Institute of Cybernetics at Tallinn Technical University
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CENS

Centre for Nonlinear Studies
Estonian Centre of Excellence in Research

Annual Report

2004

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Contents

Abstract

The report includes a brief overview on all the activities of CENS 2004. Described are studies and results on: (i) dynamics of microstructured materials and solitons; (ii) water waves and optical waves; (iii) biomechanics and biophysics; (iv) fractality and econophysics; (v) general nonlinear wave theory including acoustodiagnostics and waves in materials with internal interfaces; (vi) dynamics of piano hammers; (vii) optical nonlinearity and photoelasticity; (viii) geometric approach to nonlinear problems; (ix) interaction solitons and waves from fast ferries on sea; (x) biosignals in general and the EEG. The international programmes and projects are described. The full records of papers, reports, abstracts, conferences, visitors, networking, etc are all included.

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

See also: Centres of Excellence of Estonian Science, Tallinn, 2004, 45-57.

Sisukord

Lühikokkuvõte

Käesolev aruanne on ülevaade Mittelineaarsete Protsesside Analüüsi Keskuse (CENS) tegevusest 2004.a.. Põhiraskus on tulemustel järgmistes suundades: (i) lainelevi mikrostruktuursetes materjalides ja solitonid; (ii) pinnalained ja optilised lained; (iii) biomehaanika ja biofüüsika, (iv) fraktaalsus ja ökonofüüsika; (v) mittelineaarne lainelevi rakendustega akustodiagnostikas; (vi) klaverihaamrite dünaamika, (vii) optiline mittelineaarsus ja fotoelastsus; (viii) mittelineaarsete protsesside geomeetriline teooria; (ix) interaktsioonisolitonid meres ja kiirlaevade tekitatud lained; (x) biosignaalid ja EEG analüüs. CENSi rahvusvahelised programmid on kirjeldatud detailsemalt kui varem. Esitatud on publikatsioonide, aruannete, konverentside, külaliste jm nimekirjad.

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

Vaata: Eesti teaduse tippkeskused, Tallinn, 2004, 43-55.

1. Introduction

This Report is the sixth Annual Report of CENS, following CENS 1999 - 2003. The present CENS is one of the Estonian Centres of Excellence in Research (the whole number of such Centres is 10). The period of awarding this title with additional funding is 2003 - 2006. The general overview on all Centres is published in 2004 "Centres of Excellence of Estonian Science", Association of Centres, Tallinn, 2004, 163 pp., see CENS, (pp. 45-57); see also a short summary in CENS Annual Report 2003.

The present Report includes a short summary of research fields (Section 2), the description of current results in 2004 and research cooperation (Section 3), an overview on funding (Section 4), and then the publications records, lists of conferences together with all the publicity of results (Section 5). The last Section 6 gives conclusions and foresight ideas.

2. Overview on CENS

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, microstructured 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.

3. Current results 2004

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 the third- and fifth- order dispersive and the fourth order nonlinear terms, is used for modelling the wave propagation in microstructured solids like martensitic-austenitic alloys. The model equation is solved numerically under localised initial conditions by making use of the pseudospectral method. In 2004 the main attention was paid to the analysis of the propagation of solitary waves emerged from $\text{sech}^2 x$ type localised initial disturbances. Possible solution types were defined already in 2003. The existence of a threshold is established. Below the threshold, the relatively small solitary waves decay in time. However, if the amplitude exceeds a certain threshold, i.e. the critical value, then such a solitary wave can propagate with nearly a constant speed and amplitude and consequently conserve the energy. The value of the critical amplitude is found to depend on both dispersion parameters and corresponding dependencies were found. One more interesting conclusion can be drawn here — the weaker the dispersion (the case when both dispersion parameters decrease simultaneously) the smaller the mass and the energy of the initial pulse that can result a solitary wave. Pilot numerical experiments with solitary waves having different amplitudes (and therefore different speeds) demonstrate that their interaction is not perfectly elastic — there exist a certain small transfer of energy and/or mass between interacting solitary waves. Due to this phenomenon the slower solitary wave moves more slowly and the faster one even faster (A.Salupere, O.Ilison).

Solitary waves in granular materials
The studies of wave propagation in granular materials are continued by making use of a hierarchical KdV equation. The model equation involves three material parameters (two different dispersion parameters and one microstructure parameter). Numerical solutions are found under localised initial conditions by making use of pseudospectral method. It is found that possible solution types in the case of localised initial conditions and in the case of harmonic initial conditions (analysed in 2003) are the same — a KdV soliton ensemble and an ensemble of equal amplitude solitons. Both ensembles can exist simultaneously and the ensemble of equal amplitude solitons can be suppressed or amplified in the case of localised as well as harmonic initial conditions. The analysis of the behaviour of the solutions in the three-dimensional space of material parameters is in progress (A.Salupere, L.Ilison).

Wave hierarchies
Wave propagation in microstructured materials is directly affected by the existence of internal space scale(s) in the compound matter. In this case the classical continuum theory cannot be used. Based on the Mindlin model, the balance laws for macro- and microstructure are formulated separately. Using the slaving principles relating macro- and microdisplacements, the governing equations are derived for a single- and two-scale (scale within scale) cases. These equations exhibit hierarchical properties assigning the wave operators to internal scales. In terms of macrodisplacements, higher-order dispersive terms appear having a clear physical background (microinertia, wave speed in microstructure) related to the scale of the microstructure. Full, approximated (corresponding to hierarchical models), and simplified dispersion relations are derived and

analysed to demonstrate the validity of the hierarchical governing equations. Linear theory is based on the quadratic free energy function, in nonlinear theory the cubic terms should also be taken into account. The corresponding governing equation includes nonlinearities in both macro- and microscale. Such consistent modelling opens up new possibilities to Nondestructive Testing (NDT) of material properties (J.Engelbrecht, F.Pastrone, M.Braun, A.Berezovski).

3.1.2 Water waves and optical waves

Surface Waves

Continued development efficient and accurate solver for 2D free surface problem using half analytical/half numerical approach based on conformal mapping technique, with extensions to variable bottom and inclusion of wave generators. The aim is to derive explicit evolution equations for the free surface of the fluid (with finite depth) without making any approximations (except assuming the potential flow hypothesis). The full potential flow inside the fluid domain including the motion of the free surface is then determined solely by two quantities: surface elevation and velocity potential at the surface related to the Lagrangian marker variable defined by a certain conformal mapping. The main advantage of the used approach over the other boundary element type of methods is that the evaluation of relevant Cauchy integrals is replaced by evaluating convolutions (given by conjugation operator) and that can be carried out using FFT with a great speed and accuracy. The derived equations turn out to be suitable for both numerical and analytical investigation of surface waves (P.Peterson).

Stability analysis of nonlinear periodic structures

The propagation properties of coherent optical waves in a stratified medium with Kerr nonlinearity has been studied. Such light-sensitive materials with periodically varying refractive indices have potential applications in optical communication systems for uniform switches, logic elements, or optical limiters due to energy spectrum with bands. The theory of light propagations in nonlinear one-dimensional periodic structures (developed by Pelinovsky et al.) has been applied to photopolymers with dispersed CdSe-nanoparticles and laser-written holograms. It has been shown that multistable behaviour in input-output power relationship can occur at very low intensities (L.Rebane, P.Peterson).

Software development

Continued development of the program "F2PY – Fortran to Python Interface Generator" (http://cens.ioc.ee/projects/f2py2e/). The aim of F2PY is to provide an automatic connection between high-level Python scripting language and high-performance Fortran/C libraries and programs. F2PY users are from various fields of sciences, e.g. it is being used in projects such as severe storm modeling and tornadogenesis (National Severe Storm Lab in Norman OK), the Bolometer Data Analysis (Max-Planck-Institut für Radioastronomie in Bonn), teaching scientific computing (University of Oslo), research on aircraft design optimization (Aircraft Computing Laboratory at Stanford University), and in many other OS projects as well as commercial ones (P.Peterson).

Continued development of the SciPy package (http://www.scipy.org/) that gathers a variety of high level science and engineering modules for Python (P.Peterson).

3.1.3 Biomechanics and biophysics

Cell energetics

In muscle and brain cells, phosphocreatine and adenylate kinase shuttles provide a link between ATP producing and ATP consuming sites. As a part of phosphocreatine shuttle, the functional coupling between mitochondrial creatine kinase (MiCK) and adenine nucleotide translocase (ANT) has been identified by stimulating oxidative phosphorylation with creatine (Cr) further examined with kinetic and structural studies. Recently, it has been shown that the coupling plays an important role in preventing the opening of permeability transition pore and, thus, is critical for the cell life. However, regardless of the large amount of experimental data on functional coupling between MiCK and ANT, dating back to the 1970-s, the intimate mechanism of the interaction between the proteins is still not clear.

The aim of our work was to identify the simplest mechanism that was able to reproduce the available experimental data on functional coupling between MiCK and ANT. Two alternative mechanisms were studied: (1) dynamic compartmentation of ATP and ADP, which assumes the differences in concentrations of the substrates between intermembrane space and surrounding solution due to some diffusion restriction; (2) direct transfer of the substrates between MiCK and ANT. The mathematical models based on these possible mechanisms were composed and simulation results were compared with the available experimental data. The first model, based on dynamic compartmentation mechanism, was not sufficient to reproduce the measured values of apparent dissociation constants of MiCK reaction coupled to oxidative phosphorylation. The second model which assumes the direct transfer of substrates between MiCK and ANT is shown to be in good agreement with experiments. Namely, the second model reproduced the measured constants and the estimated ADP flux, entering mitochondria after MiCK reaction. This model is thermodynamically consistent, utilizing the free energy profiles of reactions. The analysis revealed the minimal changes in free energy profile of MiCK-ANT interaction required to reproduce the experimental data (M.Vendelin, M.Lemba).

Heart rate variability (HRV)

We have derived analytic relationship between the multifractal spectrum of intermittent time series (such as sequences of heart interbeat intervals), and the multi-scaling exponent describing the length-distribution of low-variability periods. We have shown that if the value of the multi-scaling exponent exceeds unity, it does describe such scale-invariant features of HRV, which cannot be described by the multi-fractal formalism. The analysis of the length-distribution of low-variability periods has been also applied to the electro-encephalogram data; this turned out to be a sensitive technique for detecting the presence of weak stressors (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 severalfold. Based on the computer simulations of these experiments performed by us, 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).

3.1.4 Fractality and econophysics

Statistical topography
An analytical relationship has been derived for the exponents describing the light intensity distribution from rough self-affine surfaces, as well as the fractal dimension of the speckle pattern. Both three-dimensional and two-dimensional geometry has been studied; the roughness exponent has been assumed to be in the range $1 < H < 2$ (J.Kalda).

Turbulent diffusion
We have generalized the model of turbulent diffusion (which has been until now applicable only to two-dimensional flows), and applied it for studying three-dimensional turbulent diffusion. We have also derived an approach for studying pair dispersion ("Richardson law") in fully developed turbulence of compressible fluids (e.g. free-slip surface flows), and derived analytical expressions for the scaling exponents of the pair-dispersion time-evolution exponents (J.Kalda).

Econophysics
The scaling properties of the time series of asset prices and trading volumes of stock markets have been analyzed. It has been shown that similarly to the asset prices, the trading volume data obey multi-scaling length distribution of low-variability periods. In the case of asset prices, such scaling behavior can be used for risk forecasts: the probability of observing next day a large price movement is (super-universally) inversely proportional to the length of the ongoing low-variability period. Finally, a method is devised for a multi-factor scaling analysis. We apply the simplest, two-factor model to equity index and trading volume time series (R.Kitt).

3.1.5 General nonlinear wave theory

Acoustodiagnostics of inhomogeneous and prestressed solids
The theoretical research to improve the algorithms of ultrasonic nondestructive methods for (i) qualitative determination of inhomogeneous prestress in material, (ii) quantitative evaluation of two-parametric inhomogeneous prestress in materials and (iii) evaluation of physical properties of weakly inhomogeneous material was carried on. All methods were proposed in previous years and they make use of boundary oscillations evoked by simultaneous propagation of two ultrasonic waves.

Influence of higher order nonlinear effects, such as evolution of the third harmonic, interaction of three first harmonics, etc., on the results obtained by first two algorithms was studied on the basis of the cumbersome analytical solution numerically. It cleared up that the behaviour of the higher order nonlinear effects is qualitatively different in comparison with the behaviour of the main part of nonlinear effects. For example, the third harmonic modulates the boundary oscillations also in the prestress free physically homogeneous material. Essential is that this modulation is a higher order small effect and it may be neglected in practical applications.

The minimal amount of information, necessary for evaluation of the two-parametric inhomogeneous prestress field on the basis of boundary oscillations was clarified for the second ultrasonic nondestructive method. The conclusion was that the considered prestress field may be evaluated on the basis of information recorded on both, two parallel boundaries at one instant.

The third method - the resonance method for evaluation of weakly inhomogeneous physical properties of the nonlinear elastic material was developed. The new phenomenon was discovered - the resonance values of the boundary oscillation amplitudes form cascades on the amplitude - frequency plane. The layout of these cascades is dependent on the kind of material property and on the character of spatial variation of this property. This phenomenon was studied in detail. The spatial variation of the density, the linear and the nonlinear elastic coefficient was described by polynomials up to the third order. The influence of variation of polynomial constants on the behaviour of cascades was clarified. It cleared up that the shift of the resonance cascade with respect to the cascade that corresponds to the homogeneous material depends on the absolute value of each polynomial constant and the direction of the shift - on the sign of the constant. Different shift corridors correspond to the variation of different polynomial constants that characterize the material inhomogeneity. The assumption that the resulting shift of cascades caused by simultaneous variation of different constants is roughly equal to the vectorial sum of shifts caused by separate variation of these constants needs further investigation (A.Ravasoo, A.Braunbrück).

Wave propagation in materials with internal interfaces

1. Numerical simulation of plane wave propagation in linear and nonlinear piecewise homogeneous media: application to shock waves in laminates.

Numerous simulations of one-dimensional linear and nonlinear wave propagation in laminates with different geometry and physical properties are performed for the dispersion analysis. It is found that the behaviour of strong shock waves can be described in terms of nonlinear wave propagation.

2. Numerical simulation of elastic wave propagation in two-dimensional Functionally Graded Materials (FGM) structures: comparison between different FGM models.

It is shown, that the results of numerical simulations for one-dimensional FGM are coincided with analytical solution. In two-dimensional cases, the prediction of final state of FGM seems to be the same for continuous, layered, or random grading but there are essential differences in intermediate states.

3. Numerical simulation of straight-through Mode I crack propagation in brittle materials: similarity with phase-transition front propagation.

The velocity of crack tip in brittle materials is determined in the similar way as in the case of phase-transition fronts. This provides the possibility to simulate the straight-through Mode I crack propagation by a thermodynamic model for phase-transition front propagation (A.Berezovski).

Piano hammers - theoretical and experimental studies

Investigation of piano hammers is focused on the numerical simulation of the hammer-string interaction. The main attention is dedicated to analysis of the special cases of the piano scale design. This study is based on the physical models of hammer and string, and gives the possibility to calculate the motion of strings and hammers, the history of the acting forces, and to simulate the spectra of the string vibrations. The behaviour of the piano hammer is described by a three-parameter hysteretic model with experimentally determined parameters. The string is assumed to be perfectly flexible. Computer simulation of the hammer-string interaction is used for determination of tension of the string terminated on the bass and treble bridges, for optimization of the striking point position, and for investigation of multiple contacts.

Special attention is given to the hammer-string interaction for bass notes. In addition, the problem what can cause the hammer to rebound is clarified. For a linear elastic hammer interacting with a long flexible string the exact solution of the equation describing the hammer motion is derived. It was shown that in some cases no reflected wave is needed to assist the hammer for going away from the string. The numerical simulation carried out for the first ten hammers and strings of *Parlour Grand Piano* shows that the real hysteretic hammer leave the string before the string begins pushing back on the hammer (A.Stulov).

3.1.6 Optical nonlinearity and photoelasticity

Non-linear integrated photoelasticity

On the basis of the electromagnetic theory of light the basic equations of integrated photoelasticity have been derived bearing in mind their application in photoelastic tomography. By mathematical treatment of the equations the Pauli matrix formalism has been applied. Analysing the orders of magnitude of different terms in the equations, mathematically correct justification of abandoning certain terms has been given. It has been shown that the precision of the linear approximation depends both on the value of the dielectric tensor and on its derivative.

Some preliminary numerical experiments with the non-linear algorithm of integrated photoelasticity for the axisymmetric case have been carried out.

A method for the assessment of the residual stress in non-axisymmetric bottles with a thick bottom has been elaborated. The method permits measurement of stress at the external surface of the bottle. Stress field in the bottom is measured with photoelastic tomography.

In cooperation with the University of Valenciennes detailed investigations of the stress distribution through the thickness of tempered glass plates were started. Stress fields in 14 plates were measured with the scattered light method (L.Ainola, H.Aben, J.Anton, A.Errapart).

3.2 Tartu University

Geometric approach to nonlinear problems (M.Rahula)

Tensors in the flow of vector field. The transformation of tensor field in the flow of vector field is described by Lie-Maclaurin series with Lie derivatives for coefficients. As the tensor field is given in natural or anholonomic basis the calculations begin with derivation formulae and the matrix C determined through the components of vector field and object of anholonomity. The first application is the search for invariants of vector field on the plane. The 1-form ω associated with the vector field X on condition $d\omega = 0$ is a differential of invariant $\omega = dI$. If ω is not exact we need know an infinitesimal symmetry P. Then the inverse of $\omega(P)$ is an integrating factor for ω.

Tensor representations of linear group. Operator of linear group $GL(n, R)$ is a linear vector field X in the space R^n. Its flow is determinated by exponential law $U' = CU \Rightarrow U_t = e^{tC}U$, for fixed $U \in R^n$, constant matrix C as an element of Lie algebra

$gl(n,R)$ and exponential e^{tC} as 1-parametric subgroup of $GL(n,R)$. If the tensor field is invariant in the flow its components satisfy a linear ordinary differential equation corresponding to Hamilton-Cayley formula. And on the contrary, if the components are invariant the tensor field itself with Lie derivatives satisfies a similar but dual differential equation. Both cases are described with the help of proper values (in the knot points of a network on complex plane). This is a new approach to the infinitesimal methods in theory of algebraic invariants (D.Hilbert, H.Weyl) and polynomial dynamics (K.Sibirski, D.Boularas).

Universal structure of jet space. In the space of infinite jets of smooth maps total differentiation operators D, Cartan forms ω and Lie vector fields P (symmetries of distribution D) are in the foreground. Operator D is a linear vector field. Its flow on the fibers is determined by $U_t = e^{tC}U$ and invariants by $I = e^{-tC}U$, when $dl = e^{-tC}\omega$. The operators $\frac{\partial}{\partial I} = \frac{\partial}{\partial U}e^{tC}$ form a basis for Lie vector fields. These objects compactly and geometrically interpreted lay the foundation of a vast domain called Symmetry Analysis (L.Ovsyannikov, P.Olver, B.Cantwell, A.Vinogradov). Universality consists in the following. When we have a triplet (X,s,F) with a vector field X on a manifold, its canonical parameter s (time) and a set F of function f and derivatives $f', f'', ...$ with respect to X it is always possible to apply by means of a map φ into the jet space thus the vector field X is φ-attached to the operator D and $t \circ \varphi = s, \quad U \circ \varphi = F$. When the triplet (X,s,F) is φ-attached to the triplet (D,t,U) the invariants $I = e^{-tC}U$ return on the manifold in the invariants $I \circ \varphi = e^{-sC}F$ of X and the Cartan forms $\omega = dU - U'dt$ in the forms $\omega \circ T\varphi = dF - F'ds$. At the same time Coker $T\varphi$ causes on the manifold the appearance of important differential operators as Laplacian, Hessian and others. Every time when we differentiate the functions or tensor fields we get from sections of jet bundle a necessary information about the invariants and symmetries for the situation (X,s,F) on the manifold.

Geometrical problems. Singularities of maps (after R.Thom) can be bound with the envelopes or, in geometrical expression, with lighting of surfaces along the trajectories of vector field. A stratification arises on the lighted surface which can be described with help of differential equations and their invariants. The study of the shadows on the screen (classification of images of singularities) is a main topic for catastophe theory. Even the simplest equations offer the substantial results (as the case $u''' = 1$ leads us via Vièta maps to Cardano formula and Cayley syzygy).

3.3 Marine Systems Institute at Tallinn Technical University (T.Soomere)

Water Waves: interaction of solitary waves

Nonlinear interaction of long-crested solitonic waves may be a reason for the existence of high-amplitude wave humps on the sea surface that could be identified with extreme (freak or rogue) waves. The properties of extreme elevation area in the vicinity of the intersection point of two long-crested shallow water waves are evaluated in the framework of two-soliton solution of the Kadomtsev-Petviashvili equation (in cooperation with J. Engelbrecht). The extent of the area where surface elevation exceeds a certain level is estimated analytically based on the study of corresponding surface isolines. Substantial areas of extreme surface elevation may occur only if the heights of the incoming waves, their intersection angle and the local water depth are specifically balanced. Thus, the fraction of sea surface occupied by extreme elevations apparently is small as compared with the area covered, e.g. by high ship-generated waves. Shown is that the area of high elevation is very narrow in the direction of its propagation. The extreme slopes at the front of the interaction soliton may be eight times as high as the maximum slope of the interacting solitons. The interaction pattern, theoretically, has unlimited life-time and may cross large sea areas in favourable conditions. Thus, one should also account for the expected life-time of the nonlinear wave humps (additionally to the fraction of the sea area covered by extreme elevation at a certain time instant) when estimating the probability of occurrence of near-resonant interaction solitons. Nonlinear resonance may occur also for solitons of unequal amplitudes. Several properties of interactions of two-soliton solutions of the Kadomtsev-Petviashvili equation with unequal amplitudes for a certain range of the phase shift are analysed. The height and location of the global maximum of the solution is established for the case when the maximum amplitude of the interaction pattern exceeds the sum of amplitudes of the incoming solitons. Shown is that the global maximum occurs at the symmetry centre of the interaction pattern. The maximum increase of the amplitude occurs in the case of equal amplitude solitons and decreases if the amplitudes of the counterparts become different. The area where the two-soliton solution exceeds the amplitude occurring in the process of linear superposition mostly depends on the phase shift parameter and less on the amplitudes of the waves provided they form a near-resonant system. For interactions of solitons with drastically different amplitudes it is roughly as large as if the amplitudes were equal. In shallow sea areas near-resonant interaction of solitonic surface wave systems with radically different amplitudes apparently becomes evident in the form of bending of crests of the larger waves. This phenomenon may drastically increase the probability of encountering a hit by a high wave possibly with a particularly large slope and arriving from an unexpected direction.

Water Waves: waves from fast ferries

The described mechanism is effective for long-crested soliton-like waves and may be uncommon for storm waves. Since a moving pressure disturbance can generate solitary waves also in open sea areas, this mechanism may occur in relatively shallow areas with heavy fast ferry traffic where soliton-like disturbances frequently occur. The primary reaction of seabed to an increased hydrodynamic activity due to ship waves consists in intensification of resuspension processes. This reaction can be identified and roughly estimated with the use of optical measurements that are much more flexible and much less expensive than geological studies of the underwater sediment transport processes possibly affecting seabed and coastline. Wake waves from fast ferries create significant changes in the optical parameters of sea water in a near-bottom layer with a thickness of about 1 m in coastal areas of Tallinn Bay with the depths from about 2 to at least 5 m. Ship traffic causes an overall increase of the optical density of water at certain depths. The long-term changes of the overall optical density can be detected with the use of classical methods, incl. laboratory analysis of water samples taken at appropriate depths and sites. Local worsening of the water quality through extensive resuspension apparently is much larger but quite complicated to follow because of the short duration of the wake-induced resuspension events. The suspended matter remains in the water column for about 5 min. Rough quantitative estimates, based on the wave-induced increase of the suspended matter in the water column owing a typical wake (about 1 g/m2) suggest that the bulk influence of fast ferry traffic in Tallinn Bay may result in an annual loss of the order of 100 litres of fine sediments from each meter of the coastal line.

Water Waves: forcing conditons
Trends of the long-term changes of sea-level wind conditions over the Gulf of Finland are shown to be different at the northern and southern coasts of the Gulf of Finland. The wind speed increased at the Finnish coast and decreased (at least during the second half of the year) in the centre of the Gulf and at the Estonian coast. The increase in the wind speed during late winter and early spring can be attributed to the changes in the large-scale circulation over this area. The decrease of the average wind speed in autumn and early winter is in an amazing contradiction with the generally recognised fact that the frequency of storms has increased during the same period.

3.4 Biomedical Engineering Centre, Tallinn Technical University

3.4.1. Biosignals interpretation: main results

The main attention was aimed to EEG analyzes to distinguish effects of weak (microwave radiation) and strong (anesthetic drugs) stressors on human brain. Studies on ECG analysis and pulse wave parameters during previous years resulted in device Tensiotrace for continuous blood pressure measurement in this year (J.Lass, K.Meigas). Digital analysis of the spectrophotometrical signal and on-line processing of its components during hemodialysis aimed to improve the adequacy and quality as well as assessment of dialysis treatment started this year (I.Fridolin).

Microwave effects on EEG

1. The comparison of the traditional spectral analysis and a new scale-invariant method - analysis of the length distribution of low variability periods (LDLVP) - to distinguish between the EEG signals with and without a weak stressor - a low-level modulated microwave field - was done. During the experiment, 23 healthy volunteers were exposed to a low-level microwave (450 MHz, 0.16 mW/cm^2, 7 Hz on-off modulation). Signals from frontal EEG channels FP1 and FP2 were analyzed. The quantitative measures of LDLVP provided a significant detection of the effect of the stressor in the case of 6 subjects exposed to the microwave field, and for none of the sham recordings. The spectral analysis revealed a significant result for 1 subject only. A significant effect of the exposure to the EEG signal was detected for 25% of subjects: microwave exposure increased the EEG variability. The effect was not detectable by power spectrum measures (M.Bachmann, J.Kalda, J.Lass, M.Säkki, H.Hinrikus).

2. The dynamics of the low-level microwave radiation effect on human EEG alpha and theta rhythms was analyzed. 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. 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 (M.Bachmann, H.Hinrikus, J.Lass, V.Tuulik).

3. Modulated microwave effect (1 W, 450 MHz carrier, 7 Hz modulation frequency) on human perception of visual information was studied utilizing the phenomenon of visual masking. The responses of the subjects in conditions with and without microwave exposure were analyzed regarding to correct identification of two stimuli and the order of their presentation. Both stimuli were recognised correctly and put in right order better (difference 5%) without exposure ($p < 0.05$) (A.Rodina, J.Lass).

3.4.2. EEG in anesthesia

1. The comparison of two instantaneous frequency (IF) estimates of spindles during propofol anesthesia at burst-supression level, based on Wigner-Ville distribution (WVD) and optimized generalized marginals Choi-Williams (GMCW) distribution was done. WVD is a fixed kernel type distribution whereas GMCW has a kernel, which was optimized for the current signal and therefore more resource consuming to calculate. The test showed that both methods yielded similar results. The results demonstrated that IF of propofol spindles is not stable during anesthesia - the overall trend is that spindles have decreasing frequency (R.Ferenets).

2. The ability of two nonlinear parameters, the Higuchi fractal dimension (HD) and spectral entropy, to follow the depth of sedation in the Intensive Care Unit was assessed. For comparison, the relative beta ratio was calculated. The results were evaluated using clinical assessment of the Ramsay score. The results show that the HD discriminates well between Ramsey scores 2-4 while beta ratio is superior for deeper levels of sedation (A.Anier, T.Lipping).

3.5 Research within international programmes

3.5.1 NATEMIS

ESF programme

Research results in 2004:

- The resonance method for nondestructive evaluation of the properties of the physically nonlinear weakly inhomogeneous elastic material was developed. The idea of the method arose during PhD Stud. A.Braunbrück's one month visits in the frame of the NATEMIS Programme to the Institute of Thermomechanics in Prague and to the Fraunhofer Institute for Nondestructive Testing in Saarbrücken. The new phenomenon was discovered - the resonance values of the boundary oscillation amplitudes evoked by simultaneous propagation of two longitudinal waves in the material form cascades on the amplitude - frequency plane. The layout of these cascades is dependent on the kind of material property and on the character of spatial variation of this property.
- Investigation of the influence of nonlinear effects of ultrasonic wave propagation on the acoustoelastic effect was carried on in collaboration with Fraunhofer Institute for Nondestructive Testing in Saarbrücken (Dr. E.Schneider) according to the agreement of scientific cooperation in frame of NATEMIS Programme on Stress Induced States of Material for 2003-2005.
- The dispersion relations that determine the behaviour of longitudinal waves in microstructured material were deduced. The accuracy of the simplified wave model was determined and the algorithm for the inverse problem was presented. The mathematical model for wave propagation process in the multilevel microstructured material was composed and the corresponding dispersion relations were derived.
- The linear and nonlinear propagation of plane waves in piece-wise homogeneous materials and in two-dimensional functionally graded materials was investigated numerically.
- Three chapters for the final report of the NATEMIS Programme in the form of book "The universality of nonclassical nonlinearity" were prepared as follows:

(i) J.Engelbrecht, F.Pastrone, M.Braun and A.Berezovski: Hierarchy of waves in non-classical materials,

(ii) A.Berezovski, J.Engelbrecht and G.A.Maugin: Modelling and numerical simulation of non- classical effects of waves, including phase transition fronts,

(iii) A.Ravasoo and A.Braunbrück: Nonlinear acoustic techniques for NDE of materials with variable properties.

Activities:
- A.Ravasoo organized the Steering Committee Meeting in Tallinn, April 23, 2004.
- J.Engelbrecht visited in the Department of Physics, Politecnico di Torino, Italy during May 12-18, 2004.
- A.Ravasoo and A.Berezovski participated at the NATEMIS Annual General Workshop in Karlskrona, Sweden during May 30 - June 4, 2004.
- Dr. C.Pecorari from the Department of Mathematics, Royal Institute of Technology, Stockholm, Sweden visited CENS during Sept. 5-9, 2004.
- Prof. F.Pastrone from the Department of Mathematics, University of Turin, Italy visited CENS during Sept. 13-19, 2004.

3.5.2 PARROT

French-Estonian science and technology collaboration program PARROT

A. "Nonlinear Stress Waves in Complex Media" — 2003–2004

A.Berezovski. Numerical simulation of straight-through Mode I crack propagation in brittle materials: similarity with phase-transition front propagation.

The velocity of crack tip in brittle materials is determined in the similar way as in the case of phase-transition fronts. This provides the possibility to simulate the straight-through Mode I crack propagation.

A.Salupere. KdV type evolution equations, including higher order dispersive and higher order nonlinear terms, are used for modelling of wave propagation in microstructured media. Numerical simulations are carried out in the case of harmonic as well as in the case of localized initial conditions. Main attention is paid to the formation of soliton type solutions. Corresponding criterions are found in terms of material parameters and initial wave characteristics.

Research visits:
A.Berezovski in the Laboratory of Modelling in Mechanics at University Paris 6, March 21-28, 2004.
A.Salupere in the Laboratory of Modelling in Mechanics at University Paris 6, Nov. 21-28, 2004.

B. "Experimental and Theoretical Study of Sound Generation Mechanisms in Grand Piano — 2005–2006

A.Stulov. The main goal of this two-year study is constructing a physical model of the grand piano. Conservation laws are used to calculate the motion of the hammer, string, soundboard, and thereby compute the sound produced by the instrument from "first principles". At present, we have two different hysteretic piano hammer models, and the rather complete information about the piano hammer features. These data were obtained experimentally using the Piano Hammer Testing Device developed and built in the Institute of Cybernetics at Tallinn University of Technology. The next step of our theoretical study is the investigation of the piano soundboard and piano bridges. Taking into account the geometry and stiffness of the soundboard (with ribs), the dependence of the bridge admittance on the frequency could be obtained. The main theoretical principles of the piano duplex scale functioning could be developed. This study will give a possibility to simulate the piano string excitation by hysteretic hammer for the real type of boundary conditions. The various numbers of strings in the choir will also be considered. It gives the possibility to investigate the energy transmission between the coupled strings that depends on the piano bridge admittance. The results obtained could be examined experimentally by studying of well-built models of corresponding parts of the piano and by testing of the real instruments. This co-operation brings together musical acousticians from different scientific centers and gives the possibility to discuss different aspects of musical acoustics.

3.5.3 FP-6

Wide-range Non-intrusive Devices toward Conservation of Historical Monuments in the Mediterranean Area (WIND-CHIME)

Specific Targeted Research Project INCO-CT-2004-509805

RDT1 - Development material technologies toward less intrusive implementations. Two work packages are considered in the first stage, WP1 devoted Ni-Ti alloys and WP2 devoted to other shape memory alloys (SMA). These WP's will select the appropriate material on the basis of the data known from the literature and, subsequently, by submitting the material to a fitness through mechanical testing and metallurgical characterization. Important for the application of these new materials is to learn how these should be applied in a damping device.

Objectives: Identification and characterization of a Ni-Ti SMA alloy with optimal properties toward cultural heritage retrofitting. Identification and characterization of other shape memory alloys, with emphasis on Cu-based SMA alloys, with optimal properties toward cultural heritage retrofitting.

Deliverable 1 is a state of art on the superelastic behaviour of alloys based on Nickel and Titanium.

Deliverable 2 is a state of art on SMA alloys not based on Nickel and Titanium.
Contribution from CENS: A.Berezovski, M.Berezovski. Utilization of shape-memory alloys for structural vibration damping. Review of recent publications. Research Report Mech 260/2004.

3.5.4 CENS - CMA

Co-operation of Estonian and Norwegian Scientific Centres within Mathematics and its Applications

In 2004 CENS and the Centre for Mathematics and its Applications (CMA), University of Oslo, started co-operation within computational mathematics.

As the first step the joint seminar was held in Tallinn on 9-10 March, 2004. In their lectures professors R.Winther, T.Lyche, T.Lindstrom (CMA) and dr E.Quak from (CMA, SINTEF) presented main topics of research at CMA. Latest results of the CENS's researchers were presented by J.Engelbrecht, J.Kalda, R.Kitt, T.Soomere, P.Peterson, A.Berezovski, A.Ravasoo, A.Salupere (see CENS seminar, section 5.4).

As a result of the seminar the application for Marie Curie Host Fellowship for Transfer of Knowledge has been prepared.

The twinning of complementary national "Centres of Excellence" in a joint effort within computational mathematics, combined with the inclusion of experienced third-party researchers, is to create a synergy to achieve strong research results at the frontiers of science that no group can reach on its own. One team will contribute modelling expertise (Centre for Nonlinear Studies, CENS, Tallinn University of Technology, Estonia) and the other one mathematical theory (Centre for Mathematics for Applications, CMA, University of Oslo, Norway) to the development of numerical methods. Well-focussed interdisciplinary research projects will be solicited to tackle problems in biomechanics and nonlinear wave modelling. An integral part of the research effort will be the transfer of scientific knowledge to CENS in identified areas of need, such as geometry, which is one of the research pillars of CMA in Oslo, and specifically geometric modelling and processing. The scientific achievements will be complemented by targeted efforts to transfer other important knowledge to CENS: the team from Estonia, a new member state, needs to develop collaborations with international industry, through the Norwegian Foundation for Industrial and Technical Research (SINTEF), which is an official partner of CMA. The CENS team also needs to build institutional competence in international project management to be able to take a serious role in Europe-wide research activities, such as in the EU's FP6 and future FP7, as a mediator for related Estonian industry. In addition the work plans of incoming researchers in Tallinn and outgoing fellows visiting Oslo are to incorporate the development of innovative teaching material at university level (for students in science and technology, and also future teachers) and activities geared towards the popularization of mathematics to raise societal awareness.

The proposal "Co-operation of Estonian and Norwegian Scientific Centres within Mathematics and its Applications" has been favourable evaluated and the process of contract preparation is actually finished.

3.5.5 FP-6, ERA-NET Complexity. Contract N ERAS-CT-2004-011810

Specific Support Action (SSA) is to be completed from 1 August 2004 until 30 April 2005. The SSA involves 9 participants from Belgium, Denmark, Estonia, U.K., Greece, the Netherlands, Portugal and Spain, represented by Research Councils or Ministries of Education and Research. In case of Estonia, the Ministry of Education and Research runs the programme "Estonian Centres of Excellence in Research", one subprogramme of which is that of CENS. The Ministry has authorized Estonian Academy of Sciences (J.Engelbrecht) to represent the Programme.

Objectives. Scientific research has traditionally examined simplified elements extracted from systems in an attempt to establish principles on which they operate and, where possible, to formulate a mathematical model capable of reproducing the behaviour of the original system. However, a large variety of systems with many interacting components show holistic properties when driven out of equilibrium. In these systems coherent structures emerge from the system as a whole, which cannot be explained by the behaviour of the single elements. Such systems, comprising a large number of interactive elements which may organized on many scales, are known as complex systems.

The intriguing thing about complex systems is that it includes examples from almost all aspects of the real and conceptual world, where interactions in the system are associated with exchange of energy or information. Among such examples is the metabolic and signalling network in a living cell of a biological organism, growth of bacterial colonies, spread of deceases, the biocomplex evolution of life encountered in ecosystems (including processes like natural selection), earthquakes, forest fires, and the evolution in financial markets and in social networks. Certain chemical reactions and the transport of light, sound, fluids, and even cars or people generate complex phenomena like turbulence and emerging traffic jams and crowd behaviour.

Complex phenomena are encountered in the communication industry, in optical, micro-electronic and biological materials and chips, in the underground exploration for oil and gas, in the complex distribution networks supplying water and heat, in traffic flows, and not surprisingly in the weather. Here, a rapidly increasing number of new measuring devices and software technologies are being developed by innovative enterprises that have opened new markets, introducing the novel and exciting methods derived from complexity research.

Processes involving many people in interaction are generally complex, and new fields of complexity have emerged to undertake research of such complex processes. One of these is econophysics, dealing with the complex dynamics in economy and in the financial markets, accepting the now ample evidence of non-equilibrium states and so-called fat tales in the distribution of fluctuations in price and in exchange rates. The understanding of complexity in economics has provided the field with new technical indicators, with new insight in risk and volatility, and new measures for putting together a portfolio of stocks.

The science of complexity has emerged from the physical and mathematical science of nonlinear dynamics and non-equilibrium statistical physics. Complex systems evolve in a logical way, but in a way that may not be predictable from the original conditions. Understanding the concept of deterministic chaos and the complex patterns that are formed by nonlinearities has been central steps in the scientific development. Moreover, driven out of equilibrium, complex systems generate fractal structures and scale invariant distributions, and entirely new types of phase transitions have been discovered with a potential great impact on future technologies and new material designs. The observations have given rise to new concepts such as multifractality and self-organized criticality, and entirely new non-equlibrium statistical methods has been introduced to understand the variety of complex phenomena encountered.

In parallel to the concentrated development of a theoretical framework and the numerous experimental discoveries of complex phenomena, a wide variety of computer programming and modelling techniques has been developed. This and the advent of powerful computers have empowered researchers to study in greater detail the emergence and development of complex systems and phenomena. Computers with massive data-handling capacity are constantly being updated to compute ocean and weather conditions. New and better neural network algorithms are being built and refined to imitate the learning process of our brains and adaptive robots based on artificial intelligence are constructed to solve complex problems or control complex systems. Bioinformatic programmes are developed to analyse genomic information from DNA chips in order to reveal the genetic secrets behind our cellular functions.

3.5.6 Marie-Curie return grant

ERG 6, N14826, "Cardiac energetics" - pending

Requested project start date: 01.01.2006

Full title: Cardiac energetics in silico: microcompartmentation of adenine nucleotides and the crosstalk between organelles. Marie Curie Fellow: Marko Vendelin.

The general aim of this project is to study alternations of mitochondrial energetics, microcompartmentation of adenine nucleotides, the crosstalk between intracellular organelles and cellular energy transfer in health and disease using mathematical modeling. The specific goals of this project are 1) to describe microcompartmentation of adenine nucleotides and the crosstalk between organelles in the cardiac muscle cells a 2) to apply the knowledge acquired in studies of isolated mitochondria and skinned cardiac cells to analyze energy transfer the beating heart. For this, we will continue our mathematical modeling of intracellular energy transfer and analyze the energy fluxes estimated for beating heart.

3.5.7 PAPA

EU Contract "Programme for a BAltic network to assess and upgrade an oPerational observing and forecAsting System in the region" (PAPA, 2002-2005). Within this cooperation, possibilities of coupling of circulation, water level, wave and ecological models in the Baltic Sea basin with different resolutions and/or based on different descriptions of the underlying physical processes are analyzed. Existing experience of one-way and two-way coupling in operational oceanographic models is discussed. Details of models that may be used as the large-scale counterparts of the Baltic Sea basin as well as planned local operational models are listed. Areas that may need two-way nesting are identified. Some advanced techniques for model coupling and their relevance for the Baltic Sea conditions are discussed.

PAPA (Programme for a BAltic network to assess and upgrade an oPerational observing and forecAsting System in the region, 2002-2006, coordinator in Estonia Marine Systems Institute) is an interactive network of 15 European centres of excellence in operational ocean monitoring, modelling and forecasting in all Baltic countries. It is mostly focused on the special demands for rapid data delivery, optimal model performance, data exchange, user friendly product dissemination etc. that are required by an operational service. An important constituent of PAPA is the improvement and further development of numerical modelling capabilities with purpose of design of model coupling and local forecasting systems, optimally integrated with observing systems. As contemporary models of the Baltic Sea dynamics require a resolution and computer capacity that cannot be met at all operational institutes, it is an advantage to only run a full Baltic Sea model at one or two places, and to provide an operational interface to local models. There is also an acute need for local models resolving archipelagos and other coastal areas with complicated topography. Water waves group in CENS represents Estonian research into surface wave measurement, analysis and modelling in the PAPA consortium, and leads Task 5.2 targeted to planning a general interface between Baltic Sea models and local (coastal area) operational models. Contractor from CENS – T.Soomere.

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 "Dynamical and optical processes in coastal sea areas", supervisor T.Soomere.

3. Long-term block grant "Bioelectrical signal interpretation", supervisor H.Hinrikus.

4.2 Estonian grants (Estonian Science Foundation)

1. H.Aben, ETF grant 4972, "Nonlinear integrated photo-elasticity", (2001-2005).
2. A.Berezovski, J.Engelbrecht, M.Berezovski, T.Peets, ETF grant 5765, "Numerical simulation of wave propagation in materials with internal interfaces", (2004-2006).
3. J.Janno, A.Ravasoo, ETF grant 4706, "Inverse problems for description of properties and states of inhomogeneous materials", (2001-2004).
4. A.Stulov, ETF grant 5566, "Sound Generation mechanisms in Grand Pianos", (2003-2006).
5. P.Peterson, ETF grant 5767, "Extreme waves: analysis of free surface models", (2004-2007).
6. A.Salupere, ETF grant 5565, "Wave dynamics and wave hierarchy in microstructured materials", (2003-2006).
7. J.Kalda, ETF grant 5036, "Statistical topography for dynamical dissipative systems at self-organized criticality", (2002-2004).
8. T.Soomere, ETF grant 5762, "Wind wave climate of the Baltic Sea and its dependence on nonlinear effects", (2004-2007).
9. V.Tuulik, ETF grant 5625, "Analysis and monitoring of EEG patterns during propofol anesthesia", (2003-2005).
10. H.Hinrikus, ETF grant 5143, "Mechanisms of biological interaction of the EMF", (2002-2005).

4.3 International grants

1. A.Ravasoo. European Science Foundation Programme "Nonlinear Acoustic Techniques for Micro-Scale Damage Diagnostics" (NATEMIS) – see 3.5.1.
2. A.Berezovski. FP-6 "Wide-range Non-intrusive devices toward Conservation of Historical Monuments in the Mediterranean Area (WIND-CHIME) – see 3.5.3.
3. A.Salupere, A.Berezovski. PARROT – see 3.5.2.

4.4 Contracts

1. T.Soomere. EU contract PAPA "Programme for a BAltic network to assess and upgrade an oPerational observing and forecAsting System in the region" (2002-2005; group of water waves contributes to Modelling workpackage).

4.5 International projects

1. M.Vendelin. Marie Curie Fellowship, HPMF-CT-2002-01914, University of Grenoble (2003-2004).

4.6 Additional funding

1. Estonian Programme for Centre of Excellence in Research - block grant.

5. Publicity of Results

5.1.1 Research Reports

1.	Mech 257/04	O.Ilison, A.Salupere. Propagation of sech^2-type solitary waves in higher order KdV-type systems.
2.	Mech 258/04	CENS presentations at ICTAM 04. August 15-21, Warsaw.
3.	Mech 259/04	J.Janno, J.Engelbrecht. Solitary waves in nonlinear microstructured materials.
4.	Mech 260/04	A.Berezovski, M.Berezovski. Utilization of shape-memory alloys for structural vibration damping.
5.	Mech 261/04	A.Berezovski, G.A.Maugin. Moving phase boundaries in solids: I. Thermomechanical description.
6.	Mech 262/04	A.Berezovski, G.A.Maugin. Moving phase boundaries in solids: II. Thermoelastic phases in two dimensions.
7.	Mech 263/04	A.Stulov. Special cases of the piano scale design
8.	Mech 264/04	A.Stulov. Piano hammer-string interaction.
9.	Mech 265/04	A.Ravasoo. Wave interaction in inhomogeneously prestressed materials.
10.	Mech 266/04	A.Braunbrück, A.Ravasoo. Wave interaction resonances in inhomogeneous elastic materials.
11.	Mech 267/04	A.Braunbrück, A.Ravasoo. Nonlinear resonance of waves in inhomogeneous materials.
12.	Mech 268/04	A.Ravasoo. Ultrasonic wave interaction for NDE of inhomogeneous prestress in materials.
13.	Mech 269/04	L.Rebane. Propagation characteristics of coherent optical waves in a stratified medium with Kerr nonlinearity.
14.	Mech 270/04	P.Peterson. Exact evolution of surface waves: potential flow and conformal mapping.
15.	PAPA Report	T.Soomere, S.Dick, M.Gästgifvars, V.Huess, J.W.Nielsen. Project plan for implementation of interfacing between Baltic scale models to local (coastal area) models, Report to EU project PAPA, http://www.boos.org/papa/index.html, PAPA - Model nesting plan, 22pp. (www-publication).

5.1.2 Lecture Notes

1.	Mech 02/04	A.Berezovski. An Introduction to Continuum Mechanics in Material Space.
2.	Mech 03/04	A.Berezovski. Thermodynamics of Finite Volumes.
3.	Mech 04/04	G.Maugin. Generalized Continuum Mechanics: Three Paths; F.Pastrone. Mathematical Models of Microstructured Solids; M.Braun. Nonlinear Elasticity Theory.

5.2 Publications

Books, proceedings and theses

1. Proceedings of the Estonian Academy of Sciences, Engineering (special issue on biomedical engineering) 2004, vol.10, N2, guest editor H.Hinrikus.
2. M.Rahula. Vector Fields and Symmetries, Tartu, Tartu University Press, 2004, 236 p, ISBN 9985-56-861-3 (in Russian).

Papers (refereed)

1. A.Berezovski and G.A.Maugin. On the thermodynamic conditions at moving phase-transition fronts in thermoelastic solids. - J. Non-Equilib. Thermodyn., 2004, 29, 37-51.
2. W.Muschik and A.Berezovski. Thermodynamic interaction between two discrete systems in non-equilibrium. - J. Non-Equilib. Thermodyn., 2004, 29, 237-255.
3. A.Ravasoo. Ultrasonic wave interaction for NDE of inhomogeneous prestress in materials. - In: 2004 ASME International Mechanical Engineering Congress. November 13-19, 2004, Anaheim, California, USA., vol. 3, CD-ROM, 8p.
4. A.Stulov. Piano string motion and spectra. - In: Proceedings of International Symposium on Musical Acoustics, Nara, Japan, March 31 - April 3, 2004, Planting the Grains and Harvesting the Ears. Kyoto : Musical Acoustics Research Group, 2004, 215-218.
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8. A.Stulov. Dynamic behavior and mechanical features of wool felt. - Acta Mechanica, 2004, 169, 1-4, 13-21.
9. M.Säkki, J.Kalda, M.Vainu and M.Laan. - The distribution of low-variability periods in human heartbeat dynamics. Physica A, 2004, 338, 1-2, 255-260.
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12. R.Kitt and J.Kalda. Properties of low-variability periods in financial time series. - Physica A, available online since 11 September, 2004 (vol. 345, 622-634).

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28. A.Erm, T.Soomere. Influence of fast ship waves on the optical properties of sea water in Tallinn Bay, Baltic Sea. Proc. - Estonian Acad. Sci. Biol. Ecol., 2004, 53, 3, 161-178.

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47. A.Errapart, H.Aben, L.Ainola. Photoelastic tomography in linear approximation. - In: Proc. X International Congress & Exposition on Experimental and Applied Mechanics. Costa Mesa, California, 2004, CD-ROM, 8p.

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Abstracts

1. A.Berezovski, G.A.Maugin. Stress-induced martensitic phase transition front propagation. - In: ICTAM04 Abstract Book and CD - ROM Proceedings of 21^{th} International Congress of Theoretical and Applied Mechanics, ICTAM 2004, August 15-21, 2004, Warsaw, Poland, p. 300.

2. A.Berezovski, J.Engelbrecht, G.A.Maugin. Wave propagation in functionally graded materials. - In: ICTAM04 Abstract Book and CD - ROM Proceedings of 21^{th} International Congress of Theoretical and Applied Mechanics, ICTAM 2004, August 15-21, 2004, Warsaw, Poland, p. 266.

3. A.Berezovski, G.A.Maugin. Non-equilibrium description and numerical simulation of phase-transition front propagation in thermoelastic solids. - In: The International Symposium on Trends in Applications of Mathematics to Mechanics (STAMM'2004), Darmstadt, Germany, August 22-27, 2004, Book of Abstracts, pp. 6-7.

4. A.Braunbrück, A.Ravasoo. Wave interaction resonances in inhomogeneous elastic materials. - In: ICTAM04 Abstract Book and CD - ROM Proceedings of 21^{th} International Congress of Theoretical and Applied Mechanics, ICTAM 2004, August 15-21, 2004, Warsaw, Poland, p. 281.

5. A.Braunbrück, A.Ravasoo. Nonlinear resonance of waves in inhomogeneous materials. - In: Int. Symposium on Trends in Applications of Mathematics to Mechanics (STAMM'2004), Final Program, August 22-28, Lufthansa Bildungszentrum Seeheim, Germany, p. 9.

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7. A.Braunbrück, A.Ravasoo. Influence of material inhomogeneity on nonlinear wave interaction. - In: Abstracts, 12th Congress on Sound and Vibration, Lisbon, Portugal, July 11-14, 2005, (submitted).

8. J.Engelbrecht, M.Vendelin. Mathematical modelling of cardiac mechanoenergetics. In: Abstracts, IUTAM Symp. on Mechanics of Biological Tissues. May 27 - June 2, 2004, Graz, Austria, p. 36.

9. O.Ilison, A.Salupere. On the propagation of solitary waves in microstructured solids. - In: ICTAM04 Abstract Book and CD - ROM Proceedings of 21^{th} International Congress of Theoretical and Applied Mechanics, ICTAM 2004, August 15-21, 2004, Warsaw, Poland, p. 275.

10. A.Salupere, J.Engelbrecht. Hidden and driven solitons in microstructured media. - In: ICTAM04 Abstract Book and CD - ROM Proceedings of 21^{th} International Congress of Theoretical and Applied Mechanics, ICTAM 2004, August 15-21, 2004, Warsaw, Poland, p. 278.

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12. A.Stulov. Piano hammer-string interaction. - In: Congress Program and Abstract of ICA 2004, The 18th International Congress on Acoustics "Acoustical Science and Technology for Quality of Life" : Kyoto International Conference Hall, April 4-9, 2004, Kyoto, Japan, p. 188.

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14. R.Põder. Specific properties of waves from high-speed ferries in the coastal area of Tallinn Bay: an application of the cnoidal wave theory. - In: Finalists, 2004 Stockholm Junior Water Prize, Stockholm International Water Institute, 2004, p. 5.

15. K.Rannat, P.Miidla, L.Kulmar, A.Lange. Water vapor tomography for air-space surveillance, Geophys. Res. Abstr., CD-ROM, 2004 p. 6.

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17. A.Erm, T.Soomere. Influence of fast ship waves on the optical properties of sea water in Tallinn Bay. - In: XXIX Congress of the International Association of Theoretical and Applied Limnology, Lahti, Finland, August 8-14, 2004. Abstract Book. International Association of Theoretical and Applied Limnology, Lahti 2004, p. 49.

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19. J.Elken, T.Soomere. Effects of wind regime shift on sediment transport in small bays of non-tidal seas.- In: The Baltic. The 8th Marine Geological Conference, September 23-28, 2004, Tartu, Estonia. Abstracts. Excursion guide. I.Puura, I.Tuuling, T.Hang (Eds.), Institute of Geology, University of Tartu, 2004, p. 11.

20. A.Erm, T.Soomere. Optical measurements of sediment resuspension caused by wakes from fast ferries in the Tallinn Bay. - In: The Baltic. The 8th Marine Geological Conference, September 23-28, 2004, Tartu, Estonia. Abstracts. Excursion guide. I.Puura, I.Tuuling, T.Hang (Eds.), Institute of Geology, University of Tartu, 2004, p. 14.

21. T.Soomere, J.Engelbrecht. Extreme elevations and slopes of interacting Kadomtsev-Petviashvili solitons in shallow water. - In: Rogue Waves 2004, SeaTechWeek 2004, Le Quartz, Brest, France, 20-22 October, 2004, Abstracts, IFREMER, Brest 2004, pp. 38-39.

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23. V.Tuulik, R.Ferenets, J.Lass, J.Helemäe. The new methods for the analysing of surface EMG signals. - In: 78th ICB Seminar, Warsaw, Poland, December 1-4, 2004.

24. H.Hinrikus, M.Bachmann, J. Lass. Quasi-Thermal Effect of Microwave Radiation. - In: Proc. of 3rd International Workshop on Biological Effects of EMF-s, Kos, Greece, October 4-8, 2004, p. 74.

General papers and essays

1. Centre for Nonlinear Studies. - In: E.Lippmaa (ed.) Centres of Excellence of Estonian Science. Tallinn, 2004, pp. 45-57 (the same in Estonian, pp. 43-55).

2. J.Engelbrecht. Mõtterajad. Estonian Academy of Sciences, Tallinn, 2004, 456 pp. , (in Estonian).

3. J.Engelbrecht. Attractors of Thoughts. Estonian Academy of Sciences, Tallinn, 2004, 174 pp.

4. A.Berezovski. Materials with changing properties. - In: Estonian Science Awards. Estonian Acad. Sci., Tallinn, 2004, pp. 48-57, (in Estonian).

5. J.Kalda. Nonlinear intermittent world. - In: Leaves and Stars 2004, ed. by I.Rohtmets, MTÜ Loodusajakiri, 2004, pp. 141-145, (in Estonian).

Submitted papers

1. A.Berezovski and G.A.Maugin. Driving force in simulation of phase transition front propagation. Mechanics of Material Forces, Kluwer, (accepted).

2. A.Berezovski and G.A.Maugin. Stress-induced phase transition front propagation in thermoelastic solids. Eur. J. Mech. Solids, (accepted).

3. J.Engelbrecht, A.Berezovski, F.Pastrone, M.Braun. Waves in microstructured materials and dispersion. Phil. Mag., (accepted).

4. A.Berezovski and G.A.Maugin. Thermomechanics of moving phase boundaries in solids. Proc. 11th International Conference on Fracture, Turin, 2005, (submitted).

5. A.Berezovski, J.Engelbrecht, G.A.Maugin. Dynamics of phase boundaries in thermoelastic solids. Proc. of Third European Conference on Structural Control, Vienna, 2004, (submitted).

6. A.Berezovski and G.A.Maugin. Non-equilibrium description and numerical simulation of phase-transition front propagation in thermoelastic solids. Proc. of the International Symposium on Trends in Applications of Mathematics to Mechanics (STAMM'2004), (accepted).

7. A.Berezovski, J.Engelbrecht, G.A.Maugin. Modelling and numerical simulation of non-classical effects of waves, including phase transition fronts. (NATEMIS book), (submitted).

8. A.Braunbrück and A.Ravasoo. Application of counterpropagating nonlinear waves to material characterization. Acta Mechanica, (accepted).

9. A.Braunbrück and A.Ravasoo. Nonlinear resonance of waves in inhomogeneous materials. Proc. Int. Symposium on Trends in Applications of Mathematics to Mechanics (STAMM'2004) , Aug. 22 - 28, Darmstadt, Germany, (accepted).

10. A.Stulov. Experimental and computational studies of piano hammer. - Acustica - acta acustica, (accepted).

11. J.Kalda. "Oceanic coastline and superuniversality of percolation clusters. - (Phys. Rev. E.).

12. J.Kalda. K-spectrum of aging passive scalars in Lagrangian chaotic fluid flows. - (Phys. Rev. E.).

13. A.Salupere, J.Engelbrecht, O.Ilison, and L.Ilison. On solitons in microstructured solids and granular materials. Mathematics and Computers in Simulation, (accepted).

14. J.Engelbrecht, A.Salupere. On the problem of periodicity and hidden solitons for the KdV model. Chaos, (accepted).

15. O.Ilison, and A.Salupere. Propagation of sech^2-type solitary waves in higher order KdV-type systems. Chaos, Solitons & Fractals, (accepted).

16. T.Soomere. Wind wave statistics in Tallinn Bay, Boreal Environment Research, (submitted).

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18. M.Bachmann, J.Kalda, J.Lass, V.Tuulik, M.Säkki, H.Hinrikus. Method of nonlinear analysis of electroencephalogram for detection of the effect of low-level electromagnetic field. Medical & Biological Engineering & Computing, (accepted).

19. A.Rodina, J.Lass, J.Riipulk, T.Bachmann, H.Hinrikus. Study of Effects of Low-level Microwave Field by Method of Face Masking. Bioelectromagnetics, (submitted).

20. J.Janno, J.Engelbrecht. Solitary waves in nonlinear microstructured materials. J. Phys A. Math. Gen., (submitted).

21. J.Janno, J.Engelbrecht. Waves in microstructured solids: inverse problems. Wave Motion, (submitted).

22. J.Engelbrecht, M.Vendelin. Mathematical Modelling of Cardiac Mechanoenergetics. Proc. IUTAM Symp. on Mechanics of Biological Tissues, (submitted).

23. V.Saks, K.Guerrero, M.Vendelin, J.Engelbrecht, E.Seppet. The creatine kinase isoenzymes in organized metabolic networks and regulation of cellular respiration: a new role for Maxwell's demon. Molecular Physiology of Enzymes, (submitted).

5.3 Conferences

1. Ninth International Workshop on Nonlinear Elasticity in Materials: IWNEM 9, joint with NATEMIS Annual General Workshop 2004, May 30 - June 4, 2004, Blekinge Institute of Technology, Karlskrona, Sweden
   A.Berezovski, J.Engelbrecht, G.A.Maugin. Stress-induced phase transition front propagation in thermoelastic solids.
   A.Ravasoo. Nonlinear effects of wave propagation for prestress evaluation.

2. IUTAM Symposium on Mechanics of Biological Tissue, June 27 - 2 July, 2004, Graz, Austria.
   J.Engelbrecht, M.Vendelin. Mathematical modelling of cardiac mechanoenergetics.

3. Third European Conference of Structural Control, 12-15 July, 2004, Vienna, Austria
   A.Berezovski, J.Engelbrecht, G.A.Maugin. Dynamics of phase boundaries in thermoelastic solids.

4. The XXI International Congress of Theoretical and Applied Mechanics - ICTAM 04, 15-21 August, 2004, Warsaw, Poland
   A.Berezovski, G.A.Maugin. Stress-induced martensitic phase transition front propagation.
   A.Berezovski, J.Engelbrecht, G.A.Maugin. Wave propagation in functionally graded materials.
   Braunbrück A. and Ravasoo A. Wave interaction resonances in inhomogeneous elastic materials.
   O.Ilison, A.Salupere. On the propagation of solitary waves in microstructured solids.
   A.Salupere, J.Engelbrecht. Hidden and driven solitons in microstructured media.
   A.Stulov. Mechanical features of piano hammer felt.
   T.Soomere. Fast ferry traffic as a qualitatively new key factor of environmental processes in non-tidal sea areas.

5. The International Symposium on Trends in Applications of Mathematics to Mechanics – STAMM'2004, 22-28 August, 2004, Seeheim, Darmstadt, Germany
   A.Berezovski, G.A.Maugin. On equilibrium description and numerical simulation of phase-transition front propagation in thermoelastic solids.
   Braunbrück A. and Ravasoo A. Nonlinear resonance of waves in inhomogeneous materials.

6. 2004 ASME International Mechanical Engineering Congress. 13-19 November, 2004, Anaheim, California, USA.
   A.Ravasoo. Ultrasonic wave interaction for NDE of inhomogeneous prestress in materials.

7. International Symposium on Musical Acoustics, ISMA 2004, March 31 - April 3, 2004, Nara, Japan.
   A.Stulov. Piano string motion and spectra.

8. The 18th International Congress on Acoustics, ICA 2004, Kyoto International Conference Hall, 4-9 April, 2004, Kyoto, Japan.
   A.Stulov. Piano hammer-string interaction.

9. The XVth Session of the Russian Acoustical Society, 15-18 November, 2004, Nizhny Novgorod, Russia.
   A.Stulov. On hereditary properties of piano hammers.

10. 22nd IUPAP International Conference On Statistical Physics STATPHYS-22, 4-9 July, 2004, Bangalore, India.
    J.Kalda. Transport of passive scalars by three-dimensional chaotic flows.

11. WSEAS Nonlinear Analysis, Systems and Chaos (NOLASC), 29-31 Detsember, 2004, Ateena.
    R.Kitt. Pareto-Zipf's law in variability of financial time series.

12. EGU General Assembly, 25-30 April, 2004, Nice.
    K.Rannat, P.Miidla, L.Kulmar, A.Lange. Water vapor tomography for air-space surveillance.

13. PAPA Workshop, 23-24 May, 2004, Norrköping, Sweden.
    T.Soomere. Interfacing between Baltic scale models to local (coastal area) models: outcome from PAPA WP5.

14. BALTEX Study Conference, 24-28 May, 2004, Gudhjem, Bornholm.
    S.Keevallik, T.Soomere. Trends in Wind Speed over the Gulf on Finland 1961-2000.

15. The 19th Congress of the International Association of Theoretical and Applied Limnology, 8-14 August, 2004, Lahti, Finland.
    A.Erm, T.Soomere. Influence of fast ship waves on the optical properties of sea water in Tallinn Bay.

16. The 8th Marine Geological Conference, 23-28 September, 2004, Tartu, Estonia.
    J.Elken, T.Soomere. Effects of wind regime shift on sediment transport in small bays of non-tidal seas;
    A.Erm, T.Soomere. Optical measurements of sediment resuspension caused by wakes from fast ferries in the Tallinn Bay.

17. Rogue Waves 2004, SeaTechWeek 2004, Le Quartz, 20-22 October, 2004, Brest, France.
    T.Soomere, J.Engelbrecht. Extreme elevations and slopes of interacting Kadomtsev-Petviashvili solitons in shallow water.

18. ERASTAR Project Promotion Workshop 12-15 January, 2004, Delft, The Netherlands.
    T.Soomere, (discussion only).

19. PAPA WP5 & BOOS Model Group Workshop, 24 February, 2004, Helsinki.
    T.Soomere. Nonlinear interaction of solitonic ship wash.

20. BOOS Annual Meeting & PAPA workshop, 23-25 May, 2004, Norrköping.
    T.Soomere. Interfacing between Baltic scale models to local (coastal area) models: outcome from PAPA WP5.

21. Seminar on water quality in Tallinn Bay, 30 April, 2004, Naissaar, Tallinn.
    T.Soomere. The influence of high speed ship wakes on coastal processes in Tallinn Bay.

22. EUROCEAN 2004, 10-13 May, 2004, Galway, Ireland.
T.Soomere, (discussion only).

23. PAPA WP5 & BOOS Model Group Workshop, 30 June - 01 July, 2004, Helsinki.
T.Soomere. Wind wave statistics in Tallinn Bay with the use of a simple model.

24. BALTDER meeting, Marine Station Hel, 22-24 August, 2004, Poland.
T.Soomere. Fast ferry traffic as a qualitatively new key factor of environmental processes in non-tidal sea areas.

25. PAPA Annual Meeting, Køge, 29-30 November, 2004, Denmark.
T.Soomere, (discussion only).

26. The Stockholm Junior Water Prize 2004, August, 2004, Stockholm.
R.Põder, Specific properties of waves from high-speed ferries in the coastal area of Tallinn Bay: an application of the cnoidal wave theory.

27. Medicon 2004 X Mediterranean Conference on Medical and Biological Engineering, July 31 - 5 August, 2004, Ischia, Italy.
H.Hinrikus. Effect of the Microwave Radiation on Human EEG at Different Modulation Frequencies.
R.Ferenets. Comparing Time-frequency Methods for Estimating Instantaneous Frequency of Spindles During Propofol Anesthesia.
I.Fridolin. Solute Removal Rate Assessment During Hemodialysis Using a Spectrophotometrical Technique.
I.Hlimonenko, (discussion only).

28. 26th Annual International Conference of the IEEE EMBS, San Francisco, 1-5 September, 2004, USA.
J.Lass. Microwave radiation has modulation frequency dependent stimulating effect on human EEG rhythms.
A.Anier. Higuchi Fractal Dimension and Spectral Entropy as Measures of Depth of Sedation in Intensive Care Unit.

29. 3rd International Workshop on Biological Effects of EMF-s, Kos, 4-8 October, 2004, Greece.
H.Hinrikus, M.Bachmann. Quasi-Thermal Effect of Microwave Radiation.

30. WHO, EC, COST281 International Conference on Electromagnetic fields "From Bioeffects to Legislation", 8-9 November, 2004, Ljubljana, Slovenia.
H.Hinrikus. EMF regulations and research in Estonia.

31. International workshop for postgraduate students on Biomedical Engineering, 13-14 October, 2004, Tallinn.
H.Hinrikus. Presentation of the Proc. of the Estonian Academy of Sciences, Engineering 10/2 2004, special issue on Biomedical Engineering.
K.Meigas, J.Lass. Model-based Interpretation of Intramyocardial Electrograms for Cardiac Risk Assessment and Surveillance.
M.Bachmann. Power Spectrum Distinguishes the Effect of Microwave Stimulation on Human EEG at Rest.
A.Rodina. Study of Effects of Low-level Microwave Field by Method of Face Masking.

A.Anier. Higuchi Fractal Dimension and Spectral Entropy as Measures of Depth of Sedation in Intensive Care Unit.
I.Hlimonenko. Pulse Wave Transit Time in Patients With Hyperlipidaemia and Hypertension.

32. International Conference "Geometry in Odessa - 2004, Differential Geometry and its Applications", 18-27 May, 2004, Odessa.
M.Rahula. Vector Fields and Symmetries.

33. International Conference "Secondary Calculus in Mathematics and Theoretical Physics", 17-19 June, 2004, Santo Stefano del Sole, Avellino, Italy.
M.Rahula. Vector Fields and Symmetries.

34. Photonics Europe. Conference No. 5457 "Optical Metrology in Production Engineering", 27-30 April, 2004, Strasbourg.
H.Aben, A.Errapart, L.Ainola, J.Anton. Photoelastic tomography for residual stress measurement in glass.

35. X International Congress & Exposition on Experimental and Applied Mechanics, 7-10 June, 2004, Costa Mesa, California.
A.Errapart, H.Aben, L.Ainola. Photoelastic tomography in linear approximation

36. 12th International Conference on Experimental Mechanics, 31 Aug. - 3 September, 2004, Bari.
H.Aben, A.Errapart. Photoelastic tomography: possibilities and limitations.

5.4 Seminars, workshop

5.4.1 Intensive week "Nonlinear Waves and Applications"

Tallinn, 13-18 September, 2004. The Intensive Week was organized by Centre for Nonlinear Studies (CENS) in the Institute of Cybernetics at TUT. The tutorials were intended mainly for doctoral students, the seminars served the aim to disseminate latest research results. Tutorial lectures were held by professors Gérard A.Maugin (University Pierre and Marie Curie, Paris), Franco Pastrone (University of Torino) and Manfred Braun (Duisburg-Essen University).

Programme of the week included three tutorials:

1.	G.A.Maugin.	Introduction to the mechanics of generalized continua and applications;
2.	M.Braun.	Nonlinear elasticity theory;
3.	F.Pastrone.	Mathematical models of microstructured solids (Cosserat, vectorial microstructure, etc.).

Seminar talks by J.Engelbrecht, A.Salupere, A.Berezovski, J.Kalda, A.Braunbrück, R.Kitt, M.Säkki, L.Ilison, O.Ilison, M.Berezovski, A.Errapart.

Round table talk "Future – new ideas and looks forward" summarized the intensive week seminars. All tutorials are available in Lecture Notes Mech 4/04 "Nonlinear waves and applications", Tallinn 2004.

5.4.2 CMA (Norway) and CENS joint seminar

Tallinn, March 9-10, 2004. The aim of the seminar was to acquaint the researchers of CMA and CENS with the research topics of both centres and to find the common problems for further co-operation.

Programme of the seminar:
J.Engelbrecht. Introduction. CENS and mathematical studies in Estonia.
R.Winther. Introduction. CMA and mathematical studies in Norway.
T.Lyche. "Geometric modelling at CMA."
J.Kalda. "Rough surfaces, statistical topography and geological landscapes".
R.Kitt. "Scale-invariant analysis of financial time-series".
T.Lindstrom. "Stochastic analysis at CMA".
T.Soomere. "The influence of ship wake wash on coasts".
P.Peterson. "Modelling of freak waves".
R.Winther "PDEs at CMA".
A.Berezovski. "Waves in complex microstructured materials".
J.Engelbrecht. "Hierarchy of waves in multi-scale complex materials".
A.Ravasoo. "Acoustodiagnostics of material inhomogeneities".
A.Salupere. "Solitonic structures in systems with complicated dispersion".
J.Kalda. "Intermittent structures and convective diffusion".
E.Quak. "Industrial geometry at SINTEF".
Round Table Summary and the steps ahead.

The seminar resulted in the successful application in the FP-6 Marie Curie ToK Scheme – see 3.5.4.

5.4.3 Workshop on Biomedical Engineering

International workshop for postgraduate students on Biomedical Engineering, October 13-14, 2004, The workshop included presentations of invited speakers: Professor Helmut Hutten from Austria, professor Jos Spaan from Netherlands, professor Jaakko Malmivuo from Finland and dr. Milan Tysler from Slovakia and postgraduate students from Estonian universities. The presentation "Model-based Interpretation of Intramyocardial Electrograms for Cardiac Risk Assessment and Surveillance" given by Professor Hutten touched the monitoring of the patients with cardiac diseases. The latest research in the field of intramyocardial electrograms seems to offer interesting possibilities to improve this kind of monitoring. Professor Spaan demonstrated a model of coronary structure obtained by reconstructing information from the 40 micrometer cutted slices of the real hearth. More profound investigation of the capillaries led to discovery of the tiny villi inside the capillary wall, called glycocalyx. As believed, the villi is directly related to the health of the coronary vessels. An captivating historical review about the formation and origin of the theoretical understanding and technical principles of the EEG and MEG signal measurement was given by Professor Malmivuo. As a conclusion a very democratic suggestion was given that the best results can be revealed in the combination of both methods. Finally Dr Tysler told about several interesting results obtained by modeling of the cardiac electric field in order to detect abnormalities in myocardium e.g. local arrhythmic sources. The workshop continued with the presentations from the Estonian research students. New perspectives in differential servo-oscillometry were described by Jaan Talts from the University of

Tartu (UT) and the presentation about the pulse wave transit time in patients with hyperlipidaemia and hypertension was given by Irina Hlimonenko from the Tallinn University of Technology (TUT). The studies in Focault cardiography were described by Sergei Malchenko (UT), Maie Bachmann from TUT presented research within the topic "Power Spectrum Distinguishes the Effect of Microwave Stimulation on Human EEG at Rest", Andres Anier (TUT) told how the Higuchi fractal dimension and spectral entropy as a measure of sedation depth may be used for monitoring the patients in the intensive care unit, and the presentation given by Anastassia Rodina (TUT) dealing with the study of effects of low-level microwave field by the "face masking" method. Fruitful discussion was interesting and useful for young researchers. The workshop was dedicated to 10th anniversary of the Biomedical Engineering Centre and 54 participants from different countries (Austria, Finland, Greece, Latvia, Netherlands, Slovakkia, Sweden, Estonia) attended.

5.4.4 The 4th Glass Summer School

Tallinn, June 26-28, 2004. An intensive three-day course containing lectures, equipment demonstrations, practical stress measurements and informal discussions. 6 participants (Hungary, Poland, the Netherlands, Belgium, Estonia).

5.4.5 Tallinn Seminars on Mechanics

1. 26.01.2004. Aleksander KLAUSON (TUT). Modelling of the nondestructive testing of metal pipelines.
2. 16.02.2004:
   Priit KULU (TUT). Research and development on the field of material science and technology in the Institute of Material Engineering.
   Irina PREIS (TUT, Institute of Material Engineering). Study of fatigue of the powder composites.
3. 28.04.2004. Irina GORYACHEVA (Institute for Problems of Mechanics, Moscow) Advanced Problems of Contact Mechanics in Tribology.
4. 30.04.2004. Sandor KALISZKI (Budapest Technical University). The Application of Mathematical Programming to the Optimal Design of Elasto-Plastic Structures.
5. 10.05.2004. Andras SZEKERES (Budapest Technical University) Thermo-Hygro-Mechanics and other Fields of Human Culture: History of Science, Art, Literature.
6. 7.09.2004. Yoshiharu MORIMOTO (Japanese Society of Experimental Mechanics, University of Wakayama) Optical Methods and Image Processing for Shape, Deformation and Stress Measurement.
7. 2.12.2004. Hui-Hui DAI (Department of Mathematics, City University of Hong Kong, China) On Constructing the Unique Solution for the Phase Transition in a Hyperelastic Rod.
8. 3.12.2004. Hui-Hui DAI (Department of Mathematics, City University of Hong Kong, China) Dynamical Phase Transitions in Slender Elastic Cylinders: A Nonlinear Wave Approach.

5.4.6 Seminars for post-graduate students

1. Seminar on Applied Mathematics, Institute of Cybernetics, February 2004.
   P.Peterson. Extreme waves.

2. A.Berezovski. Special seminar: "Mechanics of Continuous Media".
   15 March: Basic Concepts of Thermodynamics.
   29 March: Thermodynamic potentials and Maxwell's relations.
   12 April: Thermodynamic Interaction between Two Discrete Systems in Non-Equilibrium.
   26 April: Thermodynamic conditions at discontinuities.

5.5 Seminars outside the home Institute

1. T.Soomere. Natural and anthropogenic waves in non-tidal sea areas.
   Technical University Harburg-Hamburg, Germany, 15 November, 2004.

2. T.Soomere. The role of waves from fast ferries in non-tidal sea areas.
   Kolloquium Mechatronik und Schiffstechnisches Kolloquium, Universitet Duisburg-Essen, 19 November, 2004.

3. T.Soomere. Natural and anthropogenic waves in non-tidal sea area.
   GKSS Geesthacht, Institute for Coastal Research, 23 November, 2004.

4. J.Engelbrecht. Hierarchy of waves in microstructured materials.
   Department of Mathematics, University of Turin, 14 May, 2004.

5.6 Supportive grants (travel, etc.)

1. 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, March 21-28, 2004 Paris, France - A.Berezovski; November 21-28, 2004, A.Salupere.

2. European Science Foundation Programme NATEMIS grant for participating the Ninth International Workshop on Nonlinear Elasticty in Materials: IWNEM 9, joint with NATEMIS Annual General Workshop 2004, May 30- June 4, 2004, Blekinge Institute of Technology, Karlskrona, Sweden - A.Berezovski, A.Ravasoo.

3. Organizing Committee grant for participating the XXI International Congress of Theoretical and Applied Mechanics - ICTAM04, August 15-21, 2004, Warsaw, Poland - J.Engelbrecht, A.Berezovski, A.Braunbrück, A.Stulov.

4. European Science Foundation Grant through the NATEMIS programme for one-week research work in the Department of Physics, Politecnico di Torino, Italy, May 12-18, 2004 - J.Engelbrecht.

5. Grant from Tallinn Technical University PhD Stud. – for participation at the Int. Symp. on Trends in Applications of Mathematics to Mechanics (STAMM'2004), Lufthansa Bildungszentrum Seeheim, Germany, August 22-28, 2004 - A.Braunbrück.

6. Participation at the XVth Session of the Russian Acoustical Society was funded in part through the U.S. Embassy in Tallinn - A.Stulov.

7. Travel grant from Norwegian Academy of Sciences to Trondheim. Norwegian University of Science and Technology (collaboration with the "Complex" laboratory), October 7-21, 2004 - J.Kalda.

8. Participating in Winter School on "Electromagnetic fields and their effects", Chalmers University, January 2004 - L.Rebane.

9. Research on biosignals interpretation, R.Lepikson stipend, Estonian Foundation of National Culture - J.Lass.

10. Estonian Ministry of Education and Research, Kristjan Jaak grant for doctoral study and research at Tampere University of Technology, January 1 - December 31 - R.Ferenets.

11. Erasmus grant for post graduate study at University of Patras, January 4 - May 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 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.

Marine Systems Institute:

- Division of Atmospheric Sciences, Department of Physical Sciences, University of Helsinki, Marie Curie Chair project PBL - TRMES ("Planetary Boundary Layers - Theory, Modelling and Role in Earth Systems"): 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, Implementation of WaMoS in the Baltic Sea.

Centre of Biomedical Engineering:

- COST281 Potential Health Implications from Mobile Communication Systems Estonian Programme on Biomedical Engineering.

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 TUT:
   - Dynamics
   - Statics
   - Continuum Mechanics
   - Special Topics in Mechanics
   - Seminars and Special Seminars for BSc, MSc and PhD students

2. J.Engelbrecht – courses in TUT:
   - Mathematical modelling
   - Biomechanics

3. A.Berezovski – courses in TUT:
   - Special Seminars for BSc, MSc and PhD students

4. J.Kalda :
   - Training of the Estonian and Finnish teams for 35. International Physics Olympiad 15-23 July, Pohang, South Korea Estonian students won two bronze medals and three honourable mentions
   - Participation in the organization of 2nd Estonian-Finnish Olympiad 28-30 April 2004, Tallinn
   - 2nd Academic Olympiad in Physics 11 February. 2004, University of Tartu
   - 51 Estonian Physics Olympiad 7-8 March 2004

5. T.Soomere:
   - Lectures in the Open University course "Design of harbour constructions"
   - Supervising of junior researcher's studies of nonlinear ship waves

6. Courses at TUT:
   - J.Lass, T.Lipping, R.Ferenets – Signal processing
   - J.Lass, T.Lipping, R.Ferenets – Physiological signal processing
   - H.Hinrikus, M.Bachmann – Biological effects of electromagnetic field

Lectures:

1. T.Soomere. Dynamics of Linear and Nonlinear Surface Waves, with Application to the Baltic Sea, University of Helsinki, 20 February 2004.

2. T.Soomere: "Waves from High Speed Ferries in Non-Tidal Areas".
   "Hydrodynamic Studies of Saaremaa Deep Harbour".
   BEST Estonia summer course: "Walk on water - the mystery of hydrostructures".

3. M.Rahula. Universal structure of jet structures. University of Technology, Kaunas, 15-17 November, 2004, and Pedagogical University, Vilnius, 18 November, 2004.

Participation in schools:

1. M.Berezovski: Jyväskylä Summer School 2004, Jyväskylä, Finland, 16-27 August, 2004. SC4: Numerical Simulation of Compressible Flow (20 hours).
2. L.Ilison: Surface Waves in Geomechanics: Direct and Inverse Modeling for Soils and Rocks, 6-10 September, 2004. CISM, Udine, Italy.
3. K.Veski: Best Summer School on Bioelectromagnetism. Tampere, Finland, 9-20 August, 2004.
4. V.Retšnoi, H.Lepp: "7th Diffiety School", Santo Stefano del Sole, Avellino, Italy, July 9-31, 2004.
5. L.Rebane: Winter School. Electromagnetic fields and their effects. Chalmers University, Gothenburg, Sweden, January, 2004.

5.10 Visiting fellows and students (longer periods)

1. Pantelis Theocharakis, University of Patras, Greece, 4 October, 2004 - 5 January, 2005.

5.11 Visiting scholars

1. B.Z.Iliev, Laboratory of Mathematical Modeling in Physics Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences, Sofia, Bulgaria, 26 June - 16 July, 2004.
2. V.Kushnirevych, University of Freiburg, Deutschland, 10-20 December, 2004.
3. Prof. Hui-Hui Dai, Department of Mathematics, City University of Hong Kong, 83 Tat Chee Ave., Kowloon Tong, Hong Kong, China, visited CENS, 1-8 December.
4. Prof. I.Goryatcheva, member of Russian Acad. Sci., Institute for Problems in Mechanics, Moscow, Russia, 28 April, 2004.
5. Prof. S.Kaliszki, Budapest Technical University, Hungary, 30 April, 2004.
6. Prof. Y.Morimoto, Japanese Society of Experimental Mechanics, Japan, 7 September, 2004.
7. Dr. A.Szekeres, Budapest Technical University, Hungary, 10 May, 2004.

   For the Intensive Week, 13-18 September, 2004:

8. Prof. G.Maugin, University of Paris 6, France.
9. Prof. F.Pastrone, University of Turin, Italy.
10. Prof. M.Braun, University Duisburg-Essen, Germany.

For CENS-CMA seminar. 9-10 March, 2004:

11. Prof. R.Winther, CMA, Oslo, Norway.
12. Prof. T.Lyche, CMA, Oslo, Norway.
13. Prof. T.Lindstrom, CMA, Oslo, Norway.
14. Prof. E.Quak, CMA-SINTEF, Oslo, Norway.
15. Prof. H.Galdal, CMA, Oslo, Norway.

For the Workshop on Biomedical Engineering, 13-14 October, 2004:

16. Prof. Dr. H.Hutten, University of Technology, Graz, Austria.
17. Prof. Dr. J.A.E.Spaan, University of Amsterdam, Netherlands.
18. Prof. J.Malmivuo, Tampere University of Technology, Finland.
19. Dr. M.Tysler, Slovak Academy of Sciences, Bratislava, Slovakia.

5.12 Theses

Institute of Cybernetics:
Promoted:

1. BSc:

L.Rebane:	Propagation characteristics of coherent optical waves in a stratified medium with Kerr nonlinearity (supervisors P.Peterson and Y.Tomita, University of Electro-Communications, Tokyo, Japan)
K.Tamm:	Soliton formation in the case of Boussinesq model (supervisor A.Salupere)

2. MSc:

A.Uus:	Magnetic Levitation (supervisor J.Kalda)

In progress:

1. PhD:

A.Braunbrück:	Nonlinear waves for inhomogeneous materials characterization (supervisor A.Ravasoo)
O.Ilison:	Soliton interaction in microstructured materials (supervisor A.Salupere)
L.Ilison:	Solitons and solitary waves in hierarchical Korteweg-de Vries type systems (supervisor A.Salupere)
M.Säkki:	Heart rate variability (supervisor J.Kalda)
R.Kitt:	Financial timeseries (supervisor J.Kalda)
T.Ugam:	Dynamics of the piano sound-board (supervisor J.Engelbrecht)
M.Lemba:	Cell energetics (Fulbright scholarship, Washington University, USA)
J.Anton:	Integrated photoelasticity in case of medium birefringence (supervisor H.Aben)

2. MSc:

K.Tamm:	Wave dynamics in hierarchical systems (supervisor A.Salupere)
M.Sepp:	Bragg-solitons in nonlinear periodic structures (supervisors Y.Tomita and A.Salupere)
M.Berezovski:	Numerical simulation of elastic wave propagation in layered nonlinear media (supervisor J.Engelbrecht)
M.Randrüüt:	Reductive methods for waves in dispersive materials (supervisor J.Engelbrecht)
T.Peets:	Dispersion of waves in microstructured materials (supervisor J.Engelbrecht)

Tartu University:

Promoted:

1. BSc:

O.Bogdanova:	Problems of the mapping theory (supervisor M.Rahula)
H.Lepp:	Tensorial presentations of linear groups (supervisor M.Rahula)

Marine Systems Institute:

In progress:

1. MSc:

A.Kask :	Distribution of sand resources in the coastal area of Northern Estonia (supervisor T.Soomere)

2. PhD:

K.Rannat:	Geophysical applications of weakly nonlinear wave theory in layered medium (supervisor T.Soomere)

Centre of Biomedical Engineering:

Promoted:

1. MSc:

A.Rodina:	Modulated electromagnetic field effect on human perception of visual information (supervisor J.Lass)

2. BSc: H.Pedask, R.Tomson, J.Kalda, V.Tiri, L.Berkis, A.Štšerbakov, G.Vaik.

In progress:

1. MSc:

R.Tomson:	Analysis of the electromagnetic field effect on human EEG (supervisor H.Hinrikus)

2. PhD:

M.Bachmann:	EEG analysis for detection of the effect of microwave radiation on human brain bioelectrical activity (supervisor H.Hinrikus).
R.Ferenets:	Development of indicator, based on EEG, for assessment of the depth of anaesthesia (supervisor T.Lipping).
A.Anier:	Processing neurophysiological signals to assess the depth of sedation in intensive care unit (supervisor T.Lipping)

5.13 Distinctions
Fellows:

1. A.Berezovski – Estonian Science Award in technical sciences for this Studies in phase transformation fronts.

2. J.Engelbrecht – elected to the Academia Europaea.

3. J.Engelbrecht – Sign of Merit from the Ministry of Education and Research.

4. H.Aben – N.Alumäe Lecturer, Tallinn, Sept. 9, 2004.

Students:

1. R.Põder - III award on the contest of Estonian young researchers (Specific properties of waves from high-speed ferries in the coastal area of Tallinn Bay: an application of the cnoidal wave theory, (supervisor T.Soomere).

2. R.Põder - winner of the Estonian Junior Water Prize contest 2004, finalist of the 2004 Stockholm Junior Water Prize, (supervisor T.Soomere)

6. Summary

In 2004, Estonia has joined EU and NATO. Although the EU and NATO programmes have been open for us earlier, the new situation certainly will help consolidate the research. We stress networking, that is why in this Annual Report the international programmes and projects are described in detail. CENS has got the contracts in more than 20 countries worldwide (see 5.7. and Annex).

We have our young people studying and working abroad (Grenoble, Seattle, Tokyo), we have attended many international meetings and welcomed about 20 visitors to CENS. They all have brought new ideas and hopefully got something in return. We have a dozen of PhD students and about the same number of undergraduates working on their theses. The international meetings we have organised have been the meeting-places for seniors and juniors and well accepted by the participants.

We would like to stress the ICTAM 04 – the World Congress of Mechanics (August 2004, Warsaw, Poland). CENS had 7 presentation out of 1300 – that gives us confidence in our studies. We are certainly hoping to improve our publication records in coming years.

We are at the frontier of research in several fields – cell energetics, extreme waves, acoustodiagnostics, phase transformation, photoelasticity, fractal analysis, etc. That calls us to intensify the studies, based on recent results and supported by networking. The rising number of young people and the efforts of fellows, including 5 Estonian Science Prize Awardees are the promising conditions for that.

Given the importance of marine research, the research group in this field will be reorganised to be better focused, the modelling of cardiac energetics will hopefully pay more attention to geometry. The research within Complexity network will add more interdisciplinarity to CENS activities.

Annex: Networking

For building up the European Research Area, networking is crucial. CENS has got many contracts through various activities. Below is the lists of partners through joint programmes, contracts, etc (vf. also 5.7).

NATEMIS

Politechnics of Torino, Italy
Institute of Acoustics, CSIC, Madrid, Spain
University of Karlskrona-Ronneby, Sweden
Institute of Thermomechanics, Czech Academy of Sciences, Prague, Czech Republic
Catholic University of Leuven, Belgium
Fraunhofer. Institute for Nondestructive Testing, Saarbrücken, Germany

PARROT

For 2003 – 2004:
University of Paris 6, France

For 2005 – 2006:
IRCAM, Centre Pompidou, Paris, France
Ecole Nationale Superieure, Palaiseau, France
CNRS Laboratoire de Mecanique et d'Acoustique, Marseille, France

6 FP WIND – CHIME

University of Pavia, Italy
SIART: Sistemi Informatici Analisi Rischio Territoriale e Ambintale, Pavia, Italy
Institut National du Patrimoine, Tunis, Tunisie
Institut National de Meteorologie, Tunis, Tunisie
University of Cairo, Giza, Egypt
Ethnikon Metsovion Polytechnion, Athens, Greece
Ecole Polytechnique de Tunisie, La Marsa, Tunisie
Jordan University of Science and Technology, Irbid, Jordan
SINTEF Materials Technology, Trondheim, Norway
Universite Tlemcen, Tlemcen, Algerie.

ERA–NET Complexity

Research Councils / Ministries from Belgium, Denmark, United Kingdom, Grece, the Netherlands, Portugal, Spain.

The programmes include research in the Free University of Brussels (Prof. G.Nicolis), University of Patras (Prof. T.Bountis), etc.

CENS – CMA

Twinning of CENS, Tallinn, Estonia and CMA (Centre of Mathematics for Applications), Oslo, Norway.

PAPA

Danish Meteorological Institute, DMI, Denmark
The Federal Maritime and Hydrographic Agency, BSH, Germany
Centre of Marine Research, CMR, Lithuania
Marine Systems Institute, MSI, Estonia
Finnish Institute of Marine Research, FIMR, Finland
Finnish Environmental Agency, FEA, Finland
Institute of Meteorology and Water Management, IMWM, Poland
Institute of Oceanology, IOPAS, Poland
Institute fur Ostseeforschung Warnemunde, IOW, Germany
Latvian Hydrometeorological Agency, LHMA, Latvia
Maritime Institute of Gdansk, MIG, Poland
North-West Regional Administration for Hydrometeorology and Environmental Monitoring, NWAHEM, Russia
Royal Danish Administration of Navigation and Hydrography, RDANH, Denmark
Swedish Meteorological and Hydrological Institute, SMHI, Sweden
University of Latvia, UL, Latvia

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