ESTONIA

PROGRAMME for the Centres of Excellence in Research, Ministry of Education and Research

SUBPROGRAMME I: Centre for Nonlinear Ctudies (CENS), Institute of Cybernetics at the Tallinn Technical University, Akadeemia 21, 12618 Tallinn, Estonia.
Head of CENSS – Prof. J. Engelbrecht
Staff: 18 PhD-level fellows (incl 3 DSc) and students (see below)

FUNDING: basic funding + programme (ca 60% in addition)

MAIN ACTIVITIES:

Fractality in nature (supervisor Dr J. Kalda) – statistical topography, heart rate variability, turbulent diffusion, econophysics.
Self-organized criticality is studied by introducing new scale-invariant characteristics (measures) of self-affine surfaces. Surface roughening processes are modelled. The examples include surfaces of geological landscapes, gradient-limited surfaces, isodensity lines of passively convected scalars, streamlines of turbulent flows, etc. Special attention is paid to geometrical to the mixing of flows with turbulent power spectra. Studies in econophysics involve modelling of the intrinsic complexity of the market dynamics. After introducing the concepts of scale-invariance, intermittency, ao, new scale-invariant methods of the market fluctuation analysis are derived. The various measures of the heart rate variability have a great importance in cardiology having prognostic and diagnostic significance. Here the generalized scale-invariant aspects of the heart rate variability are studied, in particular the length-distribution of low-variability regions. The results can be used in clinical diagnostics.

Complexity in nonlinear wave motion (supervisor Prof. J. Engelbrecht) – solitonics and coherent wave fields, phase-transformation fronts, anomalies of water waves, extreme waves.
Nonlinear and dispersive effects influence greatly the wave fields in microstructured materials (alloys, granular materials, functionally graded materials, etc) and are also of importance for water waves. For that purpose, several mathematical models are derived: evolution equations of the Korteweg-de Vries type, hierarchical scale-dependent equations, compound systems, etc. Analysis is carried out using the pseudo-spectral method and the composite wave-propagation algorithm. Several types of solitary wave ensembles are analysed. The stress-driven phase-transformation fronts are shown to have a complex structure. The coherence of the solutions of the classical Korteweg-de Vries model is established. Soliton interaction is studied for 1D and 2D cases. The last interaction may cause rogue waves on the sea surface. The experiments in Tallinn Bay support the results and further experiments are planned in Marine laboratory at Enschede. Another set of experiments (Coriolis laboratory in Grenoble) has demonstrated the existence of complex system of vortex pairs that wait for the theoretical explanation. On the basis of the theoretical analysis involving nonlinearities, the inverse problems are solved where nonlinear effects can considerably enhance the informative power of methods. The methods include NDT

for inhomogeneous and prestressed materials and determining the wave amplitudes of water waves from the geometry on interacting crests. So the idea is to use complexity as an additional source of information.

Complexity in biophysics (supervisor Dr M. Vendelin) – *in silico* modelling of cardiac contraction and cell energetics, internal variables.
Cardiac contraction is strongly related to structural and functional interactions between mitochondria, myofibrils and sarcoplasmic reticulum in cardiac muscle cells. The oxygen consumption and the ATP transfer are the main physiological mechanisms for proper functioning of cardiac muscles that have hierarchical structure. The cardiac contraction is based on hierarchical modelling using the concept of internal variables derived originally for thermodynamics. These internal variables are related to cellular processes and affect the active stress in the cardiac muscle. The mathematical modelling of cellular processes especially those based on the diffusion play an important role in all the cardiac processes. The complex modelling bridges so continuum mechanics, physiology, cell energetics and computational methods, all spiced by nonlinearities. An overview on such a complex modelling is being prepared.

Research training: presently 16 graduate and undergraduate students, Annual Schools for graduate students within the programme (2003 – Nonlinear Processes in Marine Sciences; 2004 – Nonlinear Waves and Applications).

Networking: ESF programme NATEMIS, participation in the 6th FP, M. Curie ToK Programme (twinning with the Centre of Mathematical Applications, Oslo, Norway, evaluated as "A", waiting for the contract), bilateral agreements (Paris 6, Turin, Enschede, Loughborough, etc).

Web page: http://cens.ioc.ee (also Annual Reports)

References: Centres of Excellence of Estonian Science (Ed by E. Lippmaa). Association of Centres of Excellence. Tallinn, 2004, 45-57.

SUBPROGRAMME II: Centre for Dependable Computing (CDC), Institute of Cybernetics at the Tallinn Technical University, Akadeemia 21, 12618 Tallinn, Estonia
Head of CDC – Prof. J. Penjam
Staff: 24 PhD-level fellows and students

FUNDING: basic funding + programme funding

MAIN ACTIVITIES:

Complexity in software-intensive systems (supervisor Prof. L. Motus) – time-aware interaction-centred models of computation, time-counting systems with multiple metric times and simultaneous use for three time concepts, holistic self-organizing systems.
The joint research team comprises Real-time systems group (Tallinn University of Technology) and Laboratory for proactive technologies (Tartu University, Institute of

Technology). Theoretical study focuses on enhancing the concept of multi-stream interaction machine (P. Wegner) with sophisticated time counting system so as to analyse time-correctness of interactions in a forced concurrent stream processing environment. At the same time continues study of the sophisticated time model and development of taxonomy for models of computation (from Turing computations to super-Turing computations, plus time-aware computations). The theoretical research proceeds in conjunction with experiments on pilot projects.

Pilot projects are – design and building a test-bed for experimental validation of the theoretical result (KRATT – for building and studying multi-agent systems); multi-agent system for building a family of tailored applications based on digital map processing; modelling a human-centric organisation; modelling fragments of metabolic system of a bacterium; studying a multi-agent system based on the paradigm of anthill; some of the above-listed pilot projects are being implemented on an experimental heterogeneous computer network (internet plus multi-hop *ad hoc* sensor/actuator network).

Software complexity (supervisor Prof. E. Tyugu) – structural and computational complexity in distributed computing and web-based applications.
Software complexity of dependable systems has been and still is the main reason of mission-critical failures. Methods of structural synthesis, decomposition and verification are being used to increase the reliability of complex software. Grid computing, semantic web and web services strongly rely on structural descriptions, decomposition and encapsulation as methods of handling complex software. Nonclassical logic and algebraic methods are being used as instruments both in analysis and synthesis of software artifacts. Results in computational complexity obtained in theoretical computer science are being used to guide the design of structure of distributed systems, in particular, for reducing time complexity of computations by rational design of structure of distributed computing systems.

Research training: presently 24 graduate students, winter and summer schools, master classes.

Networking: Five EU projects: APPSEM II, CoLogNet, eVikings II, REASON, OpenEvidence.

Web page: http://cdc.ioc.ee/

References: Centres of Excellence of Estonian Science (Ed by E. Lippmaa). Association of Centres of Excellence. Tallinn, 2004, 153-163.