecular, and Tissue Mechanics. Woods Hole, Massachusetts, USA, June 18–21, J.Engelbrecht.
9. IEEE Swarm Intelligence Symposium, Sept 21–23, 2008, St. Louis, USA, T.Lints.
10. International Conference on Knowledge Generation, Communication and Management, June 29–July 02, 2008, Orlando, USA, I.Astrov.
11. International Multi-Conference on Engineering and Technological Innovation, June 29–July 02, 2008, Orlando, USA, I.Astrov.
12. 10th WSEAS International Conference on Mathematical methods of Computational Techniques in Electrical Engineering, October 26–28, 2008, Corfu, Greece, I.Astrov.
13. 7th WSEAS International Conference on Non-Linear Analysis, Non-Linear Systems, and Chaos, October 26–28, 2008, Corfu, Greece, I.Astrov.
14. 4th WSEAS International Conference on Wavelet Analysis and Multi-rate Systems, October 26–28, 2008, Corfu, I.Astrov.
15. 4th WSEAS International Conference on Educational Technologies, October 26–28, 2008, Corfu, Greece, I.Astrov.
16. 4th WSEAS International Conference on Dynamical Systems and Control, October 26–28, 2008, Corfu, Greece, I.Astrov.
17. 2009 World Congress on Computer Science and Information Engineering, March 31–April 02, 2009, Los Angeles, USA, I.Astrov.
18. 2nd International Multi-Conference on Engineering and Innovation, July 10–13, 2009, Orlando, USA, I.Astrov.
19. IEEE 2009 Toronto International Conference - Science and Technology for Humanity, September 27–29, 2009, Toronto, Canada, I.Astrov.
20. COST DC-ICT, open call projects reviewing, spring and fall of 2008, M.Meriste, L.Mõtus.
21. 6th International Conference on Software Engineering Research, Management and Applications, SERA 2008, August 2008, Prague, Czech, L.Mõtus.
22. IEEE International Conference on Communications, June 14–18, 2009, Dresden, Germany, L.Mõtus.
23. 2nd IFAC International Conference on Intelligent Control Systems and Signal Processing, September 21–23, 2009, Istanbul, Turkey, L.Mõtus.
24. The 3rd Annual Conference of the National Graduate School in Information and Communication Technologies, April 25–26, 2008, Voore, Estonia, E.Petlenkov.

6.7.2. Participation in journal editorial boards:

1. Abstract and Applied Analysis, Hindawi Publishing Corp. – Ü.Kotta.
2. Proceedings of Estonian Academy of Sciences – Ü.Kotta, L.Mõtus.
3. J. of Marine Systems – T.Soomere.
4. Applied Mechanics Reviews – J.Engelbrecht.
5. Amer. J. Physiol. Cell Physiology – M.Vendelin.
6. Applied Mechanics (Kiev) – J.Engelbrecht.
7. J. Theor. Applied Mechanics (Warsaw) – J.Engelbrecht.
8. Dialogue and Universalism – J.Engelbrecht.
9. Estonian J. of Engineering – J.Engelbrecht, T.Soomere, L.Mõtus.
10. J. Integrated Computer-Aided Engineering (IOS Press) – L.Mõtus.
11. Int. J. on Engineering Applications of Artificial Intelligence, (Elsevier, Emeritus Editor) – L.Mõtus.

6.7.3. Participation in professional organizations:

1. IUTAM contact: J.Engelbrecht.
2. IFAC technical committee for nonlinear systems: Ü.Kotta.
3. IFAC contact person in Estonia: S.Nõmm.

6.7.4. Other:

1. Reviewer for Martin Ondera PhD thesis "Computer-aided design of nonlinear systems and their generalized transfer functions", Slovak University of Technology, Ü.Kotta.

6.7.5. Media reflections and outreach

1. About M.Vendelin: Life in Estonia, Spring, 2008.
2. M.Vendelin, 16.08.2008: Raadio 2, R2 Piknikul.
3. TV broadcast about teaching of coastal engineering in TUT; based on material from the summer school "Waves and coastal processes" 2007; entire SEAMOCS group; broadcasted twice.
4. T.Soomere, 17.01.2008: Interview to the online version of the leading daily newspaper "Postimees" about the nature and properties of the approaching storm.
5. G.Naaber, K.Rooväli, 18.01.2008: One of the strongest storms of the last decade may hit western Estonia tonight; based on interview with T.Soomere about the nature and properties of the approaching storm.

6. T.Soomere, 18.01.2008: Estoninan state TV; live on air in the early morning broadcast “Terevisioon”; comments on the nature and extension of the approaching storm.

7. T.Soomere, 18.01.2008: The leading radio channel “Kuku Raadio”, live on air; on the nature and extension of the approaching storm.

8. T.Soomere, 18.01.2008: The Russian-language radio channel “Raadio 4”; interview by phone on the nature and extension of the approaching storm.

9. T.Soomere, 18.01.2008: Interview to the online version of the leading daily newspaper “Postimees”about the changes of the nature and properties of the approaching storm; short version in printed issue on 19.01.

10. T.Soomere, TV broadcast, series about science, presentation of newly elected members of the Estonian Academy of Sciences; broadcasted twice.

11. T.Soomere, 23.01, 26.01, 2.02: Interview to the “Marine Hour”of the radio channel “Raadio Kuku”about the activities and plans of the national commitee on marine sciences.

12. T.Soomere, 5.02, 6.02.2008: Scientists take care of sea level forecast; news at the front page of the City Paper (Tallinn); repeated on several online sources and portals.

13. T.Soomere, 11.05.2008, 17.08.2008: One-hour interview in science broadcast series “Kukkuv õun”; broadcasted by “Kuku Raadio”twice.

14. T.Soomere, 30.04.2008: Always targeting to success and unusual, interview in weekly paper “Estonian Church”.

15. T.Soomere, 10.06.2008: Comment on the measurements of water level and about their historical background; state radio channel “Vikerraadio”; line on air.

16. M.Filippov, 12.07.2008: Estonian scientists will put the Baltic Sea under careful scrutiny; paper about the ideas of the BONUS BalticWay project.

17. T.Soomere, 26.07.2008: Interview to the “Marine Hour”, Raadio Kuku, in the case of PhD defence of I.Didenkulova and about the meaning of the work done to the marine science.

18. V.Veski, Tsunami on Tallinn Bay. This bay may give answer to the world how to defend against tsunamis; paper in weekly newspaper “Maaleht”targeted to countryside people.

19. T.Soomere, 7.09.2008: One-hour interview and comments on the marine science in Estonia; broadcast series “Sixpack”; broadcasted twice.

20. T.Soomere, 23.09.2008: Interview to “Vikerraadio”about dignity and credibility in science.

21. P.Ennet, 25.09.2008: The energy of ship wakes is gradually increasing; interview to “Vikerraadio”; also published in the online version of the popular science journal “Horisont”.

22. T.Soomere, 27.09.2008: Interview to Rapla County newspaper “Nädaline”, about the connections of scientists with their home region.

23. E.Quak, Let’s go and apply, interview given for the Norwegian Research Council, published in the NFR periodical 2/2008.

7. Summary

7.1 Current year 2008

The first year of the renewed CENS has been succesful. CENS is an international node in research, its interdisciplinary studies are spearheaded fowards complexity of natural and man-made systems. Present CENS has altogether 51 researchers including the PhD and MSc students. Through 2008, 17 researchers from 12 countries were working in CENS, some for shorter periods but altogether 5 on the permanent basis. What is important for the future: CENS has presently 21 PhD and 8 MSc students including 3 PhD students from other countries and 5 post-docs. Two new Labs started (see Section 2), new agreements of co-operation were signed (Patras University; Kharkov Institute of Physics and Technology, Institute of Thermomechanics, Prague). CENS has many international grants (see Section 4) and is a partner in following international networks: Complexity-NET (representatives J.Engelbrecht, L.Mõtus); Global System Dynamics & Policies (representative T.Soomere).

The results described briefly in Section 3 show explicitly the new ideas and trends in research. From one hand, they demonstrate fundamental ideas enlarging scientific knowledge, from another hand, however, several new fields are clearly directed towards societal needs. We stress the following:

- analysis of time-series using physical methods (medical physics, financial series, turbulent mixing and transport, etc.) which can be enlarged towards social sciences;
- analysis of complexity in geology and material sciences;
- determining environmentally optimal ship routes based on the analysis of oil pollution transport;
- emergent behaviour in pervasive computing systems;
- development of the robot to replace human scrub nurse during the laparoscopic surgery.

7.2 Invited or confirmed presentations for 2009

10th International Coastal Symposium, to be held in Lisbon, 13–18 April 2009.

1. T.Healy (Waikato), T.Soomere. Sea level and tidal sedimentation – invited lecture.
2. I.Didenkulova, K.Parnell, T.Soomere, E.Pelinovsky. Shoaling and runup of long waves induced by high-speed ferries in Tallinn Bay.
3. D.Kurennoy, I.Didenkulova, K.Parnell, T.Soomere. Variability of properties of wakes from high-speed ferries.
4. L.Kelpšaite, K.Parnell, T.Soomere. Temporal changes in the relative importance of wind-wave and ship-wake energy: Tallinn Bay, the Baltic Sea.
5. I.Zaitseva-Pärnaste, Ü.Suursaar, T.Kullas, T.Soomere. Seasonal and long-term variations of wave conditions in the northern Baltic Sea.
6. A.Räämet, Ü.Suursaar, T.Kullas, T.Soomere. Reconsidering uncertainties of wave conditions in the coastal areas of the northern Baltic Sea.
7. T.Soomere, I.Didenkulova, K.Parnell. Implications of fast ferry wakes for semi-sheltered beaches, Aegna Island, Baltic Sea.

8. T.Torsvik, T.Soomere. Modeling of long waves from high speed ferries in coastal waters.
9. T.J.Dolphin, M.O.Green. Patterns of wave-orbital speed and skin friction under estuarine (fetch-limited) waves.
10. A.Kask, T.Soomere, T.Healy, N.Delpeche. Sediment transport patterns and rapid estimates of net loss of sediments for "almost equilibrium" beaches (poster presentation).
11. H.Herrmann, E.Quak. Wavelet analysis of ship wave records (poster presentation).

WCCE–ECCE–TCCE Joint Conference Earthquake & Tsunami (Istanbul, Turkey, June, 2009).

1. I.Didenkulova, E.Pelinovsky, and T.Soomere. Transformation and runup of tsunami wave along the "nonreflecting" bottom profile.
2. N.Zahibo, I.Didenkulova, E.Pelinovsky, and I.Nikolkina. Numerical simulation of tsunamis in the Caribbean Sea.

IUTAM Symposium on Recent Advances of Acoustic waves in Solids, May 25–28, 2009, Taipei.

1. J.Engelbrecht, A.Berezovski, M.Berezovski. Deformation waves in microstructured materials: theory and numerics.
2. A.Ravasoo. Counterpropagating ultrasonic waves for inhomogeneous material characterization.
3. T.Peets. Dispersion analysis of wave motion in microstructured solids.

IEEE Symposium on Computational Intelligence, March 30 – April 2, 2009, Nashville, Tennessee, USA.

1. T.Lints. Relation Learning with Bar Charts.

NATO RTO Symposium on Intelligent Uninhabited Vehicle Guidance Systems, July 2009.

1. M.Meriste, L.Motus, et.al. Interactive maps for knowledge based guidance of UAV.
2. J.-S.Preden, et.al. Vehicle guidance system in NEC context.

EUROCAST'2009, Las Palmas, Spain, February 2009.

1. M.Tõnso, Ü.Kotta. Realization of continuous-time nonlinear input-output equations: polynomial approach.

7.3 Work Plan of CENS 2008–2015: New Challenges in Complexity Studies

Our world is not a straightforward linear composition of smaller parts (particles, components, etc), as these parts interact in a nonlinear and dynamic way. The study of complex systems investigates collective properties in systems with a large number of parts that interact with each other and with their environment(s). Complexity research is intrinsically a multidisciplinary field, as these parts can be atoms or macromolecules in a physical or biological context, but also biological creatures, or people, machines and companies in a socio-economic context. While the origins lie in mathematics, natural and computer sciences, today's complexity research is spreading into the medical, economic and social sciences, as well as into key theories and enabling technologies of the artificial world, such as automatic decision-support and decision-making systems.

The systematic study of complex systems was initiated by launching the Santa Fe Institute in the USA in 1984. Complexity research has clearly intensified recently, with the Complex Systems Society founded in 2004 and the Open Network of Centres of Excellence in Complex Systems funded through the European Commission in FP6. A major European Conference on Complex Systems is organized annually since 2005. Right now the Complexity-NET, aiming to encourage cooperation and coordination of research activities in complexity studies in the EU, is funded through the European ERA-NET scheme.

CENS was founded in 1999 as a cluster-type research unit to concentrate the national research efforts within nonlinear dynamics and related areas, and it became an Estonian Centre of Excellence in 2002 up to 2007. For detailed information see the CENS Annual Reports. CENS Highlights 2003-2007 are published separately.

So far CENS has focused on *analytic research* in natural complexity such as

- Complexity in nonlinear wave motion: solitonics and coherent wave fields, phase transformation fronts, stress analysis, thermo-dynamical constraints, anomalies of water waves including extreme waves;
- Complexity in biophysics: in silico modelling of cardiac contraction and cell energetics, internal variables;
- Fractality in nature: statistical topography, multifractality, turbulent diffusion.

CENS represents Estonia in *Complexity-NET* to be the Estonian hub for *all* complexity studies. Since there are also research groups working on artificial (man-made) complexity, i.e. *synthetic approaches*, these are now also to be included in CENS:

- Complexity in software-intensive systems - emergent behaviour in proactive embedded systems, situation-aware interaction centred models of computation, time-counting systems with multiple metric times, holistic self-organizing systems;
- Nonlinear control theory - novel algebraic formalisms, catering for multiple time scales.

The overall challenge to unite analysis and synthesis approaches reflects the current trend in contemporary complexity science. The planned research covers topics in physics/mechanics, biology, computer science, and control - as listed among the great challenges in the Living Roadmap for Complex Systems Science (IST-FET Coordination Action) and in the strategic materials of *Complexity-NET*.

The following summaries describe the main fields of planned research (and list team leaders), with the latter two as newly added studies in complexity of artificial systems.

1) Wave motion in solids (A.Berezovski)
The main goal is to develop hierarchical modelling of *nonlinear wave motion in micro-structured materials*, important due to the wide usage of new materials (functionally graded materials, metal-ceramic composites, etc).
The great challenge is to build multi-scale models relating mesoscopic physics to continuum mechanics, as materials have a complicated structure over many scales and have to work under high-frequency impact and influence of coupled fields.
The studies must reflect the existence of possible nonlinearities over the scales, dispersive/dissipative effects, and thermo-dynamical consistency in numerical calculations. Keeping the nonlinearities over all scales leads to coupling effects and complexity of wave fields.
We need to understand the mechanisms of emerging solitonic structures in compound materials. As carriers of energy and information, these structures can be used for managing solitons, i.e. generating waves with prescribed properties. The existence of nonlinearities enriches the physical characteristics of wave fields and it is proposed to use this to enhance non-destructive testing.

2) Hydrodynamics and extreme waves (T.Soomere)
The studies will focus on surface waves and their effects including practical applications. A breakthrough is feasible through systematic studies of nonlinear interactions of directionally spread and/or crossing highly nonlinear shallow water waves. Our ideas combine the numerical and theoretical analysis of extreme (freak) wave generation (starting from the Kadomtsev-Petviashvili model) with studies of the run up of various incident wave shapes and irregular waves. Solvers for the two-dimensional free-surface problem will be developed, combining the conformal mapping technique with FFT, with software in the high-level Python scripting environment.
The results have direct applications in a variety of marine and coastal matters, such as understanding the mechanisms of the emergence of small-scale freak waves and nonlinear wake components generated by high-speed ferries. These may exert a considerable influence on the marine ecosystem and sea bottom in coastal areas. Knowledge about the dynamical processes on the sea surface also permits to address the problem of oil pollution transport in determining environmentally optimal ship routes, a very important general problem, and especially for the narrow Gulf of Finland.

3) Biophysics and cell energetics (M.Vendelin)
One of the most important issues is the understanding of the *regulatory mechanisms of metabolic processes and cell function in vivo.*
The main goal is to identify the structural and functional elements of adenine nucleotide compartmentation, and its role in the regulation of oxidative phosphorylation in ventricular myocytes, by a combination of experimental and theoretical qualitative methods. Raster image correlation spectroscopy will be extended to determine the diffusion coefficients in anisotropic media. To verify the results, we will combine confocal microscopy and mathematical modelling based on the 3D diffusion model. The functional aspects of oxidative phosphorylation in permeabilized cardiomyocytes will be studied by combining kinetic experiments and mathematical models. New hierarchical models with complicated nonlinearities will be derived to take into account geometry of mitochondria, concentration and interaction between enzymes:

- To identify location and extent of diffusion restriction in the cardiac muscle cells;
- To estimate the role of mitochondrial morphology in the regulation of oxidative phosphorylation;
- To estimate intracellular energy fluxes and influence of different regulatory mechanisms *in vivo*.

4) Fractality (J.Kalda)
Turbulent mixing and transport have great practical importance, e.g. in the context of pollution spreading, industrial mixing of materials, etc. We will model multi-dimensional mixing by a refined one-dimensional multi-scale stochastic Baker map, having derived an expression for the structure function's anomalous scaling exponents.
Complex geophysical systems: self-organization and power laws are very common in geophysics (earthquake dynamics, erosive/tectonic processes, etc.). We will use novel ideas to tackle the problems of modelling the evolution of two-phase media with growing volume of intrusions, and explaining the experimentally observed power laws.
Econophysics and social systems: market fluctuations provide a classical example of multifractality and intermittency. We aim to apply our novel multiscaling analysis techniques (developed for turbulent mixing) to devise non-Gaussian portfolio risk minimization techniques, in collaboration with Hansabank. Social clustering could also be analysed.
Brain oscillations: the influence of the external electromagnetic field on brain activity is a risk factor, and can be a tool to affect the brain behaviour. The recent cooperation with the Biomedical Engineering Centre (TUT) will be continued to develop scaling methods for the analysis of EEG signals to understand the effects of periodic stressors on brain oscillations, and for the cognition and processing of information in the brain.

5) Nonlinear photo-elasticity (H.Aben)
The goal is to develop the theory and algorithms of *nonlinear photoelastic tomography for non-destructive measurement of three-dimensional stress fields*.
While in conventional tomography only scalar fields are determined, in photoelastic tomography one has to determine the stress tensor field. Due to the nonlinearity of optical phenomena in anisotropic and inhomogeneous media, the inverse problem of photoelastic tomography is nonlinear. Measurement data, obtained with photoelastic experiments, is not sufficient to determine the distribution of all stress tensor components. One must also use equations from elasticity theory, leading to a complicated problem of hybrid mechanics. A photoelastic apparatus and intelligent software will be developed for applying the method in practice.
The main application is residual stress measurement in glass articles of complicated shape. A spin-off company, GlasStress Ltd, has been founded for manufacturing photoelastic tomography equipment. Based on linearized algorithms, this apparatus is being applied for quality control in many glass companies all over the world. Through the new research, nonlinear algorithms could replace the linearized algorithms.

6) Nonlinear control systems on time scales (Ü.Kotta)
Tools and methods will be developed to *unify the study of discrete- and continuous-time control systems* to reveal and explain discrepancies between these approaches. A unified approach also helps to reduce the programming effort in implementations.
Two mathematical formalisms will be used: time scale calculus and pseudo-linear algebra. Dynamical systems on time scales are an active new area of research, with the time scale formalism modelling dynamics continuous in one period and discrete in the other. Not much is known about the control systems on time scales.

Pseudo-linear algebra is a purely algebraic approach. Its great challenge is to build a framework to study nonlinear control systems on time scales, for which we will use the algebraic approach of differential forms.
Once tools of a unified framework are available, they will be applied to address some fundamental problems. One of them is the model matching problem, an abstract formulation of many control problems (like feedback linearization, system decomposition, disturbance rejection, etc.), in which the modification of the nonlinear transfer function is the core problem. Another is system reduction and different equivalence notions (transfer equivalence, input-output equivalence).

7) Emergent behaviour in proactive embedded systems (L.Mõtus)
Proactive embedded computer systems anticipate and choose dynamically, within certain limits (set by their users, their environments, and their designers), the goal-directed activities that lead to a better satisfaction of the system's goals. Some of the components in such systems are proactive, where the functionality of a component and/or patterns of the component's interaction with other components and with its environment(s) may change dynamically during the system's operation, depending on the current situation. The behaviour of such systems cannot be deduced from that of the components and from the static structure of the components' interaction.
The team is developing a *situation-aware interactive model of computation* to observe and analyse the evolution of interactions in proactive systems, to reason about the dynamically emerging behaviour, and to control certain aspects of the emergent behaviour by explicitly modifying the interaction pattern.
The computational model belongs to the subclass of multi-stream interaction machines, follows the paradigm of super-Turing computation, and can be used for behaviour verification in applications modelled by situation-aware multi-agents, e.g. systems of embedded real-time systems, human-centred organisations, and network enabled capabilities.

Scientific synergies

All the above projects are characterized by a strong influence of nonlinearities, essential interaction between the constituents, wide range of scales (in space and time) and hierarchies, and an ongoing process of reconstructing models, based on both improved theoretical understanding and increased new research/experimental data. The key concepts are: emergence, irreversibility, evolution, etc., with a need for multilevel approaches over space and time scales and for distinguishing between deterministic and chaotic behaviours.

Our groups are all interrelated by ideas and methods: continuum physics is the basis for dynamics of solids and fluids (water waves). Fractal theory is applied in biophysics, mechanics, econophysics, etc. Coherent systems (solitary waves) emerge in many cases. Feedback is to be taken into account in control systems and biophysics. Emergent behaviour in proactive systems must be addressed in control, may be used for the interpretation of information processing in the brain, and in analysing the behaviour of social groups. Scaling analysis is needed in solid mechanics, biophysics, brain research, and in control and behavioural analysis of proactive systems. Nonlinear PDEs and difference equations are basic models for the groups who all need powerful methods and computing facilities. Nonlinear inverse methods (photoelasticity and acoustodiagnostics) need new algorithms, etc.

While CENS members have collaborated in analytic (natural) complexity in the past, the addition of teams in synthetic (man-made) complexity provides new incentives for joint interdisciplinary work. The strong synergy can over time also generate new research topics by cross-fertilisation, such as studies of complex social and infrastructural networks, environmental complexity, etc.

Contribution to national and European priority areas

The planned studies are clearly at the forefront of science, enlarging the general knowledge base significantly. The quality of the involved researchers (36 with PhD/DSc, including 4 members of the Estonian Academy of Sciences, and 19 PhD students) and of their work is documented in the accompanying material, also activities in national and international projects.

There are strong application components in *all* the projects described. The studies in complex materials and acoustodiagnostics (topic 1) and photoelasticity (5) will lead to technological applications in material science. Water wave research (2) helps to explain the changes and threats in Estonian and international waters, and at the coast. Cell energetics (3) studies increase our understanding how to fight cardiac problems. Fractality (4) is a key aspect for both natural problems (environmental issues such as pollution diffusion, but also brain research) and man-made effects (portfolio risk minimization). Control systems (6) are essential in IT and other high-tech domains. Proactive technologies and situation-aware interactive computation (7) form the (theoretical and technological) basis of ubiquitous/pervasive computing systems. Thus our research goals contribute very clearly to the strategic objectives for *Knowledge-based Estonia 2007-2013*, through both research and development of internationally competitive high quality, especially in three nationally identified focal points: material technologies (1,5), information technologies (6,7) and health (3,4). All these are also important areas for the EU's FP7. Given that pollution knows no national borders, strong European emphasis is also placed on the environment. In this respect, the studies in (2) are of great importance not just for Estonia, but for all countries bordering the Baltic Sea, and beyond.

Annex

1. Contents of the book "Applied Wave Mathematics". Ed. by E.Quak, T.Soomere (to be published by Springer in 2009).

2. Flyer of the book "Numerical Simulation of Waves and Fronts in Inhomogeneous Solids" by A.Berezovski, J.Engelbrecht; G.A.Maugin, World Scientific, 2008.

3. Flyer "Modern Photoelastic Technology for Residual Stress Measurement in Glass".

5. Information about the International Conference "Complexity of Nonlinear Waves", Oct. 5–7, 2009 in Tallinn.

6. Article "The secrets of the heart lie in a systemic approach", Life in Estonia, 2008 spring (with permission).

Applied Wave Mathematics –

Selected Topics in Solids, Fluids, and Mathematical Methods
(title agreed with Springer Verlag)

The edited volume "Applied Wave Mathematics"consists of contributions related to the EU Marie Curie Transfer of Knowledge Project Collaboration of Estonian and Norwegian Scientific Centres within Mathematics for Applications, CENS-CMA (2005–2009). This project finances exchange visits to and from CENS, the Centre for Nonlinear Studies at the Institute of Cybernetics of Tallinn University of Technology in Estonia.

The papers fit the general theme of "mathematics in the analysis of wave phenomena"and are written in a tutorial style, intended for non-specialist researchers and students. They first describe a problem setting that is currently of interest in the scientific community, and then the authors communicate their own experiences in tackling the problem. Therefore each manuscript is not meant as a survey of the work of others or a new research paper of the authors' own latest results. Each contribution was carefully reviewed by two external referees.

The final goal was to produce a book, which highlights the importance of applied mathematics for relevant issues in the studies of waves in different media, which describes the approaches taken by the authors in an understandable way, and which can be used for educational purposes, such as material for a course or a seminar.

Seven contributions describe research highlights of CENS members, two the work of members of CMA, the Centre of Mathematics for Applications, University of Oslo, Norway, as the partner institution of CENS in the Marie Curie project, and three the field of work of foreign research fellows who visited CENS as part of the project. The papers address selected topics concerning the investigation of wave phenomena in solids and fluids, as well as some of the mathematical methods that form the foundations of the numerical treatment.

Part I: **WAVES IN SOLIDS**

1. Jüri Engelbrecht (CENS), **Deformation Waves in Solids**
2. Arkadi Berezovski, Mikhail Berezovski, Jüri Engelbrecht (all CENS), **Waves in Inhomogeneous Solids**
3. Arvi Ravasoo (CENS), **Perturbation Technique for Wave Interaction in Prestressed Material**

Part II: **MESOSCOPIC THEORY**

1. Christina Papenfuss (Berlin, project fellow), **Dynamics of Internal Variables from the Mesoscopic Background on the Example of Liquid Crystals and Ferrofluids**
2. Heiko Herrmann (CENS), **Towards a Description of Twist Waves in Mesoscopic Continuum Physics**
3. Peter Ván (Budapest, project fellow), **Weakly Nonlocal Non-equilibrium Thermodynamics - Variational Principles and Second Law**.

Part III: **WAVES IN FLUIDS**

1. Tarmo Soomere (CENS), **Long Ship Waves in Shallow Water Bodies**
2. Irina Didenkulova (CENS), **New Trends in the Analytical Theory of Long Wave Runup**
3. Tomas Torsvik (Bergen, project fellow), **Modelling of Long Ship Waves**.

Part IV: **MATHEMATICAL METHODS**

1. Andrus Salupere (CENS), **Pseudospectral Method and Discrete Spectral Analysis**
2. Snorre Christiansen (CMA), **Foundations of Finite Element Methods for Wave Equations of Maxwell Type**
3. Nils Henrik Risebro (CMA), **An Introduction to the Theory of Scalar Conservation Laws with Spatially Discontinuous Flux Functions**

E. Quak · T. Soomere (Eds.)
Applied Wave Mathematics

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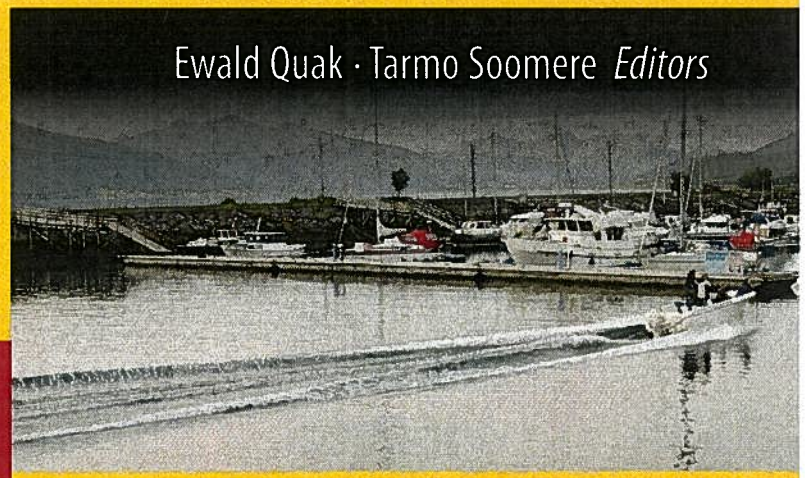
Applied Wave Mathematics

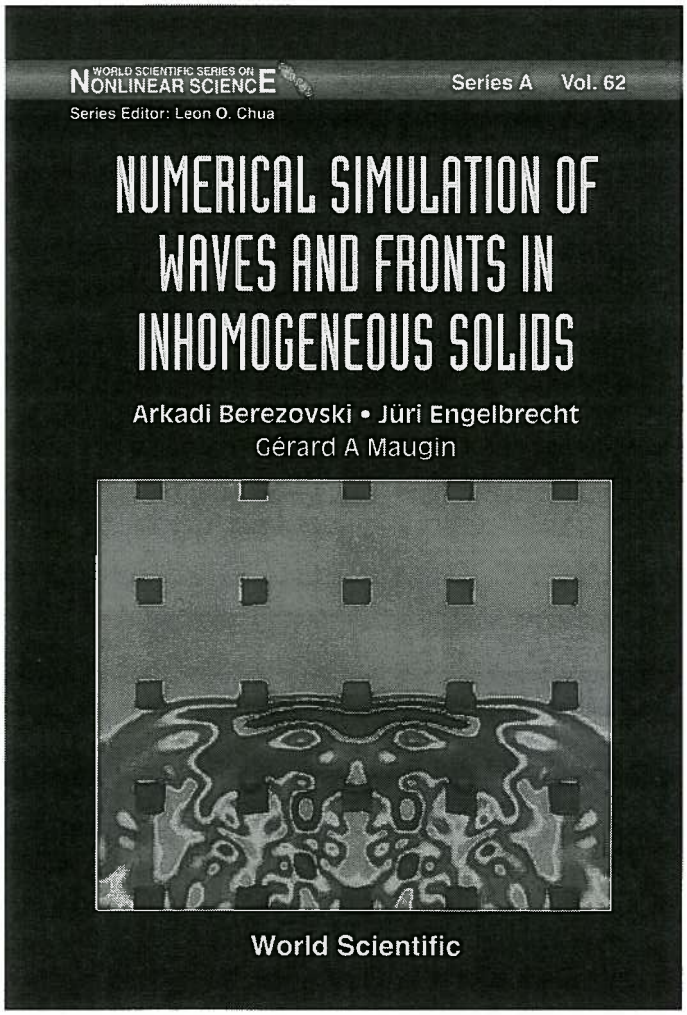
Ewald Quak · Tarmo Soomere *Editors*



Applied Wave Mathematics

Selected Topics in Solids, Fluids, and Mathematical Methods

CENS CMA Springer



World Scientific Series on Nonlinear Science, Series A – Vol. 62

NUMERICAL SIMULATION OF WAVES AND FRONTS IN INHOMOGENEOUS SOLIDS

Arkadi Berezovski, Jüri Engelbrecht
Tallinn University of Technology, Estonia
Gérard A Maugin
Université Pierre et Marie Curie, France

This book shows the advanced methods of numerical simulation of waves and fronts propagation in inhomogeneous solids and introduces related important ideas associated with the application of numerical methods for these problems. Great care has been taken throughout the book to seek a balance between the thermomechanical analysis and numerical techniques. It is suitable for advanced undergraduate and graduate courses in continuum mechanics and engineering. Necessary prerequisites for this text are basic continuum mechanics and thermodynamics. Some elementary knowledge of numerical methods for partial differential equations is also preferable.

Contents: Material Inhomogeneities in Thermomechanics; Local Phase Equilibrium and Jump Relations at Moving Discontinuities; Linear Thermoelasticity; Wave Propagation in Inhomogeneous Solids; Macroscopic Dynamics of Phase Transition Fronts; Two-Dimensional Elastic Waves in Inhomogeneous Media; Two-Dimensional Waves in Functionally Graded Materials; Phase Transitions Fronts in Two Dimensions; Dynamics of a Straight Brittle Crack.

Readership: Advanced undergraduates, graduate students and researchers in numerical and computational mathematics, material sciences and computational physics.

Key Features

- Includes non-standard topics such as the distinction between true- and quasi-inhomogeneities, the local equilibrium jump relations at discontinuities, and the material description of continuum mechanics
- Utilizes numerical experiments to illustrate the strong interaction between the achievements in continuum mechanics and the development of numerical methods

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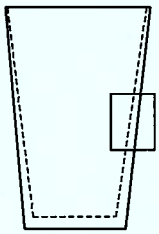
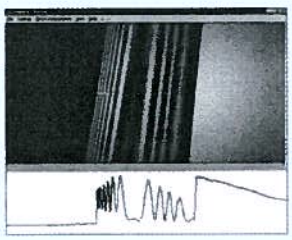
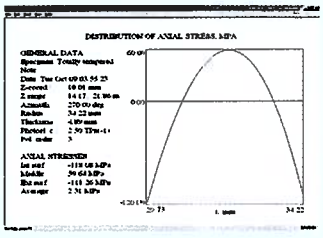


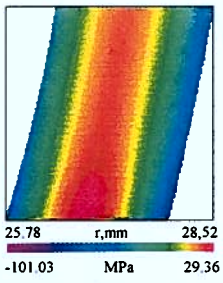
Geometry of a tumbler



Physical and digitized fringe patterns



Stress distribution through the wall



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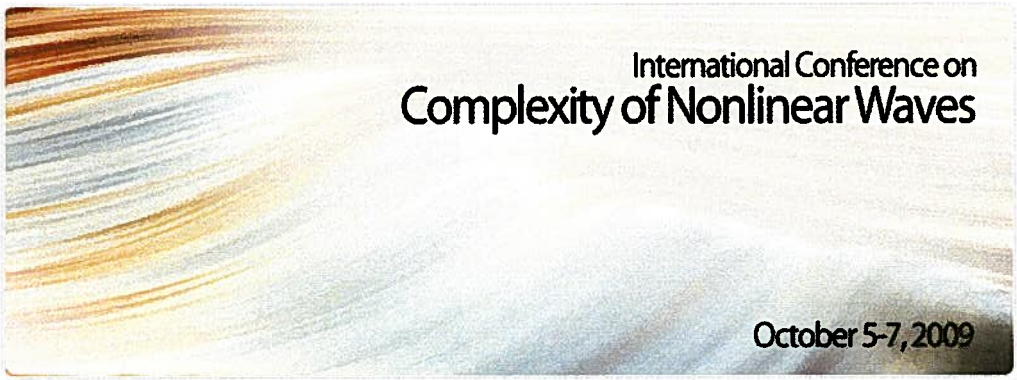

International Conference on

Complexity of Nonlinear Waves

October 5-7, 2009

organised by

Dr. Arkadi Berezovski **Prof. Tarmo Soomere**

Centre for Nonlinear Studies
Institute of Cybernetics
Tallinn University of Technology
Tallinn, Estonia

The conference will provide a forum for presentation and discussion of innovative complex models and methods for computer based simulation of dynamical processes in mechanics. Applications from solid mechanics, fluid mechanics, biomechanics, thermomechanics, and material sciences are welcome. The Conference will mark also 10 years of activities of the Centre for Nonlinear Studies – CENS. During the last decade, the complexity of wave fields in solids and fluids has been one of the focal issues in CENS. One of the key speakers at the Conference will be Prof. Jüri Engelbrecht, the Head of CENS, who will celebrate in 2009 his 70th anniversary.

The Conference is hosted by

Centre for Nonlinear Studies

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The secrets of the heart lie in a systemic approach

Text: Tiit Kändler
Photos: Pressifoto

"Welcome to the site of the Laboratory of Systems Biology. The Laboratory of Systems Biology is a part of the Centre for Nonlinear Studies in the Institute of Cybernetics, Tallinn University of Technology."

Thus reads the opening sentence on the webpage of the laboratory led by Marko Vendelin. The lab is still quite new and it was opened largely owing to the fact that Vendelin received the Wellcome Trust's International Senior Research Fellowship. First and foremost, the aim of the grant is to discover the secrets of how the heart muscle works, more precisely to discover how the cardiac cells are divided into micro-compartments and how this influences energy fluxes in the cell.

"In the last few years, several new things have been discovered about the interplay between the intracellular structures of the heart muscle and a lot of further research is needed. The decision of such a large and reputable international foundation as the Wellcome Trust to finance Marko Vendelin's planned research into the structural and functional relationships of heart cells demonstrates the high level of scientific research done in the Centre for Nonlinear Studies of the Institute of Cybernetics at the Tallinn University of Technology. Furthermore, it is a tribute to the research potential of the whole research group," confirms Mati Kutser, Research Secretary of the Institute of Cybernetics.

"The main aim of the laboratory is to study the regulation of intracellular processes and to understand the functional influences of intracellular interactions. For this, a mixture of experimental and theoretical approaches is used," the new lab explains on its webpage.

The heart can't be turned off

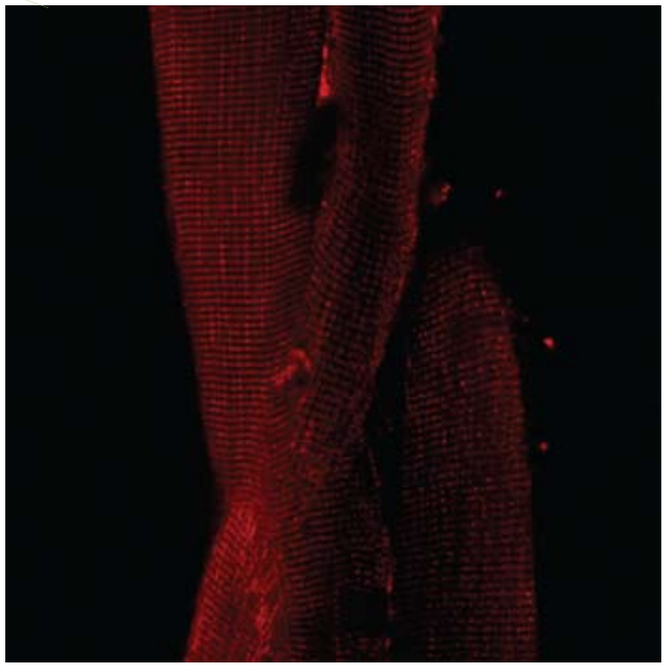
But what does it all mean? It means that Vendelin and his colleagues work in the field known as systems biology. With a systemic approach, they try to discover, for example, how the heart muscles work. "As we have no clue about how much we do not understand about the working of the heart, I cannot answer how much we already do know. A lot is known, but there are always surprises," says Vendelin.

Vendelin began to mathematically model the work of the heart when he started his job at the Mechanics Department of the Institute of Cybernetics after graduation from university. The department is led by the academician Jüri Engelbrecht. At the age of 27, Vendelin received his PhD in "The mechanoenergetics of the heart in silico".

All of this took place thanks to cooperation with the working group at the Chemical and Biological Physics Institute led by Valdur Saks. There was also co-operation with Enn Seppet's research group at the University of Tartu. "They carried out experiments, while my task was to create the mathematical model on the basis of experimental data," explains Vendelin.

In March 2006, the Journal of Physiology published an article by Valdur Saks and his Swiss, French and American colleagues on the bioenergetics of the heart, and the article has already had an impact. Marko Vendelin was also one of the authors. After publication, the article became the most read in the journal. The work of heart muscles, more precisely the question of how they get their energy, is still a mystery and therefore of interest.

But mathematical modelling in itself quickly becomes a computer game if there is no serious experimentation going on. The huge advantage of Vendelin and his colleagues was that they have a very good experiment underway in many labs, accompanied by serious modelling. For example, they thoroughly research systems of enzymes, describe and see what the computer says and afterwards test the predictions on the hearts of rats and mice.



Confocal image of mitochondria (red) in skeletal muscle.

The heart muscle is special. It needs to work all the time. It cannot be switched off for even a second. You can hold your breath, but you cannot will your heart to stop. You can rest your arm, as the work of this muscle is controlled by the central nervous system. You think - you move. But the heart muscle is autonomous. It is not controlled by the brain, only modulated. The heart has a small group of cells, the pacemaker, and this is like a battery which automatically polarises and depolarises all the time. The heart cells are connected to each other very efficiently, so that an electric signal spreads almost instantly across the whole heart.

But the modulation provided by the brain, for example, shows the heart that when you see a wolf you need to run fast. A throbbing heart gives more blood and power to the muscles. Near the heart there are baroreceptors which provide information to the central nervous system. When blood pressure becomes too high, the heart lowers it by itself by starting to beat more slowly.

Under maximum strain, the heart muscles are able to provide twenty times more blood for the body than during rest. Such an increase in capacity is guaranteed by the mechanisms inside the cells. Pathological changes in the whole system always lead to cardiovascular disease. Therefore, the achievements of scientists help medicine. When the energy transfer systems break down, the mechanoenergetic synchronisation is interrupted, the heart's ability to contract decreases and the result is heart rhythm disturbance or arrhythmia.

If the ion channels of the cell membrane, through which calcium flows in, close faster than necessary, there is less calcium and the cooperation breaks down. The rhythm is disturbed. Therefore the reason for arrhythmia and the decline in the performance of the heart is energetic. That is the first explanation for this problem – why, with some diseases, the heart loses its power; this is also called heart deficiency.

The triumph of the systemic approach

It is not enough to know all the elements. It is necessary to know the integration of elements. There has been talk of systems biology for at least 30 years, but it was always considered mostly theoretical. There was talk but no action. There have been numerous drawings of circles, boxes and triangles. But now it has become a reality.

Only a very few people bought into the philosophy of integrated systems. Most were reductionists, who claimed that it was vital to know the structure of a gene, to take a cell apart and investigate it. To date, most of the effort of scientific circles has gone into studying the structure of elements. After systems biology institutes were founded in Seattle and New Zealand and the journal Science published a short overview of systems biology by the Japanese scientist Hiroaki Kitano four years ago, all of a sudden all attention turned to systems. And thus the study of systems moved from one camp to another. Everyone who used to laugh suddenly started to talk about the same thing.

In short, systems biology helps to understand the function of biological systems, in order to predict and, if necessary, manipulate their behaviour. The final aim is to help human health.

Systems biology measures and maps biological interrelationships in cells, tissues, organs and organ systems and predicts how systems which are made up of many components that influence each other behave. Systems biology then looks for regularity where at first there only seems to be chaos.

Recently an unexpected link was discovered between the relatively large structures called cell organels. "Through indirect experimental proof and mathematical analysis, we demonstrated that the energy supplier molecule ATP is trapped between the producing and consuming parts of the cell," says Vendelin. In order to find answers confocal microscopy, mathematical modelling and biochemical data analysis are used. It is interesting that Vendelin and his colleagues experiment on rats but also on the heart cells of the trout. The heart of the fish helps to cut down on the number of lab rats and look into differences of the cellular energetics between cells of different species. This is definitely a systems biology approach. It means that the term "systems biology" is not just empty philosophical lingo. It has mathematical, physical and biological content and this approach has yielded interesting results which help to understand life.

Life is based on energy. Just as societies need energy in order to maintain production and daily life, the heart needs energy. Therefore, it is extremely important to understand the energetics of the heart. At the moment, it seems that systems biology is a big step towards that understanding. Marko Vendelin has written an article about the central issues in the transfer of energy in the heart in the publication "Molecular System Bioenergetics: Energy for Life". The article was co-written with his former tutors and older colleagues, the academicians Valdur Saks and Jüri Engelbrecht.

Of course, the equations and graphs describing energy transfer in the heart are complicated. But this poses no problem for scientists. "Scientists are happy people," believes Vendelin, "because we get to do what we like. If an exciting topic is also funded, so much the better." This opinion is probably also an example of a systemic approach.

Marko Vendelin

Career

Institution and position held

08/01/2007 - ... Tallinn University of Technology, Institute of Cybernetics at TUT; Wellcome Trust International Senior Research Fellow
2006 - 07/31/2007 Tallinn University of Technology, Institute of Cybernetics at TUT; Senior Researcher
2005 - 2005 INSERM Postdoctoral Fellow, INSERM U446, Faculté de Pharmacie, Université Paris-Sud, Châtenay-Malabry, France
2003 - 2005 EU Marie Curie Postdoctoral Fellow, INSERM E0221, Laboratory of Fundamental and Applied Bioenergetics, Université J. Fourier, France
2002 - 2003 senior researcher, Institute of Cybernetics at Tallinn University of Technology, Estonia
1997 - 2002 researcher, Institute of Cybernetics at Tallinn University of Technology, Estonia

Education

1997 - 2001 PhD studies (technical physics), Institute of Cybernetics at Tallinn University of Technology, Estonia
1995 – 1997

Administrative responsibilities

2007 - ... Head of Laboratory of Systems Biology, Institute of Cybernetics at Tallinn University of Technology2006 - ... American Journal of Physiology: Cell Physiology, associated editor, Special call on the Systems Biology of the Mitochondrion

Research activity

Degree information

Marko Vendelin, Doctor's Degree, 2001, (sup) **Jüri Engelbrecht**, Südamelihase mehanoenergeetika modelleerimine (Cardlac mechanoenergetics in silico), **Tallinn University of Technology**
Marko Vendelin, Master's Degree, 1997, (sup) **Jüri Engelbrecht**, Modelling of electrical activation of the myocardium, **Tallinn University of Technology**

Honours & Awards

2008, Yearly Award, Biosciences and Environment - Enn Seppet, Jüri Engelbrecht, Marko Vendelin, Valdur Saks; National Science Award
2007, Marko Vendelin; Wellcome Trust International Senior Research Fellowship
2002, Marko Vendelin; Marie Curie Fellowship of the European Community
1997, Marko Vendelin; Fellowship of the Netherlands organization for international cooperation in higher education (NUFFIC)

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