Institute of Cybernetics at Tallinn Technical University
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CENS

Centre for Nonlinear Studies
Estonian Centre of Excellence in Research

Annual Report

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Abstract

The Report includes a brief overview on all the activities of CENS 2002. The studies on (i) dynamics of microstructured materials and solitons including extreme waves, (ii) biomechanics and biophysics, (iii) fractality, (iv) nonlinear wave theory including acoustodiagnostics and phase transitions, (v) dynamics of piano hammers, (vi) optical nonlinearity and photoelasticity, (vii) water waves, (viii) biomedical engineering including nonlinear modelling, (xi) geometry and differential equations are all described. The Summary on the results of the Euromech Colloquium 436 is presented. The full lists of papers, reports, abstracts, conferences, lectures, etc are included.

In 2002, CENS has been awarded with the title "Estonian Centre of Excellence in Research" for 2002-2006.

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

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Lühikokkuvõte

Käesolev aruanne on ülevaade Mittelineaarsete Protsesside Analüüsi Keskuse (CENS) tegevusest 2002.a. Ülevaade haarab järgmisi uuringud: (i) lainelevi mikrostruktuursetes materjalides ja solitonid ning ekstremaalsed lained, (ii) biomehaanika ja biofüüsika, (iii) fraktaalsus, (iv) mittelineaarne lainelevi ning akustodiagnostika ja faasiüleminekud, (v) klaverihaamrite dünaamika, (vi) optiline mittelineaarsus ja fotoelastsus, (vii) lained vees, (viii) biomeditsiinitehnika ja signaalianalüüs, (ix) geomeetria ja diferentsiaalvõrrandid. Lühidalt on kirjeldatud ka Euromech'i kollokviumi 436 tulemusi. Esitatud on publikatsioonide, aruannete, konverentside, loengute jm nimekirjad.

Aastal 2002 omistati CENSile Eesti teaduse tippkeskuse nimetus (2002-2006).

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

1. Introduction

This Report is the fourth Annual Report of CENS following CENS 1999 - CENS 2001. The last Report included also the foresight programme of CENS. On that basis, CENS has applied for being included into the Estonian Programme for Centres of Excellence in Research.

In addition several groups of CENS have passed the official scientific evaluation on the regular basis. The marks given were ”excellent” (the highest mark) or ”excellent to good”.

We are extremely pleased that in November, 2002, the Ministry of Education (from January 1st, 2003 - the Ministry of Education and Research) has included CENS into the list of 10 centres (laboratories) in Estonia, called Centres of Excellence in Research for 2003 - 2006. This title involves additional funding but also responsibility. The ideas of the foresight programme should be followed (see CENS 2001).

Section 2 of this Report gives a brief overview on all the studies over 2002. The funding is described in Section 3 and Section 4 gives an overview on all the formal activities including the lists of publications, conferences, etc. Section 5 is a Summary and the Appendix is a description of CENS as it stands in the brochure of Estonian Centres of Excellence in Research.

2. Main results 2002

2.1 Institute of Cybernetics, Tallinn Technical University.

2.1.1 Dynamics of microstructured materials and solitons.

Solitary waves in microstructured solids.
The studies of wave propagation in microstuctured solids with different nonlinear properties are continued. Two Korteweg–de Vries type evolution equations with quartic and quadratic nonlinearity and both the third- and the fifth-order dispersion, FKdV and KdV435 respectively, are used as model equations. Such a dispersion corresponds to certain alloy-type materials, and is accompained directly with the quartic nonlinearity. In 2002 the main attention was paid to the long time behaviour of soliton ensembles in the case of normal dispersion (the third- and the fifth order dispersion parameters have opposite sign). Both model equations are integrated numerically by the pseudospectral method with respect to time variable under harmonic initial conditions and periodic boundary conditions. Numerical experiments were carried out in order to examine the recurrence and super-recurrence phenomena and the influence of the hidden solitons on the behaviour of the soliton ensemble. It is demonstrated that besides the visible solitons at least one hidden soliton can be detected in all studied cases. The discrete spectral analyses was applied for detection of recurrence and super-recurrence times. One can conclude that the weaker the dispersion the worse the recurrence like in the case of the KdV equation (A.Salupere, O.Ilison).

Solitary waves in granular materials.
Wave propagation in dilatant granular materials is modelled by a hierarchical Korteweg-de Vries type equation. The model equations are integrated numerically by the pseudospectral method with respect to time variable under harmonic initial conditions and periodic boundary conditions (see above) but the algorithm is more complicated because of the existence of mixed derivatives (i.e. hierarchy). Two main solution types and six subtypes are detected. In the case of the first type, a KdV type soliton train

(KdV ensemble) forms from the harmonic initial wave. In the case of the second type besides the KdV ensemble a train of nearly equal amplitude ensemble (EA ensemble) of solitary waves emerges. Both ensembles can be formed by positive as well as negative solitons. Furthermore, the EA ensemble can be suppressed or amplified. In some cases the EA ensemble even starts to dominate over the KdV ensemble. Corresponding subtypes are introduced. The character of the solution is found to be solitonic (emerging solitary waves restore their shape and speed after interaction) for all solution types and subtypes, i.e., a noteworthy phenomenon of simultaneous existence of two different structures having soliton-like behaviour is detected (A.Salupere, L.Ilison).

Wave hierarchies The studies of wave hierarchies are aimed to analyse deformation waves in microstructured solids. The main idea is to find mathematical models which are able to describe either only macrostructural behaviour or only microstructural behaviour or both, depending on the length scales of the microstructure and propagating waves. In mathematical terms such a wave motion is described by Whitham-type hierarchical evolution equations. Our earlier hypothesis was justified in case of soft tissues (Huxley-type models for cardiac muscles) and in case of materials where dissipation was important. However, if inertia of the microstructure is taken into account, then the concept of internal variables can not be used any more. Such a case, for example, is the Mindlin-type microstructured material. Starting from a basic Mindlin model, the governing equation of motion is derived. It shows explicity: (i) the wave hierarchy; (ii) the dependence of the wave-speed on the properties of the microstructure; (iii) the role of the dispersion. Characteristically, the double-dispersion appears, partly influenced by material properties, partly by inertia. The corresponding evolution equation is analysed and the role of nonlinearity is explained (J.Engelbrecht, F.Pastrone).

Based on earlier modelling, the hierarchical dissipative effects are analysed by numerical simulation (T.Sillat, J.Engelbrecht).

Extreme Waves

The aim of this research is to search/provide mathematical tools that will facilitate deterministic generation of "extreme waves"(a phenomenon where from a relatively calm wave field occasionally relatively large but non-breaking waves occur) in hydrodynamic laboratories. The following results were obtained.
(i) A model of two long waves traveling at slightly different directions, (the Kadomtsev-Petviashvili model), was considered to find the critical angle at which maximum wave height occurs due to nonlinear oblique interaction of waves.
(ii) An efficient numerical code was developed for evaluating Riemann theta functions and their derivatives that are relevant in study of cnoidal wave solutions. The relation between the Ursell number and the nonlinearity parameter of Riemann theta functions was demonstrated.
(iii) Envelope models of waves, linear model with exact dispersion and the nonlinear Schrödinger (NLS) model, were considered. For the former model, various summation methods for pseudo-differential operators was studied. The NLS phase-amplitude equations of type I (defining plane-wave solution, one-soliton solution, cnoidal wave solution) and of type II (defining soliton on finite background (SFB) solution) and the corresponding solutions were analyzed to search the possiblity of extreme wave occurances in the given wave models. In particular, the maximum wave amplification factor (3 times with respect to initial amplitudes of waves) from the nonlinear extension of

Benjamin-Feir instability, the NLS SFB solutuions, was found. The wave dislocation phenomena was reported for water waves. It was found to be a very important transition phenomena of local wave field during the process of extreme wave occurances and disappearances as well as for explaining phase singularity phenomena in the solutions of the NLS phase-amplitude model.
(iv) A model for exact (assuming only potential flow) evolution of surface waves was derived for finite (with constant and variable) depth fluid domain using conformal mapping technique. A very efficient and highly stable numerical code for the corresponding initial value problem was implemented, various numerical algorithms were tested for optimal performance and accuracy of calculations. As an example result, the resulting numerical scheme remains stable for very long runs: e.g. relative fluctuations in total energy stay typically of order 10^{-7} during 3000 wave periods (that is about 2 hours in laboratory time).

This research has been carried out in cooperation with E. van Groesen and Natanael Karjanto (both from Department of Applied Mathematics, University of Twente) within STW-project "Extreme Waves" .

Software development
A program "F2PY – Fortran to Python Interface Generator" (http://cens.ioc.ee/projects/f2py2e/) has been developed. The purpose of F2PY is to generate interface between (computationally highly efficient) Fortran routines and (a very high level and flexible) Python language (http://www.python.org/). As a result, F2PY has become an integral part of an open source library SciPy (http://www.scipy.org/) for scientific computing (P.Peterson).

2.1.2 Biomechanics and biophysics

Intracellular energy fluxes.
Recent studies have revealed structural and functional interactions between mitochondria, myofibrils and sarcoplasmic reticulum in cardiac muscle cells. We have shown earlier that such functional interactions can be reproduced by mathematical model only if diffusion of adenosine phosphates is limited within the cardiac muscle cells, in addition to the restrictions posed by mitochondrial outer membrane. The aim of our work this year was to compare two possible mechanisms by which functional coupling between Ca,MgATPases and mitochondria could be formed in cardiac skinned fibers. These mechanisms are (a) the uniform diffusion restriction and (b) the localization of diffusion limitations close to mitochondria. The reaction-diffusion model of compartmentalized energy transfer was used to analyze the following data: mitochondrial respiration rate dependency on exogenous ADP and ATP concentrations; inhibition of the respiration by pyruvate kinase (PK) and phosphoenolpyruvate (PEP) system; oxygen consumption stabilization after addition of 2mM MgATP or MgADP; ATPase activity with inhibited mitochondrial respiration; and MgADP concentration buildup in the solution after addition of MgATP. The analysis revealed that only the second mechanism considered — localization of diffusion restrictions — is able to account for the experimental data. In case of uniform diffusion restrictions, the model solution was in agreement with two measurements: the respiration rate as a function of ADP or ATP and the PK+PEP inhibition of the respiration. From our results, we conclude that intracellular diffusion restrictions are not distributed uniformly, but are localized in certain areas (M.Vendelin, M.Lemba).

Mechanical contraction of the heart muscle.
This year we investigated the relation between regional external mechanical work W and ATP consumption V_{ATP} in the left ventricle (LV). An axisymmetric finite element model of LV mechanics was used with active contractile properties of the cardiac muscle described by a Huxley-type cross-bridge model. The model reproduces the following experimentally observed findings: (a) the relationship between V_{ATP} and regional stress strain area is linear; (b) V_{ATP} levels in different parts of the LV wall are fairly evenly affected by changes in the workload. Under physiological conditions, regional $W - V_{ATP}$ relationship is approximated by a linear function with a correlation coefficient $r > 0.95$. The slope and the intercept of the $W - V_{ATP}$ relationship both depend on preload, afterload, and mechanical activation sequence of the LV. Since the slope was smaller than one in all performed simulations, the results suggest that the absolute differences in regional W are smaller than the absolute differences in regional V_{ATP} in the LV wall. From our results and the experimental data published earlier, we conclude that (a) distribution of regional W is not considerably affected by changes in the workload; (b) high-W regions in the LV wall are more susceptible to undergo necrosis during ischemia than low-W regions (M.Vendelin).

Mathematical modelling of intracellular energy fluxes
An integrated computer model for energy metabolism of the muscle cell was developed, focussing on how the energy transfer process regulates ATP synthesis in the mitochondria. Using the model, we designed experiments to resolve the long-debated issue: how high is the affinity of the respiration of heart mitochondria in situ to ADP? Experiments on skinned muscle fibres were performed by our collaborators at Free University Amsterdam and then analysed with our computer model, supporting the "high affinity hypothesis" and showing substantial diffusion gradients as the cause of previous misinterpretations. We have further successfully simulated the experimentally measured activation time of oxidative phosphorylation during quick transitions in ATP hydrolysis and its dependence on the level of creatine kinase (CK) activity. The results demonstrate the unique role of the particular CK isoenzymes: the cytosolic CK slows down the activation signal by effectively buffering it whereas the mitochondrial CK controls the rate of the phosphocreatine shuttle; the activation time is determined by a nontrivial interplay between these two counteracting factors. Based on the modeling, we have designed experiments that should allow, for the first time, to determine the flux through the phosphocreatine shuttle in the heart (O.Kongas).

2.1.3 Fractality

Statistical topography
For random Gaussian surfaces with negative Hurst exponent $H < 0$, the coastlines of oceanic islands have been mapped to the percolation clusters of (correlated) percolation problem. In the case of rough self-affine surfaces ($H > 0$), the fractal dimension of oceanic islands is calculated numerically as a function of the roughness exponent H (using a novel technique of minimizing finite-size effects). For $H = 0$, the result $d = 1.896...$ coincides with the analytic value for percolation problem (91/48), suggesting a super-universality for the correlated percolation problem. We have analyzed (analytically and numerically) the relationships between various scaling exponents of

statistical topography, both for real geological landscapes and for Gaussian surfaces. In the latter case, all the exponents are certain functions of the Hurst exponent H. However, we have shown that real geological landscapes are non-Gaussian, so that all the exponents are independent quantities measuring different aspects of the long-range order (J.Kalda).

Turbulent diffusion
We show that when an initially compact spot of a passive scalar (pollution) is spread by a high Peclet' number turbulent flow, the size-distribution of pollution spots follows a scale-dependent Zipf's law. More specifically, the differential scaling exponent is a decreasing (logarithmic) function of the diameter of the spot. Our model assumes a two-dimensional mono-scale flow (i.e. fine-scale velocity fluctuations are negligible). However, the qualitative predictions are expected to be more generic, applicable to three-dimensional turbulent flows (J.Kalda).

Econophysics
We have clarified the role of the Hurst exponent in describing financial markets. Hurst exponents have been found for time series of Baltic and international stock exchange indices using the longest available period, from the beginning of the Baltic markets in 1996, up to August 2002. The Hurst exponents found varied from market to market. While the markets with similar Hurst exponent did not have a considerable correlation, they did have similarities in economic situation. Therefore, the scaling analysis allows us to reveal hidden similarities between the markets (R.Kitt).

Heart rate variability
We have extended our previous studies of the distribution of low variability periods in the activity of human heart rate. While the distribution function follows typically a multi-scaling Zipf's law, in certain cases stretched exponentials provide a better fit. However, the correlation between the scaling type (Zipf's law or stretched exponential) and diagnosis is less significant than certain integral measures of the distribution function (J.Kalda, M.Säkki).

2.1.4 Nonlinear wave theory

Acoustodiagnostics of inhomogeneous and prestressed solids.
Theoretical investigation of simultaneous nonlinear propagation, reflection and interaction of two longitudinal waves in inhomogeneous materials has been carried out with the view to elaborate the algorithms for acoustodiagnostics of the parameters of materials and its states. Two cases have been considered: (i) the nonlinear elastic material with weakly inhomogeneous physical properties and (ii) the nonlinear elastic material undergoing inhomogeneous predeformation.

In both cases the acoustodiagnostics algorithms have been constructed on the basis of boundary measurement data. The nonlinear boundary oscillation caused by simultaneous propagation of two longitudinal waves in the material is sensitive to the physical properties of the material, to the spatial variation of these properties and to the parameters of the predeformed state. Essential is the fact that nonlinear interaction of waves amplifies the boundary oscillation amplitude and this enhances the possibilities of acoustodiagnostics in comparison with the through transmission technique.

In the first case, two model problems have been solved. First, the nonlinear elastic material is homogeneous. The rough values of material properties are known and it is necessary to determine the real values of these properties. In the second problem, there is a preliminary information that the properties of the material have a linear variation in space from the known basic values. The aim is to evaluate this variation.

The model problems have been solved resorting to the plots harmonic wave characteristics versus material properties composed on the basis of the analytical solution. Analises of these plots clears up the influence of material properties to the harmonic wave characteristics - the amplitudes and phase shifts of harmonics. Different dependence of various wave characteristics on material properties enables to propose the algorithms of acoustodiagnostics for both model problems.

In the second case, the modulation depth method for nonlinear acoustodiagnostics of two-parametric predeformed state of the nonlinear elastic material (structural element) has been elaborated. As a model problem the material undergoing predeformed state that corresponds to pure bending with tension or compression has been considered. The effect of modulation of the nonlinear boundary oscillation profile caused by the nonlinear interaction of the two- parametric predeformed state and the simultaneous propagation of two harmonic waves in the material has been investigated in detail. The dependence of the depth of modulation on the values of the predeformed state parameters has been clarified. The plots predeformed state parameters versus modulation depth values have been composed. The quantitative acoustodiagnostics problem has been solved resorting to these plots at two fixed time instants in the wave interaction interval where the amplification of the amplitude of nonlinear boundary oscillation occurs (A.Ravasoo, A.Braunbrück).

Thermodynamic model for phase-transition front propagation.
The propagation of waves and phase-transition fronts in thermoelastic solids is governed by the same field equations and equations of state (at least in the integral formulation). In linear thermoelastic media these equations can be reduced to the classical hyperbolic wave equation and to the parabolic heat equation. Problems arise in the propagation of themoelastic waves and fronts in inhomogeneous media. From a practical point of view, these problems are reduced to the construction of relevant numerical algorithms. Possible rapid variations in the properties of considered materials and the simultaneous presence of compression and shear waves require at least a second-order accuracy of the algorithms. Among successful methods with high accuracy and efficiency are the finite-volume schemes. Finite-volume numerical methods are based on the integration of governing equations over a control volume, which includes a grid element and a time step. This means that the resulting numerical scheme is expressed in terms of averaged field variables and averaged fluxes at boundaries of the grid elements. The equations of state determining the properties of a medium are also assumed to be valid for the averaged quantities. In fact, this is an assumption of the local equilibrium inside the grid element, where the local equilibrium state is determined by the averaged values of field variables. To obtain a high-order accuracy, the step-wise distribution of the field variables is changed to a piece-wise linear (or even nonlinear) distribution over the grid. Such a reconstruction leads to a better approximation from the mathematical point of view and provides a high-order accuracy together with a certain procedure for suppressing spurious oscillations during computation. However, from the thermodynamic point of view, the reconstruction destroys the local equilibrium inside grid cells. This

means that the equations of state are not valid in this case and even the meaning of thermodynamic variables (e.g. temperature and entropy) is questionable. A solution of this problem is obtained by means of the description of the non-equilibrium states inside the grid elements in the framework of the thermodynamics of discrete systems. Non-equilibrium thermodynamic conditions at the phase boundary are proposed to describe the propagation of phase-transition fronts in crystalline solids. A thermodynamically consistent form for the finite volume numerical method for thermoelastic wave and front propagation is developed. Such a reformulation provides the applicability of the Godunov type numerical schemes based on averages of field variables to the description of non-equilibrium situations. The non-equilibrium description is fulfilled by using contact quantities instead of numerical fluxes. The contact quantities satisfy the thermodynamic consistency conditions, which generalize the classical equilibrium conditions (A.Berezovski).

Piano hammers - theoretical and experimental studies
Based upon the large number of experimental data obtained using a special piano hammer testing device that was developed and built in the Institute of Cybernetics at TTU, it has been shown, that all the present-day piano hammers have as a quality the hysteretic type of the force-compression characteristics. Such a hysteretic character is a result of a century of evolution and not a chance of uncommon hammers. It has been shown that dynamical behaviour of the piano hammer can be described by different mathematical hysteretic models. The first nonlinear hysteretic model of the piano hammer is the fourth-parametric model. It is in a good agreement with experimental data, and it was developed and described in 1995. This model is based on an assumption that the hammer felt made of wool is a microstructural material possessing history-dependent properties. The second new hysteretic model is a three-parametric model. It is very similar to nonlinear Voigt model and permits a description of the dynamical hammer felt compression that is consistent with experiments as well. The both models are equivalent for the slow loading of the hammer. For the fast loading, these models give the different description of the hammer behaviour. However, this difference can be observed only for the extremely high hammer velocity that is never be in practice. Therefore, the both models can be used for simulation of the piano hammer-string interaction. Though, the first model is more physical and reasonable by nature, the second model is more simple, and valid for investigation of the hammer-string interaction for any practical values of hammer velocity as well. The results obtained will be applied to the numerical simulation of the grand piano string vibration and their spectra calculation. These results will be useful for piano stringing-scale design and for the purpose of the technological process of the hammer manufacturing improvement. This project gives the opportunity to get better the quality of the grand pianos produced by Tallinn Piano Factory (A.Stulov).

2.1.5 Optical nonlinearity and photoelasticity

Methods of the stress field tomography
A new discrete algorithm for the measurement of axisymmetric stress fields has been elaborated, which is valid in the case of weak birefringence. To avoid application of the oblique incidence method, in addition to the photoelastic measurement data the equilibrium equation and the compatibility equation (if stresses are due to external loads) or the generalized sum rule (in case of residual stress measurement in glass)

were used. The method is a generalization of the classical onion-peeling method for the case when axial stress gradient is present. In case of complicated stress fields (e.g., near welds in glass articles) the new method gives more reliable results than the polynomial approximation.

Methods of interpreting the integrated interference fringes in tempered glass articles have been developed for more complicated stress distributions. Until now the main attention has been devoted to stress distributions, which are about symmetrical in the wall of the article. In this case one can easily distinguish the zero-order fringe and location of the fringe of maximum order. In case of asymmetrical stress distribution the fringe order is often maximum at the internal surface of the object. Numbering of the interference fringes in this case is much more complicated. Using a mathematical model of the polariscope, a method of numbering the interference fringes in case of asymmetrical stress distributions has been elaborated. The method is based on the application of the K-operator (a product of the first and second derivative of the light intensity) (L.Ainola, H.Aben).

2.2 Tartu University

Geometric approach to nonlinear problems

It is shown objects of connection and curvature in the bundle as operators of type Monge-Ampère arise based on Lychagin theory. Appears that Cartan's forms in infinite jet space, that are Lie derivatives, are φ-connected with corresponding operators in the Spencer schema. In this way the problem of integration arives in the structure of an infinite jet space.

By developing theory of connection in the bundle it is shown how, in general case, the morphism of bundles with connections can be developed to automorphism of one bundle and so to movements in the different spaces. Thus, classical notations, such as Lie derivatives of connections and Killins's vector field in Riemann space, obtain a more general interpretation.

Veronese map $R^2 \rightarrow R^3$ transforms central quadrics on the cone (a known case) and linear vector field from plane R^2 to the spaceR^3 (a new case) is studied. If we interpret square forms as elements of co-space R^3 then the action of the linear vector field is transported automatically to the square forms. Thus we are dealing with representations of the linear groups, while linear vector fields are operators of the linear group GL(2,R). Situation can be transformed to polynomials by continuing linear vector fields to the infinite jets. Then the so-called infinitesimal version of the theory of algebraic invariants can be obtained (M.Rahula).

A generalization of the classical exterior calculus such that corresponding exterior differential satisfies the relation $d^N = 0$, where $N > 2$ is studied. Our approach is based on a notion of a graded q-differential algebra. It is shown that an algebra of differential forms with exterior differential satisfying $d^3 = 0$ can be constructed on a one-dimensional space only in the case when a space has a braided line structure. The generalized cohomologies associated with the mentioned above complex of differential forms is also analysed (V.Abramov).

2.3 Marine Systems Institute at Tallinn Technical University

Water Waves

It is 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 ocean, e.g. when all layers have equal depth. The flux of energy radiated in the form of internal gravity waves from a turbulent boundary layer is known to be proportional to the cubed Brunt-Väisälä frequency in the free flow N_0^3. The flux of the density variance (and consequently, the buoyancy variance) is shown to be proportional to N_0^5 . Thus, in strong stratification the effect of wave radiation on the boundary-layer turbulence could manifest itself much stronger through the budget of the buoyancy variance. Interaction of two long-crested shallow water waves is analysed in the framework of two-soliton solution of the Kadomtsev-Petviashvili equation. 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. 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).

Wind wave regime in the Tallinn Bay has been analysed with the use of a nested WAM model. Various statistical properties of the wave fields (annual mean wave heights, wave energy density, energy flux density) demonstrate that numerous banks and shallow areas at the entrances of the bay effectively shelter the bay from waves coming from the dominating wind directions. The properties of wave field vary significantly in different areas of the bay. The highest waves occur in the vicinity of the Tallinn-Helsinki ship lane where significant wave height exceeds 2 m at least once a year and may reach 4 m in extreme NNW storms. High-speed ship traffic in the Tallinn Bay amounts up to 70 traverse per day. In the coastal zone of the bay the mean energy of ship waves is 7-10% from the bulk wave energy and wave-induced power (energy flux) as high as 40% from the bulk wave power. The highest component of ship wake with the heights about 1 m has frequently periods 10-15 s and causes unusually high near-bottom velocities at the depths of 5-20 m. The wake of fast ferries is a new forcing component of vital impact on the local ecosystem that may cause considerable intensification of beach processes and have significant influence on the aquatic wildlife. Redistribution of fine sediment material in the Gulf of Riga, Baltic Sea, is investigated by Lagrangian particle transport model. A wave model was used to assure reasonable conditions for particle resuspension. Numerical experiments with uniform initial distribution of sediments reveal central deep accumulation area, northern trapping zone at the coastal shallows and dynamical import/export balance near the southern large rivers. The parameters of an exponential model for describing the absorption spectra a_{COM} of coloured dissolved organic matter in lakes with diverse water quality were determined. Attempts to describe the the spectra in the region of 350-700 nm by means of hyperexponential functions $exp(-\alpha \lambda^\eta)$ show that frequently the best fit corresponds to $\eta < 1$ whereas in the case of the traditional exponential approximation $\eta = 1$ (T.Soomere).

2.4 Biomedical Engineering Centre, Tallinn Technical University

2.4.1 Nonlinear dynamics of phrenic activity during maturation

Sudden Infant Death Syndrome (SIDS) is a major cause of death in newborns. Behind this syndrome is the disability of the infant to keep on breathing due to, most probably, hypoxia of the respiratory center in the brainstem. The well-being and the properties of the respiratory center can be evaluated by measuring the neurogram of the phrenic nerve - the main output of the respiratory center stimulating the diaphragm muscles. Changes in the phrenic neurogram during deepening hypoxia follow well-defined pattern. Firstly, the amplitude of the signal decreases until its total disappearance. After a period of relative silence in neurogram, gasping activity appears. It is suggested that failure to gasp in hypoxic conditions is crucial in SIDS. Compared to normal, eupnic activity, gasps are of higher amplitude and the onset of the activity is much sharper. The neural circuit responsible for gasping is still unclear. During a research project carried out at Dartmouth College (NH, USA), the dynamical properties of phrenic neurogram in eupnea and during gasping were compared in piglets of four age groups (ranging from 3 to 35 days). Due to its applicability to short data segments, the main parameter used for comparison was approximate entropy. It was found that the activity and therefore also the neural generator of gasping was of considerable lower complexity compared to that of eupnic neurogram. This suggests that hypoxia has strong impact on the neural circuits generating phrenic activity, probably decreasing the firing rate of these neurons (T.Lipping, M.Akay).

2.4.2 Bispectral analysis of EEG

During recent years bispectral analysis has been intensively used in EEG processing during anesthesia. Bispectral index, for example, is widely used in commercial anesthesia monitors today. Our aim was to evaluate the capability of bispectral analysis to detect the changes in the EEG signal caused by microwave stimulation. An extensive databank has been collected (over 100 recordings) containing spontaneous EEG alternating with segments of microwave stimulation. The analysis of the recordings is still in progress (J.Lass, M.Parts, T.Lipping, H.Hinrikus).

2.4.3 Nonlinear models in speech coding

Human speech is probably the most intensively analysed physiological signal. The most widely used methods for speech modeling today use Linear Predictive Coding (LPC) as the basic building block. This algorithm models speech as white noise passed through a linear filter. However, several studies have shown that speech signal is generally not linear. This is emphasized by the fact that after LPC, a residual signal, containing significant amount of information, remains. In Pori University Unit, Tampere University of Technology, research was carried out to evaluate the suitability of several nonlinear models for speech coding. The applied models contained Block Oriented Model (BOM) and Hammerstein model, both consisting of linear and nonlinear substructures. In BOM, the nonlinear substructure is in the feedback path to extract the nonlinear component of the residual signal and to subtract it from the input signal. In case of the Hammerstein model, the linear and nonlinear substructures are cascaded. The task of the nonlinearity here is to transform the nonlinear speech signal into a linearly describable one. Our studies showed that both applied models have certain advantages over the LPC method. For example, the residual of the Hammerstein model was shown to contain less information according to Akaike Information Criterion comapred to the residual of the LPC (T.Lipping, J.Turunen, P.Loula, J.Tanttu).

2.4.4. Estimating blood pressure from pulse wave transit time

The pulse wave transit time has been shown to be a useful parameter to estimate cardiovascular instability. In our work, a method was developed for estimating the variation of blood pressure using pulse wave transit time, namely the delay between the heart electrical signal and moment of reaching of pulse wave to a selected peripheral site. Our method is based on presumption that there is a singular relationship between the pulse wave delay and the variation of blood pressure in artery for a given person. The impact of the pre-ejection period and instability of the vessels' parameters on the accuracy of the estimation of the arterial blood pressure using the time delay between heart electrical signal and pulse wave arrival to a selected peripheral site was analysed. The physiological signals (such as ECG, fingertip photoplethysmograph (PPG), and invasive arterial blood pressure (IBP) as a reference signal) from Physionet Mimic database were used in this study. The group of patients consisted of 16 subjects with different diagnosis. The signals were recorded in intensive care during a long period (24-62h).An algorithm for calculation of the arterial blood pressure and characteristic parameters of the blood vessels as calibration constants of these equations were proposed. The pulse delay was detected between R-peaks and leading edge of the PPG beat. The averaged mean relative uncertainty of mean arterial blood pressure was calculated between invasive and reconstructed data and it turned to be 11.47% 9.10. The results of this study demonstrate that blood pressure calculated from the pulse wave delay can be used for long-term non-invasive arterial blood pressure monitoring purposes (H.Hinrikus, J.Lass).

2.5. Overview on Euromech 436

The EUROMECH Colloquium 436 "Nonlinear Waves in Microstructured Solids "was organized by the Institute of Cybernetics at Tallinn Technical University in Tallinn, 29 May - 1 June, 2002. The colloquium was the second in the series, the previous one (the Euromech Colloquium 348 "Nonlinear Dynamics of Heterogeneous and Microstructured Solids") was held in 1996, also in Tallinn.

This Colloquium was somewhat smaller in its audience than the 1996 colloquium. Altogether 24 contributions were presented before the participants from 8 countries. Actually the talks reflected many of the studies made within several co-operative programmes such as a NATO grant "Thermomechanics of progress and stability of phase interphases (crystals, alloys)", and two INTAS programmes on "The synergetic approach to the analysis of advanced materials - nonlinear wave dynamics of structurally sensitive media" and "The multi-level-physics approach to nonlinear localized strain waves in solids." In addition, close to these studies is the running ESF Programme NATEMIS on "Nonlinear acoustic techniques for microscale damage diagnostics." A special workshop was hold to discuss the recent results of that Programme.

As stated in calls for participation, the colloquium was planned to cover the physically motivated modelling of wave propagation in structured solid materials with a special attention to nonlinear effects related to or interacting with the microstructure. Both theoretical and experimental studies were planned to be discussed including also numerical techniques.

Altogether 6 scientific sessions were held along with 2 discussions, one on experimental techniques (related to NATEMIS) and the other on the general outcome of the colloquium. The sessions started with an Introductory lecture (J.Engelbrecht) explaining the aims to get a better understanding of physical phenomena which affect the wave propagation in microstructured solids and find out effective methods for analysing these phenomena. The general ideas of nonlinear wave mechanics in complex materials were presented (G.A.Maugin), focusing on the relationships between dynamical localized concentrations of continuous fields and the notion of quasi-particles. The complexity of rough surfaces was explained by using scaling exponents describing the geometrical properties (J.Kalda). The importance of heat and moisture transfer in solids was stressed (A.Szekeres) where coupling leads to nonlinear effects.

The surface waves in coated structures have been analysed. The shear solitons were described (A.Kovalev et al) observed also in experiments (A.Mayer et al). The corresponding evolution equations may involve nonlocal nonlinearity (terms containing a Hilbert transform). Such solitons become more and more important due to wide applications. A possibility to describe bi-layered materials by a lattice model leads to coupled equations of Klein-Gordon type (K.Khusnudtinova). The lattice model was also used in order to explain discrete multi-breather dynamics (M.Bogdan) and the slowness diagram of 2D lattices (M.Braun).

The multisoliton complex dynamics requires the solution of a nonlinear eigenvalue problem (M.Bogdan et al). On the other hand, in many practical cases exact solutions can be found only if certain differential constraints are effective (D.Fusco). If modelling is based on stepwise construction of balance laws then several mathematical models can be constructed. Waves in granular media with particle rotation were described (A.Potapov et al), in solids with vectorial microstructure (F.Pastrone) and in solids with dissipative microstructure (T.Sillat et al). Motivated by experimentally observed strong nonlinearities in a microstructure, a corresponding mathematical model was presented (J.Engelbrecht et al), where also the basic structure of the Mindlin model was explained. The various numerical results have been described using a general evolution equation (A.Porubov et al), an evolution equation with quartic nonlinearity and higher order dispersion (O.Ilison et al), a hierarchical KdV-equation (L.Ilison et al). Periodically forced solitonic structures were found (A.Salupere et al). The pseudospectral method has been used in most of these calculations.

Last but not least, the attention was turned to experimental results and their interpretation. A review of nonlinear spectroscopy techniques for microdamaged material was presented (K.Van Den Abeele). These studies are a part of NATEMIS programme, another part was described on the basis of a simplified cell approach (M.Scaleranti). It was accompanied by numerical studies of waves and fronts in structured materials (a thermodynamic approach) compared with experiments (A.Berezovski et al). It has been shown how nonlinear acoustic waves interact with material inhomogeneities (A.Braunbrück et al). Finally, it was demonstrated experimentally and theoretically that bulk solitary waves exist in plexiglas (A.Samsonov et al).

The discussion brought up the goal for the studies in the nearest future. There exists an excellent theoretical basis of continuum mechanics and there exist excellent experimental facilities. In addition, the analysis of model equations has been developing fast. The future aim is to bring all these communities together in order create a synergetic effect explaining the physical phenomena like dispersion, dissipation, existence of solitary waves, etc. based on experimentally measured material characteristics. Only such a combination of knowledge gives rise to applications of complex materials under dynamical influences.

3. Funding

3.1 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 block grant: "Dynamics of turbulent processes and nonlinear waves". Supervisor: T.Soomere.

3.2 Estonian grants (Estonian Science Foundation):

1. J.Engelbrecht, grant No 4704, "In silico studies of heart ischemia".
2. H.Aben, grant No 4972, "Nonlinear integrated photo-elasticity", 2001-2004.
3. A.Berezovski, grant No 4504, "Propagation of phase-transition fronts in solids".
4. A.Stulov, grant No 4708, "Investigation of piano hammers", 2001-2002.
5. A.Ravasoo, grant No 4706, "Inverse problems for description of properties and states of inhomogeneous materials".
6. A.Salupere, grant No 4068, "Interaction of solitary waves".
7. J.Kalda, grant No 4151, "Scale-invariance and intermittence in heart rate variability", 2000-2002.
8. J.Kalda, grant No 5036, "Statistical topography for dynamical dissipative systems at self-organized criticality", 2002-2004.
9. T.Soomere, grant No 4025, "Analysis and modelling of surface wave anomalies of the Baltic Sea", 2000-2003.
10. T.Lipping, grant No 5143, "Mechanisms of Biological Effects of Electromagnetic Fields".
11. T.Lipping, grant No 4272, "Algorithms for discrimination of life-threatening heart arrhythmia".
12. T.Lipping, grant No 4871, "Signal Processing Methods for the Detection of Changes in the EEG Signal Caused by Weak Stressors".

3.3 International grants

1. O.Kongas. EC Marie Curie Postdoctoral Fellowship. "Building Working Muscle Cells in the Computer: Biocomplexity and Metabolism" at Free University of Amsterdam.
2. A.Braunbrück. European Science Foundation Grant through the NATEMIS programme for one month research work in the Fraunhofer Institute for Nondestructive Testing, Saarbrücken, Germany, February 2002.

3. M.Vendelin: Marie Curie Fellowship, HPMF-CT-2002-01914

4. A.Salupere. Cambridge Colleges Hospitality Scheme for Central and Eastern Europe Sholars — one month in DAMTP and Magdalene College.

3.4 Contracts

1. Emhart Glass Research Inc. (USA) - contract for manufacturing and application of automatic polariscope AP-04 SM together with original sophisticated software; responsible scientist H.Aben.

2. Estonian Centre of Environmental Investments: contract "The destructive influence of ship wake wash on the beaches of the Tallinn Bay and Naissaar and Aegna Islands, and the possibilities of its neutralizing", 2001-2002; responsible scientist T. Soomere.

3. T.Soomere. Tallinn Harbour: contract for hydrodynamical monitoring of the Muuga Bay (2002); the working group was responsible for analysis of wind and wave regime in the Gulf of Finland.

3.5 International projects

1. H.Hinrikus. "Dynamic Adaptive Modelling of the Human Body (DYNAMO)" project, Ragnar Granit Institute, Tampere University of Technology.

2. A.Ravasoo. "Nonlinear Acoustic Techniques for Micro-Scale Damage Diagnostics (NATEMIS)". An European Science Foundation scientific programme.

3. T.Soomere. EU contract PAPA: "Programme for a BAltic network to assess and upgrade an oPerational observing and forecAsting System in the region"; the working group is responsible for Capacity Building work package; contributor to Modelling workpackage, 2002-2004.

3.6 Additional funding

1. Tallinn Technical University – excellence grant.

4. Publicity of Results

4.1.1 Research Reports

1.	Mech 240/02	L.Ilison, A.Salupere. Solitons in hierarchical Korteweg-de Vries systems.
2.	Mech 241/02	O.Ilison, A.Salupere. Solitons in media with higher order dispersion.
3.	Mech 242/02	A.Stulov. Experimental and computational studies of the piano hammer I: Piano hammer testing device.
4.	Mech 243/02	A.Stulov. Experimental and computational studies of the piano hammer II:. Experimental testing and numerical determination of the piano hammer parameters.
5.	Mech 244/02	A.Stulov. Nonlinear hysteretic models of piano hammer.
6.	Mech 245/02	A.Berezovski, J.Engelbrecht, G.A.Maugin. Thermodynamics of discrete systems and thermoelastic wave and front propagation.
7.	Mech 246/02	A.Ravasoo. Nonlinear interaction of ultrasonic waves in an inhomogeneously predeformed elastic material.
8.	Mech 247/02	A.Braunbrück and A.Ravasoo. Nonlinear interaction of waves with material inhomogeneity.
9.	Mech 248/02	A.Braunbrück and A.Ravasoo. Nonlinear ultrasonic wave interaction in weakly inhomogeneous elastic material.
10.		T.Soomere, J.Elken, J.Kask, S.Keevallik, T.Kõuts, J.Metsaveer, P.Peterson. The destructive influence of ship wake wash on the beaches of the Tallinn Bay and Naissaar and Aegna Islands, and the possibilities of its neutralizing; Research Report to Estonian Centre of Environmental Investments (in Estonian).
11.		T.Soomere, S.Keevallik. Wind regime in the Muuga Bay and in its neighbourhood.
12.		T.Soomere. Remote wave fields in the Muuga Bay.
13.		T.Soomere, K.Rannat. Wave measurements in the Muuga Bay.

4.2 Publications

Books, proceedings and theses

1. J.Lass "Biosignal Interpretation: Study of Cardiac Arrhythmias and Electromagnetic Field Effects on Human Nervous System". PhD thesis, Tallinn, TU, 2002.

2. Euromech 436 "Nonlinear Waves in Microstructured Solids", Book of Abstracts, Tallinn, CENS, 2002, 30 pp.

3. T.Lipping (ed.) Signal Processing Research Series: Comparative analysis of linear and nonlinear parametric models for speech coding. Tampere University of Technology, Pori, 2002 (ISBN 952-9607-49-0).

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1. J.Engelbrecht, A.Ravasoo, and A.Salupere. Nonlinear waves in solids and inverse problems. Proc. IUTAM Symposium on Computational Mechanics of Solid Materials at Large Strains, University of Stuttgart, August 20-24, 2001, Germany, (accepted).

2. A.Berezovski and G.A.Maugin. Dynamics of impact-induced phase transition fronts. Journal de Physique IV. (ICOMAT'02), (accepted).

3. A.Berezovski and G.A.Maugin. Simulation of impact-induced martensitic phase-transition front propagation in thermoelastic solids. in: IUTAM Symposium on Dynamics of Advanced Materials and Smart Structures, K.Watanabe, F.Ziegler (eds). Kluwer, Dordrecht, 2003, pp. 9-18, (accepted).

4. A.Berezovski, J.Engelbrecht and G.A.Maugin. Numerical simulation of waves and fronts in structured materials: a thermodynamic approach. Proc. Estonian Acad. Sci. Phys.Mat., (accepted).

5. J.Engelbrecht, F.Pastrone. Waves in microstructured solids with strong nonlinearities in microscale. Proc. Estonian Acad. Sci. Phys.Mat., (accepted).

6. T.Sillat, J.Engelbrecht. Deformation waves in dissipative microstructured materials. Proc. Estonian Acad. Sci. Phys.Mat., (accepted).

7. G.A.Maugin and A.Berezovski. Impact-induced phase transformations fronts propagation. Proceedings of the NATO ARW on New Trends in Phase Transformations and Their Applications to Smart Structures, Metz, April 23-26, 2002, (submitted).

8. A.Berezovski, J.Engelbrecht and G.A.Maugin. Numerical simulation of two-dimensional wave propagation in functionally graded materials. Eur. J. Mech. Solids, (submitted).

9. A.Berezovski, J.Engelbrecht and G.A.Maugin. Numerical simulation of moving phase boundaries in solids. Interfaces and Free Boundaries, (submitted).

10. A.Berezovski and G.A.Maugin. Simulation of wave and front propagation in elastic and thermoelastic heterogeneous materials. Computational Materials Science, (submitted).

11. A.Stulov. Experimental and computational studies of the piano hammer I: Piano hammer testing device, Acta Acustica, (submitted).

12. A.Stulov. Experimental and computational studies of the piano hammer II: Experimental testing and numerical determination of the piano hammer parameters, Acta Acustica, (submitted).

13. A.Stulov. Two nonlinear hysteretic models of piano hammer, (to be published in: Proceedings of 16th International Symposium on Nonlinear Acoustics, Moscow, Russia, 19 - 23 August 2002).

14. O.Kongas, M.J.Wagner, F.ter Veld, K.Nicolay, J.H.G.M. van Beek, K.Krab. Mitochondrial outer membrane is not a major diffusion barrier for ADP in mouse heart skinned fiber bundles. J. Biol. Chem., (submitted).

15. A.Ravasoo. Wave profile distortion and NDT of inhomogeneously predeformed material. Proc. Euromech 419 Colloquium, 3-6 October 2000, Prague, Czech Republic, (accepted).

16. A.Braunbrück, A.Ravasoo. Nonlinear interaction of waves with material inhomogeneity. Proc. Estonian Acad. Sci. Phys. Math., (accepted).

17. A.Braunbrück, A.Ravasoo. Nonlinear ultrasonic waves interaction in weakly inhomogeneous elastic material. Proc. Joint Baltic-Nordic Acoustical Meeting 2002. 26-28 August 2002. TU of Denmark, Copenhagen, Denmark, (accepted).

18. A.Salupere, J.Engelbrecht, P.Peterson. On the long-time behaviour of soliton ensembles. Mathematics and Computers in Simulation, (accepted).

19. A.Salupere, M.Kukk. Periodically forced solitonic structures in dispersive media. Proc. Estonian Acad. Sci. Phys. Math., (accepted).

20. O.Ilison, A.Salupere. On formation of solitons in media with higher order dispersive effects. Proc. Estonian Acad. Sci. Phys. Math., (accepted).

21. L.Ilison, A.Salupere. Solitons in hierarchical Korteweg-de Vries type systems. Proc. Estonian Acad. Sci. Phys. Math., (accepted).

22. M.Vendelin, P.H.M.Bovendeerd, and Theo Arts. In silico relation between regional mechanical work and ATP consumption in the cardiac left ventricle. Biophys. J., (accepted).

23. T.N.Andrienko, A.V.Kuznetsov, T.Kaambre, Y.Usson, A.Orosco, F.Appaix, T.Tiivel, P.Sikk, M.Vendelin, R.Margreiter, and V.A.Saks. Metabolic consequences of functional complexes of mitochondria, myofibrils and sarcoplasmic reticulum in muscle cells. J. Exp. Biol., (accepted).

24. V.Saks, A.Kuznetsov, T.Andrienko, T.Kaambre, K.Guerrero, Y.Usson, F.Appaix, P.Sikk, M.Lemba, and M.Vendelin. Heterogeneity of ADP diffusion and regulation of respiration in cardiac cells. Biophys. J., (accepted).

25. R.Kitt. An importance of Hurst exponent in describing financial markets submitted to Proc. Est. Acad. Sci., (accepted).

26. J.Kalda, M. Säkki, M.Vainu, M.Laan. Zipf's law in human heartbeat dynamics. e-print: physics/0110075 submitted to Phys. Rev.Lett., (under revision).

27. M.Säkki, J.Kalda, M.Vainu, M.Laan. What does measure the scaling exponent of the correlation sum in the case of human heart rate? E-print: physics/0112031, to Chaos, (submitted).

28. J.Kalda. Gradient limited surfaces: Formation of geological landscapes e-print: cond-mat/0203593 submitted to Phys. Rev.Lett., (under revision).

29. J.Kalda. Super-universality of percolation clusters. e-print: cond-mat/0210650. New Journal of Physics, (submitted).

30. E.van Groesen, N.Karjanto, P.Peterson, Andonowati. Wave dislocation and nonlinear amplitude amplification for extreme fluid surface waves. Journal Physics Letters A.

31. N.Karjanto, E.van Groesen, and P.Peterson. Investigation of the maximum amplitude increase from the Benjamin-Feir instability. Journal of the Indonesian Mathematical Society (Journal MIHMI).

32. P.Peterson, T.Soomere, J.Engelbrecht, and E.van Groesen. Interaction soliton as a possible model for extreme waves. Nonlinear Processes in Geophysics, (submitted).

33. L.Ainola, H.Aben. On hybrid thermomechanics for multilayered cylinders. J. Thermal Stresses, (submitted).

34. J.Anton, A.Errapart, H.Aben. Measurement of tempering stresses in axisymmetric glass articles. Internat. J. Forming Processes, (submitted).

35. L.Ainola, H.Aben. A new relationship for the experimental-numerical solution of the axisymmetric thermoelasticity problem. ZAMM, (submitted).

36. T.Soomere. Anisotropy of wind and wave regimes in the Baltic Proper, Journal of Sea Research, (accepted).

37. T.Soomere. Coupling coefficients and kinetic equation for Rossby waves in multi-layer ocean, Nonlinear Processes in Geophysics, (accepted).

38. L.Sipelgas, K.Kallio, H.Arst, A.Erm, P.Oja, T.Soomere. Optical properties of dissolved organic matter in Finnish and Estonian lakes, Nordic Hydrology, (accepted).

39. T.Soomere, K.Rannat, J.Elken and K.Myrberg. Natural and anthropogenic wave forcing in the Tallinn Bay, Baltic Sea, conditionally accepted by WIT Press for "Coastal Engineering 2003".

40. T.Soomere. Natural Wave Regime of the Tallinn Bay, Publicationes Instituti Geographici Universitatis Tartuensis 93, 2003, (accepted).

41. K.Meigas, H.Hinrikus, R.Kattai, and J.Lass. Self-mixing in a diode laser as a method for cardiovascular diagnostics. Journal of Biomedical Optics, (accepted).

4.3 Conferences

1. Finnish Estonian Colloquium in Mathematics, May 27-29, 2002, Tallinn.
   J.Engelbrecht. Wave motion and nonlinear evolution equations.

2. Workshop. Dynamical Systems Methods in Nonlinear Wave Equations. Loughborough University, July 4, 2002, Loughborough.
   J.Engelbrecht. Modified KdV-type equations and solitary waves.

3. NATEMIS topical meeting "LISA and other techniques and applications", Part II, May 31, 2002, Tallinn.
   A.Berezovski, J.Engelbrecht, G.A.Maugin W. Muschik. Numerical simulation of waves and fronts in structured materials: a thermodynamic approach.

4. ALLEA, General Assembly, March 14, 2002, Rome.
   J.Engelbrecht. On national strategies of research in smaller European countries.

5. ETL aastakonverents, March 22, 2002, Tallinn.
   J.Engelbrecht. Eesti teadusstrateegiast.

6. Konverents "Kindlus ja kindlusetus muutuvas maailmas", March 27, 2002, Tallinn.
   J.Engelbrecht. Kaosest ja korrast täppisteadustes.

7. International conference "Baltic Transfer", April 7, 2002, Berlin.
   J.Engelbrecht. Research in smaller countries.

8. Conference of Nordic-Baltic Academies, April 22, 2002, Stockholm.
   J.Engelbrecht. On research locally and globally.

9. Pärnu juhtimiskonverents. 10.okt.,2002, Pärnu.
   J.Engelbrecht ja R.Minka. Kord ja kaos (in Estonian).

10. Eesti III Sotsiaalteadlaste konverents, 22.nov., 2002, Tallinn.
J.Engelbrecht. Suured ja väikesed teaduspõllul (in Estonian).

11. 6th FP Launching Conference, Nov. 12, 2002, Brussels.
J.Engelbrecht. Choices and obstacles. Round table "Future of S&T Policy in Europe.

12. Conference "Flexible Europe - mobility as a tool for enhancing research capacity, Sept. 19, 2002, Tallinn.
J.Engelbrecht. Flexible Europe.

13. IUTAM Symposium on Dynamics of Advanced Materials and Smart Structures, May 20-24, 2002, Yonezawa, Japan.
A.Berezovski, G.A.Maugin. Simulation of impact-induced martensitic phase-transition front propagation in thermoelastic solids.

14. EUROMECH Colloquium 436, Nonlinear Waves in Microstructured Solids, May 29-June 01, 2002, Tallinn, Estonia.
J.Kalda. Topography of rough surfaces: methods and applications.
T.Sillat, J.Engelbrecht. Deformation waves in dissipative microstructured materials.
J.Engelbrecht, F.Pastrone. Waves in microstructured solids with strong nonlinearities in microscale.
A.Berezovski,J.Engelbrecht, G.A.Maugin, W.Muschik. Numerical simulation of waves and fronts in structured materials: a thermodynamic approach.
A.Braunbrück, A.Ravasoo. Nonlinear interaction of waves with material inhomogeneity.
O.Ilison, A.Salupere. Solitons in media with higher order dispersion.
L.Ilison, A.Salupere. Solitons in hierarchical Korteweg-de Vries type systems.
A.Salupere, M.Kukk. Periodically forced solitonic structures in dispersive media.

15. International Conference on Martensitic Transformations - ICOMAT 02, June 10-14, 2002, Espoo, Finland.
A.Berezovski, G.A.Maugin. Dynamics of impact-induced phase transition fronts.

16. Third International Symposium on Finite Volumes for Complex Applications - Problems and Perspectives, June 24-28, 2002, Porquerolles, France.
A.Berezovski, J.Engelbrecht, G.A.Maugin. Numerical simulation of thermoelastic wave and front propagation.

17. 16th International Symposium on Nonlinear Acoustics, 19-23 August 2002, Moscow, Russia.
A.Stulov. Experimental and computational studies of the piano hammer.

18. 10th BioThermoKinetics Conference, Sept. 7-10, 2002, Archachon, France.
O.Kongas. Diffusion barriers for ADP in the cardiac cell.

19. 12th European Bioenergetics Conference, Sept. 10-15, 2002, Archachon, France.
O.Kongas. How sensitive are in situ mitochondria to stimulation by ADP?.
M.Vendelin and V.Saks, Poster: Movement of the metabolites within the skinned fiber: quantifying intracellular restrictions *in silico*.

20. Forum Acusticum Sevilla 2002. 16-20 Sept., 2002, Sevilla, Spain.
    A.Ravasoo. Invited talk: Nonlinear interaction of ultrasonic waves in an inhomogeneously predeformed elastic material.

21. The First International Conference "Inverse Problems: Modeling and Simulation", July 14-21, 2002, Fethiye, Turkey.
    A.Ravasoo. Identification of inhomogeneous predeformation in nonlinear elastic material from ultrasonic boundary measurements.

22. Joint Baltic-Nordic Acoustical Meeting 2002. 26-28 August 2002. TU of Denmark, Copenhagen, Denmark.
    A.Braunbrück. Nonlinear ultrasonic waves interaction in weakly inhomogeneous elastic material.

23. XI Estonian Days of Mechanics, Sept. 12-13, Tallinn.
    J.Kalda. On fractal dimension of "ocean islands" and super-universality of percolation clusters.
    A.Braunbrück. Interaction of longitudinal waves in inhomogeneous material.
    A.Ravasoo. Inhomogeneous prestress and interaction of ultrasound.
    L.Ilison. Solitons in hierarchical KdV-type systems.
    O.Ilison. Solitons in systems with higher order dispersion.
    J.Engelbrecht. Waves in microstructured materials.
    A.Berezovski. A thermodynamic approach to numerical simulation of thermoelastic waves and fronts.
    T.Soomere. A ghost walking around the Tallinn Bay and caused by fast ferries.

24. Dynamical System Methods in Nonlinear Evolution Equations, 4-5 July, 2002, Loughborough, UK.
    J.Engelbrecht, A.Salupere, P.Peterson, O.Ilison, L.Ilison. Modified KdV-type equations and solitary waves.

25. Dynamics Days Europe, July 15-19, 2002, Heidelberg, Germany.
    A.Salupere, J.Engelbrecht, L.Ilison, M.Kukk. Emergence of Soliton Ensembles from KdV-like Systems.

26. 15th Nordic Seminar on Computational Mechanics, 18-19 Oct., 2002 Aalborg, Denmark.
    O.Ilison, A.Salupere. On propagation of solitons in media with higher order dispersion.
    L.Ilison, A.Salupere. On solitons in dilatant granular materials.

27. The 3rd European Interdisciplinary School on Nonlinear Dynamics for System and Signal Analysis Euroattractor 2002, Warshaw, June 2002.
    M.Säkki, J.Kalda. On the Zipf's law in human heartbeat dynamics.

28. International Conference Modern problems of theoretical physics (MPTP-2002), Dec. 9-15, 2002, Kyiv, Ukraine.
    M.Säkki, J.Kalda. On the scaling of low-variability periods in human heart rate.

29. 27th General Assembly of the European Geophysical Society, 21-26 April, 2002, Nice, France.
    J.Kalda. Earth's surface: a new model and its statistical topography.

30. In 8th Estonian Mathematics Days, Kääriku, Estonia, June 26-28 2002.
P.Peterson. Searching for extreme waves.

31. Modelling of Glass Forming and Tempering, Valenciennes, 23-25 January, 2002.
H.Aben. Measuring of tempering stresses in axisymmetric glass articles.

32. 2002 Glass Odyssey, Montpellier, 2-6 June, 2002.
H.Aben. Integrated photoelasticity for residual stress measurement in glass articles of complicated shape.

33. 2002 BSSM Internat. Conference on Advances in Experimental Mechanics, Stratford-upon-Avon, 27-29 August, 2002.
H.Aben. Automatic fringe analysis in tempered axisymmetric glass.

34. 27th General Assembly of the European Geophysical Society, Nice, April 2002.
T.Soomere, S. Keevallik. Anisotropy of wind and wave regimes in the Baltic Proper and the Gulf of Finland.
T.Soomere. Coupling coefficients in the kinetic theory of Rossby waves.
K.Kasemets, T.Soomere. Sensitivity of the high-resolution WAM model with respect to time step.

35. 12th Conference of the European Consortium for Mathematics in Industry, Jurmala, Latvia, September 10-14, 2002.
P.Miidla, K.Rannat. Numerical modeling of layered structure of thermohaline fields.

36. Symposium "The Changing State of the Gulf of Finland Ecosystem", 28-30 October 2002, Tallinn.
T.Soomere. Anthropogenic component of wave forcing in the Tallinn Bay.

37. T.Soomere. 3rd EuroGOOS Conference, 3-6 December 2002, Athens.

38. H.Hinrikus. IEEE EMBS International Workshop on Biosignal Interpretation, June 24-26, 2002, Villa Olmo, Como, Italy.

39. H.Hinrikus. IFMBE 12th Nordic Baltic Conference on Biomedical Engineering and Medical Physics June 18- 2 , 2002, Reykjavik, Iceland.

40. H.Hinrikus. IFMBE BEMS 2nd International Workshop on Biological Effects of Electromagnetic Fields, 7-11 Oct., 2002, Rhodes, Greece.

41. H.Hinrikus. IFMBE 2nd European Medical & Biological Engineering Conference, Vienna, Austria, 04-08 Dec., 2002.

4.4 Seminars outside the home Institute

1. J.Engelbrecht and H.Martinson - Building of the scientific capacity in Europe - an Estonian perspective. Seminar "A New Science Policy for the European Union", April 23, 2002, Stockholm.

2. J.Engelbrecht. Soliton ensembles and the periodicity of their interaction patterns. Torino University, Jan 16, 2002, Torino.

3. J.Engelbrecht. On nets and structures. Seminar of V.Kulbach, TTU, April 5, 2002, Tallinn (in Estonian).

4. J.Engelbrecht. On activities of basic funding. Seminar of the Ministry of Education, March 8, 2002, Tartu (in Estonian).
5. M.Vendelin. Helsinki, March 26th 2002, Mathematical modeling of organized energy metabolism in muscle cells, Helsinki University.
6. O.Kongas, "High K(m) of oxidative phosphorylation for ADP in skinned muscle fibers: where does it stem from?", Advances in muscle respiration studies, Aug. 28, 2002, National Institute of Chemical Physics and Biophysics, Tallinn, Estonia.
7. A.Berezovski. European Science Foundation Programme NATEMIS topical meeting "LISA and other techniques and applications", Jan. 27 - Febr. 3, 2002, Torino, Italy, Finite-volume simulation of thermoelastic wave and front propagation.
8. A.Berezovski. Helsinki University of Technology, Laboratory for Mechanics of Materials, Espoo, Finland, June 9-15, 2002, Finite-volume simulations of thermoelastic wave and front propagation in inhomogeneous solids
9. A.Braunbrück. Seminar at the Fraunhofer Institute for Nondestructive Testing in Saarbrücken, Germany on Feb. 4. Modulation of nonlinear effects and inhomogeneity.
10. A.Braunbrück. Institute of Cybernetics at TTU, annual seminar in Roosta, Oct. 17-18. Interaction of longitudinal waves in inhomogeneous material.
11. A.Ravasoo. V. Kulbach - 75. April 5, Tallinn. Acoustodiagnostics of stress.
12. P.Peterson. Modeling of Extreme Waves. Exact solver for free-surface problem. MPCM Seminar, University of Twente, December 2002.
13. T.Soomere. Lecture at the Finnish Institute of Marine Research, 14 Nov. 2002, Tallinn. Natural and ship waves in the Tallinn Bay.

4.5 Supportive grants (travel, etc.)

1. European Science Foundation Programme NATEMIS grant for participating the NATEMIS topical meeting "LISA and other techniques and applications", January 27-February 3, 2002, Torino, Italy - A. Berezovski.
2. European Science Foundation Programme NATEMIS seminar. Jan. 13-20, 2002, Torino, Italy - J.Engelbrecht.
3. Estonian Academic Foundation for International Exchange grant for research visit in the framework of the program of scientific cooperation "Nonlinear dynamics, constitutive modelling, and numerical modelling of material behaviour" (2001-2004), Helsinki University of Technology, Laboratory for Mechanics of Materials, Espoo, Finland, June 9-15, 2002 - A. Berezovski.
4. Local Organizing committee grant for participating the IUTAM Symposium on Dynamics of Advanced Materials and Smart Structures, Yonezawa, Japan, May 20-24, 2002 - A. Berezovski.
5. Prof. Maugin (Max Planck Award for International Cooperation) grant for participating the Third International Symposium on Finite Volumes for Complex Applications - Problems and Perspectives, Porquerolles, France, June 24-28, 2002 - A. Berezovski.

6. Tallinn Piano Factory grant - for participation at 16th International Symposium on Nonlinear Acoustics. - A.Stulov.

7. European Science Foundation Grant through the NATEMIS programme for participation at the Forum Acusticum Sevilla 2002. 16-20 September 2002, Sevilla, Spain - A.Ravasoo.

8. Grant from Tallinn Technical University PhD Stud. Basic Funding for participation at the Joint Baltic-Nordic Acoustical Meeting 2002. 26-28 August 2002. TU of Denmark, Copenhagen, Denmark - A.Braunbrück.

9. Post-doc position at Dartmouth College, Hanover, NH, USA - T.Lipping.

4.6 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.

Marine Systems Institute:

- EU contract PAPA: "Programme for a BAltic network to assess and upgrade an oPerational observing and forec Asting System in the region"; MSI is responsible for Capacity Building work package; contributor to Modelling workpackage.
- Participation Baltic Operational Oceanographic System (BOOS) - a Baltic-wide cooperation of oceanographical and meteorological institutions.
- 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.

4.7 Research programmes (national)

1. Estonian Programme on Mechanics.
2. Estonian Programme on Biomedical Engineering.

4.8 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
3. J.Kalda – Training of the Estonian and Finnish teams for the 33rd International Physics Olympiad.
4. J.Lass, R.Ferenets – Signal Processing, TTU, Spring 2002.
5. T.Lipping, J.Lass, R.Ferenets – Physiological signal processing, TTU, Autumn, 2002.

4.9 Longer visits of fellows

1. O.Kongas – post-doc position at Amsterdam Free University.
2. P.Peterson – 2001-2002 - post-doc, University of Twente, The Netherlands.
3. T.Lipping – post-doc position at Dartmouth College, Hanover, NH, USA.

4.10 Visiting scholars

1. J.Malmivuo, Ragnar Granit Institute, Tampere University of Technology, "Bioelectromagnetism".
2. V.Jäntti, Oulu University Hospital, "The role of signal processing in anaesthesia monitoring".
3. Prof. R.Jeltsch, ETH, Zürich, "The method of Transport for Systems of Hyperbolic Conservation Laws".
4. Dr. A.Szekeres, Budapest Technical University, "Heat and Moisture in Composites".

4.11 Theses

Institute of Cybernetics:

Promoted:

1. MSc: T.Ugam. One-dimensional numerical modelling of shess-induced phase transition front propagation in shape memory alloys. Supervisor: J.Engelbrecht.

In progress:

1. PhD: O.Ilison, M.Säkki, R.Kitt, A.Braunbrück, T.Ugam, J.Anton.
2. MSc: L.Ilison, M.Lemba.
3. BSc: M.Sepp, T.Arula, P.Rask, R.Prekup, K.Enno

Tartu University:

Promoted:

1. PhD: T.Tseluiko. Supervisors: V.Goldberg, M.Rahula.
2. MSc: V.Retsnoi, H.Lepp, R.Fortuna-Juks. Supervisor: M.Rahula.

Marine Systems Institute:

In progress:

1. PhD: K.Kasemets.
2. MSc: R.Randmeri.

Centre of Biomedical Engineering:

Promoted:

1. PhD: J.Lass. Biosignal Interpretation: Study of Cardiac Arrhytmias and Electromagnetic Field Effects on Human Nervous System. Supervisor: H.Hinrikus.
2. MSc: A.Anier. Multiresolution analyses of physiological signals. Supervisor: T.Lipping.
   R.Ferenets. Time-frequency Distributions and Wavelets for Analyzing EMG Signals. Supervisor: J.Lass.
   I.Tepner. Monitoring Blood Pressure from Pulse Wave Transit Time. Supervisor: J.Lass.
3. BSc: I.Hlimonenko. An Analysis of Photoplethysmographic Signal Detected in the fingertip. Supervisor: K.Meigas.
   J.Helemäe. Registration and Analysis of Electromyograms Recorded by Surface Electrodes. Supervisor: V.Tuulik.
   I.Kuzmina. Registration and Analysis of Elektromyograms. Supervisor: V.Tuulik.

In progress:

1. MSc: M.Parts, Ü.Olli. Supervisor: J.Lass.

4.12 Distinctions

1. T.Soomere, J.Elken (Estonian Marine Institute), T.Kõuts (EMI), J.Kask (Estonian Geological Survey), U.Liiv (Corson). Cycle of studies "Hydrodynamical and geological investigations of possible deep harbour sites in north-western Saaremaa Island". - Estonian Science Award.
2. J.Engelbrecht: N.Alumäe lecture, awarded by the Estonian National Committee for Mechanics, Sept. 12, 2002.
3. J.Kalda - elected to the European Academy of Sciences and Arts.

4.13 Exhibitions, fairs

1. H.Hinrikus. Technology Fair 2002, Tallinn.

4.14 Conferences and seminars organized

1. EUROMECH 436. "Nonlinear Waves in Microstructured Solids" May 29 - June 01, 2002, Tallinn, Estonia. Co-chairmen: Prof. J.Engelbrecht, Institute of Cybernetics at TTU; Prof.G.A. Maugin, University of Pierre and Marie Curie. There were 25 participants from France, Hungary, Ukraine, Russia, Germany, England, Italy, Belgium and Estonia.
2. H.Aben. The 2nd Glass Stress Summer School, Tallinn, 14-16 August 2002. There were 11 participants from glass companies and universities from France, Germany, Italy, England, Finland, Turkey, Hungary, Poland, and USA.
3. XI Estonian Days of Mechanics, 12-13 September, 2002.

Seminars (over academic terms):
- cell energetics;
- thermodynamics;
- solitons;
- thermomechanics of moving phase boundaries.
- doctoral seminar on independent component analysis

5. Summary

5.1 General remarks.

In our previous report (CENS 2001) we have formulated a foresight programme which now has been estimated to be a part of the Estonian programme of Centres of Excellence in Research. Given the results of the year 2002, we have the potential to follow our targets but we have also to work even harder. One of the tools is networking with our partners worldwide. This means that the Invisible College including researchers and centres interested in nonlinear studies should become more visible. Another direction is to invite more young people to join the CENS for their graduate studies. The additional funding for 2003 - 2006 gives more possibilities to invite lecturers from abroad to give short graduate courses or to organize summer/winter schools. Undoubtedly, our research plans need to be fulfilled.

With this short summary we are looking to the future with great hopes.

5.2 Publicity on CENS

1. Centre for Nonlinear Studies. In: S.Kivi (ed), Excellence in Research 2001-2002, Estonia. Ministry of Education, Tartu, 2002, 30-31.
2. Institute of Cybernetics, Centre for Nonlinear Studies (CENS). In: Tallinn Technical University, Research and Development. Tallinn, 2002, 20.
3. J.Engelbrecht. Mechanics - an endless frontier of science. In: J.Engelbrecht and R.Küttner (eds), Science in Estonia: Technical Sciences. Estonian Academy of Sciences, Tallinn, 2002, 21-24 (in Estonian).
4. H.Aben, L.Ainola, J.Anton, A.Errapart. Integrated photoelasticity for nondestructive residual stress measurements in glass. Ibid., 9-14 (in Estonian).
5. H.Hinrikus, J.Lass, T.Lipping, K.Meigas, J.Riipulk. Technology for enhancing the quality of life - biomedical engineering. Ibid., 31-38 (in Estonian).
6. J.Engelbrecht. Frontiers of ideas. Mente et Manu (Weekly of Tallinn Technical University), 2002, No 28, 3 (in Estonian).

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