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CENS

Centre for Nonlinear Studies

Estonian Centre of Excellence in Research

Annual Report

2003

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Abstract

The Report includes a brief overview on all the activities of CENS 2003. Described are the studies on: (i) dynamics of microstructured materials and solitons; (ii) surface waves; (iii) biomechanics and biophysics, (iv) fractality and econophysics; (v) nonlinear wave theory including acoustodiagnostics and termodynamics; (vi) dynamics of piano hammers; (vii) optical nonlinearity and photoelasticity; (viii) geometry; (ix) wind driven waves and ship wash; (x) EEG analysis. The summaries on the Advanced Study School "Nonlinear Processes in Marine Sciences", as well as on international programmes NATEMIS and PARROT are presented. The full lists of papers, reports, abstracts, conferences, etc are all included.

Keywords: nonlinear dynamics, microstructured solids, solitons, acoustodiagnostics, photoelasticity; cardiac contraction, cell energetics, signal processing, water waves, differential equations.

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Lühikokkuvõte

Käesolev aruanne on ülevaade Mittelineaarsete Protsesside Analüüsi Keskuse (CENS) tegevusest 2003.a. Ülevaade kirjeldab tulemusi järgmistes suundades: (i) lainelevi mikrostruktuursetes materjalides ja solitonid; (ii) pinnalained vees; (iii) biomehaanika ja biofüüsika, (iv) fraktaalsus ja ökonofüüsika; (v) mittelineaarne lainelevi ning akustodiagnostika ja termodünaamika; (vi) klaverihaamrite dünaamika, (vii) optiline mittelineaarsus ja fotoelastsus; (viii) geomeetria; (ix) tuulelained ja laevalained; (x) EEG analüüs. Esitatud on ülevaade rahvusvahelisest koolist mereteaduste alal ning kokkuvõtted rahvusvaheliste programmide NATEMIS ja PARROT täitmisest. Esitatud on samuti publikatsioonide, aruannete, konverentside, loengute jm nimekirjad.

Võtmesõnad:
mittelineaarne dünaamika, mikrostruktuuriga materjalid, solitonid, akustodiagnostika, fotoelastsus, südamelihase ja rakuenergeetika, signaalitöötlus, pinnalained, diferentsiaalvõrrandid.

1. Introduction

This Report is the fifth Annual Report of CENS, following CENS 1999 - 2002. CENS acts as an Estonian Centre of Excellence in Research. This title was awarded by the Ministry of Education and Research for 2003 - 2006 to ten Centres together with additional funding. Needless to say, this means also a bigger responsibility.

Within the Programme for Centres of Excellence in Research, a general overview will be published in 2004 about all the Centres. As far as CENS has already compiled and submitted its overview, this Report includes a part of this material as Section 2. Further, Section 3 gives a brief summary on current studies. Section 4 is about funding and Section 5 includes the lists of publications and of other activities.

Section 6 is devoted to summaries and further prospects.

2. Overview on CENS

The CENS was founded already in 1999 in order to bring under one umbrella the scientific potential in Estonia engaged in interdisciplinary studies of complex nonlinear processes ("non-linear science"). Many problems on the frontier of science that stem from solid mechanics, fluid dynamics, fractality of nature, biophysics, optics together with the theory of differential equations are interwoven into the general framework of complexity and nonlinear dynamics.

This framework includes both coherent (eg soliton dynamics) and chaotic phenomena. Nonlinearity is a fundamental property of nature and the additivity is lost in nonlinear systems that gives rise to new phenomena and is extremely important as for understanding nature as well for high technology.

The present research of CENS involves:

- Nonlinear waves: complexity of wave motion in solids, coherent wave fields, solitonics and surface waves, phase-transformation fronts, acoustodiagnostics of material properties, micro-structured materials, impact;
- Fractality and biophysics: complexity in biophysics, *in silico* modelling of cardiac mechanics and cell energetics, heart rate variability, turbulent diffusion, statistical topography and flooding, econophysics;
- Nonlinear integrated photoelasticity: stress field tomography (tensor tomography), complexity of interference fringes;
- Water waves: marine physics, multimodal waves, wind wave forecast, anomalies of wave fields, extreme waves;
- Geometric approach: Lie-Cartan methods, flows of vector fields on tensor fields;
- Nonlinear signal processing: analysis of physiological signals (EKG, EEG), and applications in cardiology and brain research (hypoxic states of the brain).

The main aim of CENS is to be at the frontier of science in all these fields and also react to national interests.

The International Advisory Board:

Prof. Josef Ballmann, RWTH Aachen; Prof. Bengt Lundberg, Uppsala University; Prof. Gérard A. Maugin, University of Paris 6; Prof. H.Keith Moffat, Cambridge University; Prof. Valdur Saks, University of Grenoble; Dr. Andras Szekeres, Budapest Technical University; Prof. Dick van Campen, Eindhoven University of Technology; Prof. Embrecht van Groesen, Twente University has approved this aim and the main results of recent years:

- the concepts and analyses of hidden solitons, soliton patterns and solitary ensembles;
- thermodynamical modelling of phase transition front propagation and FGMs;
- methods of acoustodiagnostics for NDT;
- mathematical models of hysteretic piano hammers;
- novel models for describing cardiac mechanoenergetics and cell energetics;
- explanation of cardiac arrhythmias on the basis of a quiescent nerve pulse equation;
- solving an inverse problem of a 2D soliton pattern with interaction solitons;
- kinetic theory for multimodal water waves;
- expaining complexity of geophysical turbulence;
- theory of interference blots in photoelasticity;
- optical tensor field tomography;
- algebra of supersymmetry and Lie derivatives;
- nonlinear EEG signal processing.

CENS is funded by the Ministry of Education and Research and by Estonian SF grants, altogether in 2003 in sum about of 4 MEEK There have been several international grants (BMBF, NATO etc) and presently an ESF programme (NATEMIS), the Parrot programme and the EU contract PAPA. A project of the 6th FP is to be starting. Several international contracts are related to photoelasticity.

There are many international co-operation agreements and working contacts (Paris 6, Twente, Eindhoven, Helsinki, Uppsala, Lyngby, Turin, Aachen, Grenoble, Wroclav, Hong Kong; Budapest, Loughborouh). The fellows have been recognised by the Humboldt Fond, Marie Curie Fond (two recent post-doc positions), Fulbright Fond, etc. In Estonia, the collaboration is with the NICPB, TU, MSI at TTU, IG at TTU, Estonian Diagnostic Centre. Contracts from Marine Department and Tallinn Port are related to measurements of wave fields.

During the last 5 years 5 Ph Ds have been promoted, presently there are 8 PhD students. The International Schools are organized (in 2003 the Third Glass Stress Summer School and the Advanced Study School in "Nonlinear Processes in Marine Sciences".

CENS has a cluster of Athlons (altogether 32) functioning as a system of parallel networks. The Laboratory of Photoelasticity is well equipped including automatic polariscopes and a polariscope for magnetophotoelasticity.

3. Current results 2003

3.1 Institute of Cybernetics, Tallinn Technical University.

3.1.1 Dynamics of microstructured materials and solitons.

Solitary waves in microstructured solids.
A KdV type evolution equation, including fourth order nonlinearity and both the third- and the fifth order dispersion is used as model equation. In 2003 the main attention was paid to soliton formation from localised initial excitation. In order to determine relations between the solution types and the amplitude of the initial wave the model equation was integrated numerically for different values of material parameters (the 3rd and the 5th order dispersion parameters). The pseudospectral method and a $\text{sech}^2 x$ type initial condition were used. Three solution types were detected: (i) the initial localised wave decaying to a chaotic wave-train; (ii) emerging of ensembles of positive and negative solitons form; (iii) emerging of constant amplitude solitary wave (with or without tail) propagating with constant speed forms. Characteristic values for the initial wave amplitude, determining the solution type are found over the wide range of dispersion parameters. In order to analyse the specific influence of higher order nonlinear effects on the soliton formation numerical solutions of the modified KdV equation (with third order dispersive term only) were found and examined. The nonlinearity was given in the form of cubic as well as quartic potential, but the dispersive term was of the third (i.e. of the lowest) order. Results were compared with that of the KdV (quadratic nonlinearity) (A.Salupere, O.Ilison, M.Sepp).

Solitary waves in granular materials.
The studies of wave propagation in granular materials have been continuing based on a hierarchical KdV equation. The model equation involves three material parameters (two different dispersion parameters and one microstructure parameter). Numerical solutions are found under harmonic initial conditions by the pseudospectral method. In the present case two different solitonic structures can be emerged from the harmonic initial wave — a KdV soliton ensemble and an ensemble of equal amplitude solitons. It is remarkable that both the ensembles can exist simultaneously. Possible solution types are found earlier. In 2003, more than 10000 additional numerical experiments were carried out in order to analyse the behaviour of solutions in the three dimensional space of material parameters. As a result relations between different solution types and dispersion types are established and domains in the material parameters space corresponding to different solution types are found. The phenomenon of amplification and domination of the ensemble of equal amplitude solitons is found to depend on the mutual ratio of dispersion parameters. This ratio determines is the equal amplitude ensemble suppressed or amplified (including the domination over that of the KdV) as well as the number of solitons in the equal amplitude ensemble (A.Salupere, L.Ilison).

Wave hierarchies
The Mindlin model derived earlier has been studied in all its variants. Possessing clear hierarchical properties, this model has a certain advantages over simplified models of structured materials including the laminates. The dispersion relations have been derived. Possible generalizations of the model are proposed (J.Engelbrecht, F.Pastrone, M.Braun).

Surface Waves

For reliable testing of ships and offshore structures, as well as for coastal engineering topics, it is necessary that experiments in hydrodynamic laboratories are performed in wave fields that reflect realistic situations at sea. This concerns wave fields with high and steep waves that are only poorly described and understood by current mathematical models: the relevant concepts — nonlinearity, dispersion, and multi-dimensionality — are too difficult to tackle in one package.

This study aims at developing mathematical models that would support solving the problem of determinstic generation of waves. This is the key problem for producing desired waves at the described position in the wave tank where ship models are floated for performing sea-keeping experiments.

The main results of this study are as follows. An efficient and highly accurate solver for 2D free surface problem is developed using half analytical/half numerical approach based on conformal mapping technique. The solver is successfully tested against the exact solution (Stokes waves) of the free surface problem over a large number of wave periods with a very high accuracy, stability, and efficiency of the numerical algorithm. For achieving such good results several algorithmic techniques were developed and improved, for instance, using high order finite difference scheme to solve the problem of amplification of numerical noise from using differentiation schemes based on Fast Fourier Transforms. Also, the best possible algorithm (in the sense of stability and efficiency) for time-integrating the system of free surface equations in conformal variables was determined and implemented (P.Peterson).

Software development

Continued the development of the program "F2PY – Fortran to Python Interface Generator" (http://cens.ioc.ee/projects/f2py2e/). Its purpose is to scan Fortran 77/90/95 codes and produce extension modules for Python language (http://www.python.org/) which allows users to call (computationally highly efficient) Fortran or C routines from (a very high level and flexible) Python language and vice-versa.

Developing modules for scientific computations within the SciPy project (http://www.scipy.org/). These modules are actively used in the numerical solver for free surface problems (P.Peterson).

3.1.2 Biomechanics and biophysics

Cell energetics.

Recent studies have revealed the structural and functional interactions between mitochondria, myofibrils and sarcoplasmic reticulum in cardiac cells leading to direct channeling of adenosine phosphates between organelles. It can be shown using mathematical models that such channeling indicates diffusion limitations of adenosine phosphates in cardiac cells due to very specific intracellular structural organization (Saks et al, 2003, Biophys J 84:3436). In this study, we looked into structural and functional aspects of the interaction between organelles in cardiac muscle cells. First, on the basis of quantitative analysis of confocal images of cardiomyocites, we have shown that mitochondria are precisely organized in the cardiac muscle cells with rather small variation of distances between the neighboring mitochondria. The average distance is almost the same for longitudinal and transversal direction and about 1.4 times larger in diagonal direction, i.e. the neighboring mitochondria are forming almost a perfect square in the images. Second, we analyzed the possible role of two principally different modes of restriction distribution for adenosine phosphates: (a) the uniform diffusion restriction and (b) the localized diffusion limitation in the vicinity of mitochondria. The reaction-diffusion model of cardiac skinned fiber and permeabilized cell was composed to describe diffusion of metabolites in a cross-section. According to our analysis, it is possible to identify the distribution of diffusion restriction by comparing the simulation results with the measured stabilization of respiration rate after injection of 2mM ATP into the solution. Only the second mechanism considered - localization of diffusion restrictions - is able to account for the experimental data. Probably, these localized restrictions are the result of structural organization of the cell and the basis for functional coupling between ATPases and mitochondria in the cardiac muscle cells (M.Vendelin, M.Lemba).

Heart rate variability (HRV)
Analytical approach has been used to compare and classify the most important non-linear measures of heart rate variability. According to this classification, these measures which address similar physical features of HRV are put into the same group. Besides, inter-beat interval increment distribution has been studied. Preliminary results indicate that for healthy subjects, this distribution corresponds to a stationary Lévi distribution (J.Kalda, M.Säkki).

Mathematical modelling of intracellular energy fluxes
An integrated computer model for energy metabolism of the muscle has been previously developed, focussing on how the energy transfer process regulates ATP synthesis in the mitochondria. Oxygen consumption of mitochondria in saponin-skinned cardiac fiber bundles has an order of magnitude higher apparent Michaelis constant K_m to ADP than isolated mitochondria. Experiments performed by our collaborators at Free University Amsterdam showed that incubating skinned cardiac fiber bundles of wild type or creatine kinase (CK) double-knockout mouse with CK and creatine or with yeast hexokinase and glucose as extramitochondrial ADP producing systems decreases the apparent K_m of the bundles several fold. Based on the computer simulations of these experiments performed by us in 2003, including cardiac muscle of both genetically modified and normal mice, we conclude that the affinity to ADP of mitochondria in mouse heart is of the same order of magnitude as that of isolated mitochondria, while the high apparent K_m of the bundles is caused by the diffusion gradients outside mitochondria (O.Kongas).

3.1.3 Fractality

Statistical topography
Statistical topography of random surfaces. The scaling exponents of random surfaces with negative Hurst exponent have been studied numerically by Monte-Carlo simulations. To this end, $1 + 1$-dimensional model (4V-model) has been used. In the case of $H = -0,75$, the fractal dimension of a single isoline turned out to be $d = 1.563 + / - 0.002$. This is significantly different from the well-known exact result $d = 1.75$ for isotropic two-dimensional surfaces. Thus, in the case of $H < 0, 1 + 1$ -dimensional and 2-dimensional surfaces belong to different universality classes.

Scale-invariance in geophysics. The model of formation and merger of magmatic batches has been analysed analytically. The size-distribution law of batches has been derived. This is a power law, the scaling exponent of which is either $2/3, 5/6$, or

1, depending on the model parameters. The analytic results are in agreement with numerical experiment (J.Kalda).

Turbulent diffusion
The k-spectrum of finite-lifetime passive scalar particles has been analysed. It turned out that the spectrum is different for ageing and non-ageing particles. For non-ageing (exponentially decaying) particles, the k-spectrum is a power law. In the opposite case, the differential scaling exponent is a decreasing function of the wave-vector k (J.Kalda).

Econophysics
The distribution of low-variability periods in the long-term history of stock-market indices (MSCI World, SP500) has been studied. It turned out that similarly to what is observed for the time-series of HRV, the distribution follows a power law (Zipf's law) (R.Kitt).

3.1.4 Nonlinear wave theory

Acoustodiagnostics of inhomogeneous and prestressed solids.
The theoretical research to elaborate algorithms for nondestructive evaluation of inhomogeneous prestress field and physical inhomogeneity in solids on the basis of two ultrasonic waves simultaneous propagation data was carried on.

Generalization of the previous research results enabled to present the method for qualitative and quantitative identification of inhomogeneous prestress field in the physically nonlinear elastic material resorting to the recorded data of boundary oscillations evoked by interaction of two ultrasonic waves in the material. The method was illustrated by the example of identification of the two-parametric prestress field.

The ultrasonic nonlinear resonance method for nondestructive evaluation of the weakly inhomogeneous physical properties of the nonlinear elastic material was elaborated. The boundary oscillations caused by interaction of two counter-propagating ultrasonic waves in the material with finite thickness were considered. The idea that the boundary oscillation resonance amplitude is dependent on the inhomogeneous properties of the material and on the excitation amplitude was used. The numerical experiments for qualitative and quantitative nondestructive determination of the variable density and the variable elastic properties of the nonlinear elastic material were implemented (A.Ravasoo, A.Braunbrück).

Thermodynamic model for phase-transition front propagation.
A systematic description of the interaction between two systems is developed in the framework of thermodynamics of discrete systems. Interacting discrete systems form a composite (compound) system, which is also a discrete one. Thus a discrete system can be described as a compound system or as being non-composed. These different cases of description cause different degrees of accuracy, which are expressed by excess quantities. Such an excess quantity vanishes, if the discrete system is really non-composed. The excess quantities of power and energy exchange, and the excess entropy are calculated in the special case of an endoreversible compound system.

The propagation of stress waves in functionally graded materials (FGMs) is studied numerically by means of the composite wave-propagation algorithm. Two distinct models of FGMs are considered: i) a multilayered metal-ceramic composite with averaged properties within layers; ii) randomly embedded ceramic particles in a metal matrix with prescribed volume fraction. The numerical simulation demonstrates the applicability of that algorithm to the modelling of FGMs without any averaging procedure. The analysis based on simulation shows significant differences in the stress wave characteristics for the distinct models that can be used for optimizing the response of such structures to impact loading (A.Berezovski).

Piano hammers - theoretical and experimental studies
Experimental testing of piano hammers that consist of a wood core covered with several layers of compressed wool felt demonstrate that all hammers have the hysteretic type of the force-compression characteristics. It is shown that different mathematical hysteretic models can describe the dynamic behaviour of the hammer felt. In addition to the four-parameter nonlinear hysteretic felt model, another new three-parameter hysteretic model was developed. The both models are based on an assumption that the hammer felt made of wool is a microstructured material possessing history-dependent properties. The equivalence of these models is proved for all realistic values of hammer velocity. The problem of the flexible string excitation by hysteretic hammer is also considered (A.Stulov).

3.1.5 Optical nonlinearity and photoelasticity

Methods of the stress field tomography
The method of photoelastic tomography in linear approximation has been elaborated for the measurement of 3D stress fields.

Classical tomography is scalar field tomography where every point of the field is characterized by a scalar (e. g., the coefficient of extinction of the X-rays). In scalar field tomography, in the plane under investigation line integrals of the field in many directions (the Radon transform of the field) is measured and the field itself is determined with Radon inversion.

Radon inversion for the tensor field does not exist. The aim of the investigation was to decompose the problem of tensor field tomography into several problems of scalar field tomography for separate stress components. The method is based on the linear approximation of the solution of the equations of integrated photoelasticity. This approximation can be used when either the optical birefringence is weak or rotation of the principal stress axes on the light rays is small. In this case on every light ray it is possible to measure the parameter of isoclinics, which determines the average direction of the principal stresses, and the integral optical retardation. These measurement results determine for every light ray two integrals of the components of the stress field. From these expressions it is possible, using the equilibrium equation, to derive an expression of the Radon transform for one component of the stress tensor. The normal stress distribution can be determined using Radon inversion.

The method has been implemented using the automatic polariscope AP-05 SM, supplied with a rotary stage. By tomographic photoelastic measurements the test object is turned with a stepper motor. Software of the polariscope controls tomographic photoelastic measurements and calculates the stress field using Radon inversion. Photoelastic tomography has been used for residual stress measurement in various glass articles (optical fibre performs of complicated cross-section, high-pressure electric lamps, bottoms of different bottles, etc.) (L.Ainola, H.Aben).

3.2 Tartu University

Geometric approach to nonlinear problems
Vector fields and symmetries are studied. The following problems were analyzed and presented in the consistent form (a manuscript): tensors in the vector fields; tensor presentations of linear group; universality of jet-space structures; geometrical examples and differential equations (M.Rahula).

It is shown that the adequate geometric apparatus for the topological field theory on a four-dimensional manifold is the theory of superconnections. The Lagrangian of the topological field theory can be derived from the curvature of a superconnection and the Bianchi identity implies the supersymmetries of the Lagrangian (A.Abramov).

3.3 Marine Systems Institute at Tallinn Technical University

Water Waves
It was shown that energy exhange between specific modes of Rossby waves in a three-layer ocean model fails if and only if an eigenvector of the potential vorticity equations has a zero entry. This happens in the case of several simple vertical structures of the water masses. As a practical application, it has been demonstrated that wakes from fast ferries may form a new forcing component of vital impact of the local ecosystem of semi-open bays that may cause considerable intensification of beach processes and have significant influence on the aquatic wildlife.

Many wave systems (e.g. Rossby waves, internal waves) can be described as a superposition of a number of vertical modes in which energy exchange rate depends on both interaction and coupling coefficients. As an example of multi-modal kinetic equations for wave systems with comparable frequencies, the kinetic description of baroclinic Rossby waves in a multi-layer model ocean is analysed. Explicit expressions for the coupling coefficients are obtained for the three-layer model. Several types of interactions vanish in the case of simple vertical structures of the ocean. The largest number of void interactions occur when the top and the bottom layer are equal in depth and the medium layer is twice as thick as the top layer. Such a situation normally does not occur in the open ocean but frequently appears in the Baltic Sea conditions.

The wind field in both Baltic proper and in the largest subbasins of the Baltic Sea has an extremely complex and spatially nonhomogeneous nature. The wind anisotropy has considerably influence on the properties of wind wave fields. Wind wave statistics and wave height anomalies in the Baltic Sea are studied using the third generation wave model WAM. In certain regions wave height may increase in extreme cases about 2 m as compared to wave heights in the open sea. In many areas of the Baltic Sea the wind anisotropy much more affects wave properties than the fetch length.

The waves from fast ferries have become a problem of growing concern in the vicinity of ship lanes during the last years. High speed craft ships of various size cross Tallinn Bay up to 70 times per day during the navigation period. The ships frequently sail with speeds close to the critical velocity and produce extremely long-crested waves. A generally recognised issue of particular concern is that wakes from the high-speed craft in confined waters can cause serious environmental problems.

The heights of ship waves in the said coastal areas normally do not exceed 1 m and are moderate compared with the highest wind waves reaching this area each year.

However, wind waves of this height occur infrequently and the highest daily examples of ship-generated waves belong to the highest 1-5% of wind waves. A certain role in the vulnerability of the coasts plays the relatively mild natural wave regime of Tallinn Bay. The role of ship waves is impressive in terms of energy (it forms about 10% from the bulk wave energy) but striking in terms of energy flux or wave power: ship waves form 18-35% (27-54% during the summer season) from the total wave power at the coasts of Tallinn Bay. The anthropogenic waves may even dominate during a part of the relatively calm high navigation season (April-June) when the biological productivity is at its seasonal maximum.

The highest components of ship wakes with the heights of about 1 m have frequently periods 10-15 s that are considerable larger than periods of natural waves (typically 2-5 s, in extreme cases 6-7 s) in this area. Such high and long surface waves do not exist in natural conditions in the area in question. They cause unusually high near-bottom velocities at the depths of 5-30 m, thus forming a new forcing component of vital impact on the local ecosystem that may cause considerable intensification of beach processes as well as enhanced vertical mixing in the water body, and have significant influence on the aquatic wildlife (T.Soomere).

Interaction of two long-crested shallow water waves (such waves are frequently generated by high speed ships) is analysed in the framework of two-soliton solution of the Kadomtsev-Petviashvili equation in cooperation with the group of nonlinear waves (P. Peterson, J. Engelbrecht). The wave system is decomposed into the incoming and the interaction soliton that represents the particularly high wave hump analogous to Mach stem in the crossing area of the waves. Shown is that extreme surface elevations up to four times exceeding the amplitude of the incoming waves typically cover a very small area but in the near-resonance case they may have considerable extension (T.Soomere, P.Peterson, J.Engelbrecht).

3.4 Biomedical Engineering Centre, Tallinn Technical University

3.4.1 EEG in anesthesia

Selection of the most sensitive signal processing methods for evaluation of the EEG signals affected by different stressors continued in 2003. Independent Component Analyses (ICA) and coherence analyses are used to separate and follow the behaviour of the components of the EEG burst suppression pattern in propofol anesthesia. The signal was measured from 13 scalp electrodes and 4 depth electrodes implanted for the treatment of parkinsonism. The results show that ICA is capable in separating the components (spindle, mixed frequency, activity and sharp wave) implying that the components can be statistically described. Coherence analyses shows that the beta activity starts actually several minutes before the unset of burst suppression and slows down gradually. The results indicate that there are patterns in EEG during propofol anesthesia which have not been described earlier. Although the physiological meaning of these findings is still unclear, the discovered phenomenon is an important step towards understanding the mechanisms behind propofol anesthesia (T.Lipping, R.Ferenets, A.Anier).

3.4.2 Effect of low-level stressors on EEG

The bispectral analyses, coherence analyses and fractal dimension analyses are used to evaluate the effect of low-level microwave radiation on human EEG alpha and theta rhythms. Parallel statistical evaluation of the changes in the EEG signal energy level was performed. During the experiment ten healthy volunteers were exposed to a microwave (450 MHz) with 7 Hz frequency on-off modulation. The field power density at the scalp was 0.16 mW/cm2. Signals from the following EEG channels were used: FP1, FP2, P3, P4, T3, T4, O1 and O2. The experimental protocol consisted of one cycle of the short-term photic and ten cycles of the repetitive microwave stimulation. The parameters that calculated from the EEG bispectrum could not detect the influence of the microwave radiation. Coherence and fractal dimension analyses showed the effect in case of some individuals. In the majority of cases, photic stimulation caused changes in the EEG energy level in the occipital and microwave stimulation in the frontal region. Our experimental results demonstrated that microwave stimulation effects became apparent starting from the third stimulation cycle. Changes varied strongly from subject to subject. Therefore, photic and microwave exposure did not cause statistically significant changes in the EEG activity level for the whole group. For some subjects, clear tendencies of changes in microwave on-off cycles were noticeable (H.Hinrikus, J.Lass, M.Bachmann).

3.5 Research within international programmes

3.5.1 NATEMIS

The European Science Foundation Programme "Nonlinear Acoustic Techniques for Microscale Damage Diagnostics - NATEMIS" unites 7 teams from various European Countries. The aims and objectives of NATEMIS are:

- Creation of a very broad and interdisciplinary network for the purpose of studying experimentally and theoretically (by means of phenomenological models and supercomputer simulations) the effects of nonlinearity at a mesoscopic scale.
- Implementation of nonlinear acoustic NDE techniques for micro-damage diagnostics in materials.

Current topics:

The theoretical research to elaborate algorithms for nondestructive evaluation of inhomogeneous prestress field and physical inhomogeneity in solids on the basis of the two-wave technique (two waves are simultaneously generated and their interaction analyzed).

The possible application of the elaborated method for qualitative and quantitative identification of the inhomogeneous prestress field in the case of multiparametric prestress field.

The ultrasonic nonlinear resonance method for NDE of the weakly inhomogeneous physical properties of the nonlinear elastic material is proposed. The hierarchical modelling is used for explaining dispersive properties of microstructured materials.

Challenges

- Elaboration of methods for NDE of inhomogeneity in prestress and material properties on the basis of finite pulses or bursts interaction data.
- Solution of the texture prestress distinction problem.
- Nonlinear effects of wave propagation versus acoustoelastic effect.
- Solution of inverse problems using hierarchical models.

In 2003, CENS has participated in the NATEMIS Steering Commitee meetings (Paris, Madrid, Antverpen, Heidelberg) and three topical sessions (Madrid, Stockholm, Paris). Two fellows of CENS (A.Berezovski, J.Engelbrecht) have been working in Turin (both for one week). Dr. E.Schneider (Saarbrücken), has visited Tallinn.

The intensive cooperation within NATEMIS is with the Fraunhofer Institute for NDE (Saarbrücken), and Turin Technical University, and the University of Turin.

3.5.2 PARROT

This French-Estonian Programme of co-operation is supported by the French Ministry of Foreign Affairs and Estonian Science Foundation. CENS has a project "Nonlinear stress waves in complex media". French partner is the Department of Modelling in Mechanics, University of Paris 6 (supervisor Prof. G.A.Maugin).

The aim of this project is to elaborate effective tools for modelling and numerical calculation of wave fields in microstructured materials, including phase transformation fronts. As a result, a thermodynamically consistent algorithm for the finite volume meetod is derived based on description of non-equilibrium thermodynamic conditions at the phase boundaries. The method is also used for describing the wave-fields in functionally graded materials.

With the programme:

- Prof. G.A.Maugin gave two lectures in Tallinn (April, 2003)

  From Mathematical Physics to Engineering;

  Canonical Balance Laws in Solid Mechanics.

- A workshop (G.A.Maugin, J.Engelbrecht - chairmen) was organized by CENS in Tallinn, April 24, 2003 with talks by J.Engelbrecht, A.Berezovski, A.Ravasoo, A.Salupere, A.Stulov;
- A.Berezovski and A.Salupere visited the University of Paris 6 and presented the seminar talks;
- four papers were published in journals and five papers in conference proceedings (see the list of publications).

4. Funding

4.1 Target funding through the Ministry of Education

1. Long-term block grant: "Nonlinear dynamics and stress analysis". Supervisor: J.Engelbrecht.
2. Long-term block grant: "Interpretation of Bioelectric Signals". Supervisor: H.Hinrikus (partly related).
3. Long-term project 0142084As02: "Bioelectrical signal interpretation". Supervisor: H.Hinrikus.
4. Long-term block grant: "Dynamics of turbulent processes and nonlinear waves". Supervisor: T.Soomere.

4.2 Estonian grants (Estonian Science Foundation):

1. H.Aben, grant 4972, "Nonlinear integrated photo-elasticity", 2001-2005.
2. A.Berezovski, grant 4504, "Propagation of phase-transition fronts in solids", 2001-2003.
3. J.Engelbrecht, grant 4704, "In silico modelling of heart ischemia", 2001-2003.
4. A.Stulov, ETF grant 5566, "Sound Generation mechanisms in Grand Pianos", 2003-2006.
5. J.Janno, A.Ravasoo, grant 4706, "Inverse problems for description of properties and states of inhomogeneous materials", 2001-2004.
6. A.Salupere, grant 5565, "Wave dynamics and wave hierarchy in microstructured materials", 2003-2006.
7. J.Kalda, grant 5036, "Statistical topography for dynamical dissipative systems at self-organized criticality", 2002-2004.
8. T.Soomere, grant 4025, "Analysis and modelling of surface wave anomalies of the Baltic Sea", 2000-2003.
9. J.Lass, ESF grant 4871, "EEG signal processing for detection of changes caused by a weak stressor", 2001-2003.
10. H.Hinrikus, ESF grant 5143, "Mechanisms of Biological Interaction of the EMF", 2002-2005.
11. T.Lipping, ESF grant 5625, "Analysis and monitoring of EEG patterns during propofol anesthesia", 2003-2005.

4.3 International grants

1. J.Engelbrecht. A.V.Humboldt grant for research (2 months), University of Duisburg - Essen, Duisburg, Germany.
2. M.Lemba. Fulbright Scholarship for PhD Studies, Washington University, Seattle, USA.

3. M.Vendelin. Marie Curie Fellowship, HPMF-CT-2002-01914, University of Grenoble.

4.4 Contracts

1. EU contract PAPA: "Programme for a BAltic network to access and upgrade an oPerational observing and forecAsting System in the region" (group of water waves contributes to Modelling workpackage).

4.5 International projects

1. A.Ravasoo. "Nonlinear Acoustic Techniques for Micro-Scale Damage Diagnostics (NATEMIS)". An European Science Foundation scientific programme. (Participants: A.Berezovski, A.Braunbrück, J.Engelbrecht).

2. J.Engelbrecht. French-Estonian science and technology collaboration program PARROT "Nonlinear Stress Waves in Complex Media". (Participants: A.Berezovski, A.Salupere).

4.6 Additional funding

1. Estonian Programme for Centres of Excellence in Research - addition (50% from the basic block-grant N 1).

2. Tallinn Technical University – excellence grant.

5. Publicity of Results

5.1.1 Research Reports

1.	Mech 249/03	J.Engelbrecht, F.Pastrone, A.Berezovski. Waves in microstructured materials: comparative analysis of models.
	Quaderno N28/2003	Dept. of Mathematics, University of Turin. (same title.)
2.	Mech 250/03	J.Janno, J.Engelbrecht. Inverse problems for microstructured solids.
3.	Mech 251/03	A.Braunbrück, A.Ravasoo. Ultrasonic nonlinear resonance for characterization of material inhomogeneity.
4.	Mech 252/03	A.Ravasoo. Nonlinear diagnostics of inhomogeneous prestress field by ultrasound.
5.	Mech 253/03	A.Ravasoo. Evaluation of plane inhomogeneous stress field by ultrasonic boundary measurements.
6.	Mech 254/03	A.Stulov. Experimental and theoretical studies of piano hammer.
7.	Mech 255/03	A.Stulov. The dynamic behavior of wool felt.
8.	Mech 256/03	A.Braunbrück, A.Ravasoo. Nonlinear wave interaction for inhomogeneous elastic material characterization.

5.2 Publications

Books, proceedings and theses

1. Proc. of the Estonian Academy of Sciences. Phys.-Math., (Special issue on nonlinear waves in microstructured solids), 2003, vol. 52, N 1, guest-editors J.Engelbrecht, M.Kutser, G.Maugin.

2. Proc. of the Estonian Academy of Sciences, Engineering, (Special issue on wave studies in Tallinn Bay), 2003, vol. 9, N 3, 155-242, guest-editor T.Soomere.

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2. T.Sillat, J.Engelbrecht. Wave propagation in dissipative microstructured materials. Proc. Estonian Acad. Sci. Phys. Math., Tallinn, 2003, 52, 1, 103-114.

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Abstracts

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2. A.Berezovski, G.A.Maugin. Driving force in simulation of phase transition propagation. In: EUROMECH Colloquium 445 "Mechanics of Material Forces", May 21-24, 2003, Kaiserslautern, Germany, Book of Abstracts, p.14.

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Essays and general papers

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5. A.Braunbrück and A.Ravasoo. Nonlinear wave interaction for inhomogeneous elastic material characterization. Mechanics of Materials, (submitted).
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24. V.Abramov. On the development of differential geometry in Estonia. Seminar "Recent Developments in Mathematics in Finland and Estonia", (submitted).

5.3 Conferences

1. One-day meeting on Microstructured Materials, 5 September, 2003, Duisburg, Germany.
   J.Engelbrecht. Waves in microstructured continua.

2. Seminar on Biomechanics, September 20-21, 2003, Schwerin, Germany.
   J.Engelbrecht, M.Vendelin, O.Kongas. Mathematical modelling of cardiac contraction.

3. The 5th World Congress on Ultrasound, September 8-10, 2003, Paris, France.
   J.Engelbrecht, F.Pastrone, A.Berezovski. Wave propagation in microstructured solids.
   A.Berezovski, J.Engelbrecht, G.Maugin. Stress wave propagation in functionally graded materials.
   A.Braunbrück, A.Ravasoo. Ultrasonic nonlinear resonance for characterization of material inhomogeneity.

4. The 40th Annual Meeting of the Society of Engineering Sciences, October 12-15, 2003, Ann Arbor, USA.
   J.Engelbrecht. Nonlinear waves and microstructured solids: mathematical modeling.

5. EUROMECH Colloquium 445 Mechanics of Material Forces, May 21-24, 2003, Kaiserslautern, Germany.
   A.Berezovski, G.A.Maugin. Driving force in simulation of phase transition propagation.

6. 5th International Congress on Thermal Stresses and Related Topics, June 8-11, 2003, Virginia Tech, Blacksburg, VA, USA.
   G.A.Maugin, A.Berezovski. Recent progress in the numerical simulation of the thermoelastodynamics of phase-transition fronts.

7. WAVES 2003 - The 6th International Conference on Mathematical and Numerical Aspects of Wave Propagation, June 30 - July 4, 2003, Jyvaskyla, Finland.
   A.Berezovski, J.Engelbrecht, G.A.Maugin. Numerical simulation of thermoelastic wave and phase-transition front propagation.

8. Tenth International Congress on Sound and Vibration, July 7-10, 2003, Stockholm, Sweden.
   A.Ravasoo. Nonlinear diagnostics of inhomogeneous prestress field by ultrasound.

9. 5th EUROMECH Solid Mechanics Conference, August 17-22, 2003, Thessaloniki, Greece.
   A.Braunbrück. Nonlinear wave interaction in a material with physical inhomogeneities.

10. ATEM'03, International Conference on Advanced Technology in Experimental Mechanics 2003. September 10-12, 2003, Nagoya Congress Center, Nagoya, Japan.
    A.Ravasoo. Evaluation of plane inhomogeneous stress field by ultrasonic boundary measurements.

11. The Third International Conference on Nonlinear Evolution Equations and Wave Phenomena: Computation and Theory, April 7-10, 2003, The University of Georgia, Athens, USA
    A.Salupere, O.Ilison, L.Ilison, and J.Engelbrecht. On solitons in microstructured solids and granular materials.

12. SMAC 03, Stockholm Music Acoustic Conference, August 6-9, 2003.
    A.Stulov. "Experimental and theoretical studies of piano hammer".

13. EGS-AGU-EUG Joint Assembly, Nice, France, April 6-11, 2003.
    J.Kalda. Oceanic coastlines: percolation clusters of rough surfaces.
    J.Kalda. Zipf's law-like distribution of pollution spots in turbulent flows.
    P.D.Bons, J.Arnold, J.Kalda, A.Soesoo, M.A.Elburg Accumulation and transport of magma.

14. Frontier Science 2003. A Nonlinear World: the Real World. Pavia, Collegio Cairoli, September 8-12, 2003, Tallinn, Estonia.
    M.Säkki, J.Kalda, M.Vainu, M.Laan. The distribution of low-variability periods in human heart beat dynamics.

15. Application of Physics in Financial Analysis 4 (APFA4), Warsaw, November 13-15, 2003. R.Kitt.

16. Joint Conf. "Mathematical methods and computational techniques in electrical engineering", "Nonlinear analysis, nonlinear systems and chaos", "Wavelet analysis and multirate systems", Athens, Vouliagmeni, Greece, December 29-31, 2003.
    R.Kitt. The importance of the Hurst exponent in describing financial time series.

17. In Advanced Study School: Nonlinear Processes in Marine Sciences, Hageri, Estonia, October 12-19, 2003.
J.Kalda. An introduction to stochastic diffusion.
A.Salupere. Long-living patterns of KdV solitons.
P.Peterson. Soliton interactions and interaction solitons.
T.Soomere. Introduction to the kinetic theory of weakly nonlinear waves.
T.Soomere. Fast ferries as a new key forcing component in the Baltic Sea.

18. World Congress 2003 on Biomedical Engineering & Medical Physics. August 24-29, Sydney.
T.Lipping.

19. 25th Annual International Conference of the IEEE Engineering in Medicine and Biology Society: A New Beginning for Human Health. September 17-21, Cancun, Mexico.
T.Lipping, J.Lass, M.Parts.

20. Symposium on Neuroimaging: What are we Really Looking at? April 11-12, Helsingi.
T.Lipping, R.Ferenets.

21. V International Summer School on Biosignal Processing Workshop. June 22-30, Sienna.
R.Ferenets.

22. 1st Nordic Workshop on Brain Imaging and Neuroinformatics. 2 October, Tampere.
T.Lipping, R.Ferenets.

23. Mobile Telephoy and Health, Final Seminar of the Finnish National Research Programme 1998-2003. 17 October, Helsingi.
M.Parts.

24. 6th International Congress of the European Bioelectromagnetics Association - (EBEA). November 13-15, Budapest.
H.Hinrikus.

25. COST281 "Potential Health Implications from Mobile Communication Systems" Project Workshop. November 15-16, Budapest.
H.Hinrikus.

26. 1st MedNatNet Conference, December 13-16, Amsterdam, I. Fridolin.
H.Hinrikus.

27. Joint Assembly of EGS/AGU/EUG, Nice, April 6-11, 2003.
T.Soomere and K.Rannat. Comparison of the impact of wind waves and fast ferries wash in the Tallinn Bay, Gulf of Finland.
T.Soomere (co-author S.Keevallik). A reconstruction of marine wind properties of the Gulf of Finland.

28. BOOS (Baltic Operational Oceanographic System) Annual Meeting, Riga, May 6-10, 2003.
T.Soomere. The balance of natural and anthropogenic waves in Tallinn Bay.

29. Baltic Sea Science Congress, Helsinki, August 24-28, 2003.
R.Randmeri and T.Soomere. Elements of numerically simulated wave climate in the Gulf of Riga.
T.Soomere. The balance of natural and anthropogenic waves in Tallinn Bay.
K.Rannat (co-author A.Lange). Sea-atmosphere interaction - water vapor tomography with GPS.

30. Joint Working Group FG Special Symposium on Atmospheric Remote Sensing using Satellite Navigation Systems. Matera, Italy, October 13-15, 2003.
K.Rannat (co-authors P.Miidla and A.Lange). Water vapour tomography for air-space surveillance.

31. Annual Meeting of the European Committee of the Global Ocean Observing System. EuroGOOS, Helsinki, 10 November, 2003.
T.Soomere. Natural and anthropogenic waves in Tallinn Bay and Gulf of Finland.

32. Final Workshop COST716. December 1-3, 2003, KNMI, De Bilt, The Netherlands.
K.Rannat (co-authors P.Miidla and A.Lange). Water vapour tomography for ultra-reliable tracking in air-space surveillance.

5.4 Tallinn Seminar on Mechanics

1. 3.03.2003: A.Salupere, (Institute of Cybernetics at TTU). Solitons in nonlinear dispersive media.

2. 31.03.2003: A.Kartushinski, (Estonian Energy Research Institute). Gas-solid particle flow in horizontal channel: the flow decomposition and particle collisions.

3. 25.04.2003: Gérard Maugin, (Universite Pierre et Marie Curie, Paris). Canonical Balance Laws in Solid Mechanics: Applications to Fracture and Material Growth.

4. 28.04.2003: P.Peterson, (Institute of Cybernetics at TTU). Extreme waves and non-approximate computation of their evolution.

5. 15.05.2003: A.Szekeres, (Budapest Technical University). Asymmetry in thermoelasticity: how to heal it?

6. 22.05.2003: D.Boularas, (Limoges University). Polynomial dynamic systems: their classification by the K.Sibirski's method.
Z.Navickas, (Kaunas University). Operator methods in differential equations: contemporary applications.
M.Rahula, (Tartu University). Universal jet-space structure: review of studies by Lie-Cartan, P.Olver, A.Vinogradov and others.

7. 3.06.2003: E.Schneider, (Fraunhofer Institute for Nondestructive Testing, Saarbrücken, Germany). Third order elastic constants - their use for ultrasonic quantitative stress analyzes and material state characterization.
A.Ravasoo, (Institute of Cybernetics at TTU). Acoustodiagnostics of two-parametric inhomogeneous predeformed state of solids.

8. 4.07.2003: K.Moffatt, (DAMPT, Cambridge). George Gabriel Stokes (1819-1903) and the dynamics of viscous fluids.

9. 17.09.2003: A.Chechkin, (Institute of Physics and Technology, Kharkiv). Stohastic systems driven by non-gaussian Levy noises.

10. 17.11.2003: T.Soomere, (Institute of Marine Systems at TTU). Exact solutions of kinetic equations in the weakly nonlinear wave theory.

11. 15.12.2003: H.Aben, (Institute of Cybernetics at TTU). 50 years studies of photoelasticity in Estonia.

5.5 Seminars outside the home Institute

1. Department of Mathematics, University of Turin, Italy, May 29, 2003.
   J.Engelbrecht. Waves in microstructured solids.

2. Institute of Mechanics, University of Duisburg - Essen, Germany, Oct. 23, 2002.
   J.Engelbrecht. Modelling of cardiac mechanics.

3. Budapest University of Technology, Hungary, Nov. 11, 2002.
   J.Engelbrecht. Cardiac contraction and cell energetics.

4. Workshop on Mathematical Aspects of the Dynamics of Phase Transitions, Febr. 8-15, 2003, Cambridge, UK
   A.Berezovski. Numerical simulation of moving phase boundaries in thermoelastic solids.
   A.Berezovski. A thermomechanical model of phase-transition front propagation.

5. European Science Foundation Programme NATEMIS, April 5-12, 2003, Torino, Italy
   A.Berezovski. On the thermodynamic conditions at moving phase-transition fronts in thermoelastic solids.

6. The Laboratory of Modelling in Mechanics at University Paris 6, May 11-20, 2003
   A.Berezovski. Recent progress in the numerical simulation of the thermoelastodynamics (phase-transition fronts propagation).

7. Seminar in LMM (Laboratoire de Modelisation an Mechanique), 31 Oct. 2003, University of Paris 6, Paris, France.
   A.Salupere. On soliton ensembles in KdV-like systems.

8. Seminar at IRCAM - Institute of Research and Coordination in Acoustics - Music, Paris, France, Dec. 7-11, 2003.
   A.Stulov. Experimental studies and mathematical models of piano hammer.

9. Seminar at TTU, Faculty of Civil Engineering. Tallinn, Jan. 27, 2003.
   J.Engelbrecht. On continuum mechanics and applications.

10. Estonian-Finnish seminar on underwater optics (Tallinn, Dec. 16-17, 2003).
    K.Rannat and T.Soomere (co-authors A.Erm and A.Kask) The impact of fast ship waves on the underwater light conditions.

5.6 Supportive grants (travel, etc.)

1. Isaac Newton Institute grant for participating the Workshop on Mathematical Aspects of the Dynamics of Phase Transitions, February 8-15, 2003, Cambridge - A.Berezovski
2. European Science Foundation Programme NATEMIS grant for research visit the Politechnico di Torino, Torino, Italy:
   April 5-12, 2003 - A.Berezovski;
   May 26 - June 1, 2003 - J.Engelbrecht.
3. French-Estonian science and technology collaboration program PARROT "Nonlinear Stress Waves in Complex Media" grant for research visit the Laboratory of Modelling in Mechanics at University Paris 6, Paris, France:
   May 12-20, 2003 - A.Berezovski;
   26 Oct. - 2 Nov., 2003 - A.Salupere.
4. Prof. G.A.Maugin (Max Planck Award for International Cooperation) grant for participating the EUROMECH Colloquium 445 Mechanics of Material Forces, May 21-24, 2003, Kaiserslautern, Germany - A.Berezovski
5. Organizing Committee grant for participating the 5th International Congress on Thermal Stresses and Related Topics, June 8-11, 2003, Blacksburg, VA, USA - A.Berezovski
6. European Science Foundation Programme NATEMIS grant for participating the 5th World Congress on Ultrasonics, September 6-11, 2003, Paris, France - J.Engelbrecht, A.Berezovski, A.Braunbrück.
7. European Science Foundation Grant through the NATEMIS programme for participation at the Tenth International Congress on Sound and Vibration, July 7-10, 2003, Stockholm, Sweden - A.Ravasoo.
8. Grant from Tallinn Technical University PhD Stud. Basic Funding for participation at the 5th EUROMECH Solid Mechanics Conference, August 17-22, 2003, Thessaloniki, Greece - A.Braunbrück.
9. European Science Foundation Grant through the NATEMIS programme for participation at the scientific session "Sensors", 5 March, Madrid. Spain - A.Ravasoo.
10. CIMO (Centre for International Mobility) Study and research at University of Oulu, 01 Feb. - March 31 - R.Ferenets.
11. Estonian Ministry of Education and Research, K.Jaak grant for doctoral study and research at Tampere University of Technology, 01 Sept. - Dec. 31 - R.Ferenets.
12. ERASMUS grant for post graduate study at Milano Politechnical University, 01 Feb. - July 31 - M.Bachmann/Parts.
13. Tallinn TU, Development Fund. Scholarship for academic education (Tallinn Port) - M.Bachmann-Parts.
14. Erasmus grant for postgraduate study at University of Patras, 03 Oct. - Dec. 31 - A.Rodina.

5.7 International cooperation

Within collaborative agreements:

Institute of Cybernetics:

- Laboratory for Mechanics of Materials of Helsinki University of Technology.
- Laboratory of Theoretical and Applied Mechanics of Helsinki University of Technology.
- Department of Mathematics of City University Hong Kong.
- HAS-TUB Research Group for Continuum Mechanics, Hungarian Academy of Sciences.
- Stevin Centre for Computational and Experimental Engineering Science, Eindhoven, University of Technology.
- Department of Mathematical Modelling, Technical University of Denmark.
- Department of Mathematics, University of Turin.
- Laboratoire de Modelisation en Mecanique, Universite Pierre at Marie Curie, Paris.
- Department of Mathematical Sciences, Loughborough University, England.
- Fraunhofer Institute for Nondestructive Testing, Saarbrücken, Germany.
- European Science Foundation Programme "Nonlinear Acoustic Techniques for Micro-Scale Damage Diagnostics" (NATEMIS).
- Research and Development Department, Instrumental acoustics laboratory, IRCAM, Paris, France.
- Biomedical Engineering Centre.
- MedNatNet - Master programs in the field of Medical Natural Sciences, European Network, Socrates program.

Marine Systems Institute:

- Dept. of Meteorology, Uppsala University: Analysis of the role of atmospheric boundary layer effects on wind wave field (S.S. Zilitinkevich).
- Finnish Marine Research Institute: Modelling of wind waves in the northern part of the Baltic Sea (K.Kahma, K.Myrberg).
- GKSS Geesthacht (H.Günther): Pre-operational modelling of wave regime in the Gulf of Finland.

5.8 Research programmes (national)

1. Estonian Programme on Mechanics.

2. Estonian Programme on Biomedical Engineering.

5.9 Teaching activities

1. A.Salupere – courses in TTU:
   - Dynamics
   - Statics
   - Continuum Mechanics
   - Seminars and Special Seminars for BSc, MSc and PhD students.

2. J.Engelbrecht - courses in TTU:
   - Mathematical modelling
   - Biomechanics

3. A.Berezovski - courses in TTU:
   - Special Seminar "Mechanics of Continuous Media" for MSc and PhD students.

4. J.Kalda - Training of the Estonian and Finnish teams for the 33rd International Physics Olympiad.

5. R.Kitt - courses in TTU:
   - Financial analysis
   - Open University course for book-keepers.

Lectures:

1. J.Engelbrecht. Nonlinear dynamics, Estonian Bank, Jan. 2003.

2. J.Kalda. Intermittent World. Theatre Academy, Tallinn, Sept. 2003.

3. J.Kalda. Physics of cardiac rhythms, Institute of Cybernetics, Sept. 2003.

4. J.Engelbrecht. Basic nonlinear dynamics, Gymnasium of Old Town, Tallinn, Dec. 2003.

Schools:

1. Autumn School of the Estonian Society of Physics, Oct. 2003, Kääriku, Estonia:
   J.Kalda. Intermittent diffusion.
   A.Salupere. Solitons.

2. Advanced Study School: Nonlinear Processes in Marine Sciences, Oct. 2003, Hageri, Estonia.
   J.Kalda: An introduction to stochastic diffusion.
   A.Salupere: Long-living patterns of KdV solitons.
   T.Soomere: Introduction to the kinetic theory of weakly nonlinear waves.
   T.Soomere: Fast ferries as a new key forcing component in the Baltic Sea.
   M.Kutser: Activities of CENS.

3. BEST School in Mechatronics, June 2003, Tallinn, Estonia.
   J.Engelbrecht: "Biomechanics".

5.10 Visiting fellows and students (longer periods)

1. Fabrizio Delledonne, Italy, BSc study, Sept. 01 - Dec. 31.
2. Diana Lisette Bonilla aGuilar, Columbia, Nov. 01 - Dec. 23., research on EEG processing during anesthesia.

5.11 Visiting scholars

1. Prof. Olaf von Ramm, Duke University, USA, Thomas Lord Professor and Director of the Center for Emerging Cardiovascular Technologies, 7 July.
2. Dr. Aapo Hyvärinen, Basic Research Unit of the Helsinki Institute for Information Technology. Extensions of Independent Component Analysis as Models of Natural Images and Visual Processing. Aapo Hyvärinen, 16 May.
3. Dr. Elzbieta Olejarczyk, Institut of Biocybernetics & Biomedical Engineering, Polish Academy of Sciences. Application of fractal dimensions analyses in EEG, 17 September.
4. Dr. Sanna Koskinen, and Jaana Sarajuuri, Käpyla rehabilitation Centre, Finland, Computerised tools for evaluation of cognitive ability FORAMEN, 12 December.
5. Dr. Andras Szekeres, Budapest Technical University, May 10-20.
6. Prof. G.A.Maugin, Universite Pierre et Marie Curie, Paris, April 23-26.
7. Dr. E.Schneider, Fraunhofer Institute for Nondestructive Testing, Saarbrücken, June 2-5.
8. Prof. K.Moffat, DAMTP, Cambridge, 4 July.
9. Prof. A.Checkin, Institute of Physics and Technology, Kharkov, September 15-19.

5.12 Theses

Institute of Cybernetics:

Promoted:

1. BSc:
   K.Enno. Longitudinal wave propagation in linear heterogeneous media,
   Tallinn, 2003, (supervisor A.Berezovski).
   M.Sepp. Influence of higher-order nonlinear effects on soliton formation,
   Tallinn, 2003, (supervisor A.Salupere).
2. MSc:
   L.Ilison. Soliton-type waves in granular materials,
   Tallinn, 2003, (supervisor A.Salupere).
   M.Lemba. Functional coupling between mitochondrical creatine kinase
   and adenine nucleotide translocase in cardiac shells,
   Tallinn, 2003, (supervisor M.Vendelin).

In progress:

1. PhD:

O.Ilison, L.Ilison	(supervisor A.Salupere);
A.Braunbrück	(supervisor A.Ravasoo);
M.Säkki, R.Kitt	(supervisor J.Kalda);
T.Ugam	(supervisor J.Engelbrecht);
J.Anton	(supervisor H.Aben).
M.Lemba	

2. MSc:

M.Sepp	(supervisor A.Salupere);
M.Berezovski	(supervisor A.Berezovski);
T.Peets	(supervisor J.Engelbrecht).

Tartu University:

Promoted: MSc: V.Retsnoi.

In progress:

1. PhD:

V.Retsnoi	(supervisor M.Rahula);
D.Tseluiko	(supervisor M.Rahula);

2. MSc:
   H.Lepp,
   R.Fortuna-Juks.

Marine Systems Institute:

In progress:

1. MSc:
   R.Randmeri: Wind wave statistics in the Gulf of Riga, 2004.

2. PhD:
   K.Rannat: Numerical modelling of the vertical structure of sea, 2004-2005.
   K.Kasemets: Analysis and modelling of surface waves in two-layer medium, 2005.

Centre of Biomedical Engineering:

Promoted:

1. PhD:
   I.Fridolin: Photon Propagation in Tissue and in Biological Fluids Applied for Vascular Imaging and Haemodialysis Monitoring, (supervisor Lars-Göran Lindberg. Linköping University).

2. MSc:
   Ü.Olli: Analysis of time series of ventricular repolarisation phase duration by the methods describing chaotic processes, (supervisor J.Lass).
   M.Bachmann-Parts. Investigation of the effect of the modulated microwaves on human EEG, (supervisor J.Lass).

5.13 Distinctions

1. Jüri Engelbrecht - Chevalier, Palmes Academiques (France).
2. Lauri Ilison - Estonian Academy of Sciences student award.
3. Anastassia Rodina - National student award.

5.14 Conferences and seminars organized

5.14.1:

1. 3rd Glass Summer School, Tallinn, June 11-13, 2003. An intensive three-day course containing lectures, equipment demonstrations, practical stress measurements and informal discussions. 7 participants (US, the Netherlands, France, Poland, Germany, Italy, UK).
2. Tallinn Seminar on Mechanics (over the year, see 5.4).
3. Seminars (over academic terms):
   - continuum mechanics;
   - thermodynamics;
   - solitons;
   - thermomechanics of moving phase boundaries.

5.14.2: Advanced Study School: Nonlinear Processes in Marine Sciences, Oct. 2003, Hageri, Estonia.

A rendezvous of marine sciences and nonlinearity

During the most colourful autumn season, an international advanced study school "Nonlinear Processes in Marine Sciences" was organized jointly by the Marine Systems Institute and Institute of Cybernetics in Hageri near Tallinn. Hageri (pop. about 400) is a small village of rich history today. The name apparently dates back to ancient times and has no explicit interpretation. The site was first mentioned in Liber Census Daniae (1241/1243) as "Hakriz" or "Haccriz". From that time, the place has been permanently habited and frequently mentioned in different chronicles. It is a heart of one of the oldest Christian parishes in Estonia. The local school counts its history since 1698.

The main objective of the school was to give a systematic survey on contemporary ideas and methods dealing with the most important nonlinear phenomena in marine sciences that will be presented by leading scientists in these fields. From a wide variety of issues of both theoretical and practical interest, the school concentrated on the wave mechanics and transport processes. An introduction to the state-of-the-art of geophysical turbulent boundary layers and Lagrangian transport in geophysical flows was presented. The courses were mostly designed for PhD students. The school also attached several young researchers and marine engineers who wished to get an overview of several key nonlinear processes in marine sciences and/or were specialised in different areas of marine and environmental sciences. The main organizer and the chairman of the Scientific Committee was the leader of the group of water waves Tarmo Soomere. Financially, the school was mostly supported from the budget of CENS. Total 27 MSc or PhD students take part in the full course of the school whereas 18 participants came from abroad. The school family was particularly international and consisted of citizens of twelve countries. All the countries surrounding the Baltic Sea (except Lithuania) were represented. The most remote guests were from China and from Novosibirsk in Siberia. The largest delegations (four participants) were from Russia and Latvia. The main courses were given by the leading experts from the United Kingdom, Italy, Germany and Sweden. The courses were mainly focused on two subjects where the role of nonlinear processes is substantial in the context of marine sciences. Different wave processes were considered by the 'grand old man' of the solitonic theory of internal waves Roger Grimshaw (Loughborough) and by one of the main authors of the surface wave model WAM Heinz Günther (Geesthacht). Another focus of the school was Langrangian transport in geophysical flows. An introduction to this topic was given by one of the founders of its contemporary theory Antonello Provenzale (Torino). Further analysis of the role and behaviour of active tracers in such a transport was presented by Annalisa Bracco (Trieste). Finally, Sergej Zilitinkevich (Uppsala) presented a brilliant introduction to the state-of-the-art of the theory of atmospheric boundary layers. Additionally to the main lecture courses, a number of supplementary presentations concerning intriguing and fast developing areas of nonlinear and marine sciences were presented. An exciting special lecture about the history and the structure of the Universe was given by academician Jaan Einasto. The coordinator of the Baltic Operational Oceanographic System Erik Buch (Copenhagen) gave on overview of recent developments in operational oceanography in the Baltic Sea basin. Introductions to the Baltic marine environment (J. Elken), soliton interactions and interaction solitons (P. Peterson), kinetic theory (T. Soomere) long-living patterns of Korteweg-de Vries solitons (A. Salupere), long surface waves (A. Kokorina), and the problems connected with heavy fast ferry traffic (T. Soomere) were given by leading experts in the listed areas. Additionally to the lecture courses, the participants visited several field study sites of the Marine Systems Institute near Paldiski where T. Kõuts explained basic concepts of a new methodology of monitoring of hydrotechnical works. A real adventure was a short excursion to Padise monastery and Haapsalu bishop castle. After a couple of hours sitting in a bus, a walk to an ancient stronghold near Padise was initially considered as very pleasant. After a while, several participants and professors started to suspect that they are already completely lost in the forest. But suddenly the group reached a small forest house where the landlady incidentally has cooked lunch for the whole company. After the excursion, the participants and professors, tired but happy, were in corpore present at the students' seminar that embraced twelve papers and lasted long after midnight. As mentioned above, Hageri is a small village with no nightlife. This shortage was compensated by presenting several intriguing problems to the participants. The participants were divided into small groups and each group was expected to find a solution to a selection of problems. The solutions were presented at the end of the school whereas several solutions were of interest also for the professors. In particular, unnumerous experiments were performed in order to gain some progress towards solving a very practical problem presented by Erik Buch and concerning a bier can that was lowered to the depth of 2,000 m in the Atlantic Ocean. At the farewell dinner somehow a common opinion arose that the shool(s) must go on.

6. Summary

The year 2003 was the first under the title Centre of Excellence. Additional funding has helped a lot to consolidate our doings. We have started Advanced Schools, and invited lectures, the staff, especially students had more possibilities to attend conferences and schools abroad.

The international activities are to be stressed. We start taking part in a 6th FP programme, several applications are pending. Through the Estonian Programme for Centres of Excellence we are looking towards an ERA - NET on Complexity, etc.

Several members of our International Advisory Board have visited Tallinn. Thanks belong to all the IAB for their advice and willingness to guide the research.

For the year 2004 we plan more active month in September when we would like to concentrate on Nonlinear Waves and Applications.

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