

TTÜ KÜBERNEETIKA INSTITUUT
TEADUS- JA ARENDUSTEGEVUSE AASTAARUANNE 2013

3.1 Instituudi struktuur

TTÜ Küberneetika Instituut, Institute of Cybernetics at Tallinn University of Technology **Instituudi direktor Andrus Salupere**

- Juhtimissüsteemide osakond, Control Systems Department, head Jüri Vain
 - Foneetika ja kõnetehnoloogia laboratoorium, Laboratory of Phonetics and Speech Technology, head Einar Meister
- Mehaanika ja rakendusmatemaatika osakond, Mechanics and Applied Mathematics Department, head Jüri Engelbrecht
 - Fotoelastsuse laboratoorium, Laboratory of Photoelasticity, head Hillar Aben
 - Lainetuse dünaamika laboratoorium, Wave Engineering Laboratory, head Tarmo Soomere
 - Süsteemibioloogia laboratoorium, Laboratory of Systems Biology, head Marko Vendelin
- Tarkvara osakond, Software Department, head Ahto Kalja
- Raamatukogu, Library, head Marje Tamm

Instituudi teadustöö koordineerimine toimub kahe Eesti teaduse tippkeskuse raames: Arvutiteaduse tippkeskus EXCS, Estonian EXcellence in Computer Science EXCS, head Tarmo Uustalu.

Mittelineaarsete protsesside analüüsi keskus CENS, Centre for Nonlinear Studies, head Jüri Engelbrecht.

3.2. Instituudi teadus- ja arendustegevuse (edaspidi T&A) iseloomustus

Struktuuriüksuse koosseisu kuuluvate uurimisgruppide teadustöö kirjeldus 3.2.1.1, aruandeaastal saadud tähtsamad teadustulemused 3.2.1.2 ja olulisemad publikatsioonid 3.2.1.3

MAIN LINES OF RESEARCH

NONLINEAR DYNAMICS

Nonlinear Dynamics group deals with (i) nonlinear wave motion in solids; (ii) soft matter physics; (iii) photoelasticity. Attention is on hierarchical behaviour of microstructured solids under dynamical impact and corresponding inverse problems; solitons and solitary waves; turbulent mixing; processes with power laws; nonlinear photoelastic tomography.

Main results in 2013:

The concept of internal variables is generalized for describing the internal structure of materials as internal fields.

The negative group velocity is proved to exist for a Mindlin-type multiscale and a felt-type materials.

A novel wave equation for felt-type materials is proposed and analysed.

A universal relationship between the scaling exponents has been established describing the time-fluctuations of the intersection size of two moving fractal sets.

A novel device for optimal mixing of two compounds has been devised, which maximizes homogeneity of mixing, as described via finite-time Lyapunov exponents.

Existence of hidden solitons is demonstrated for a hierarchical KdV system in case of three types of initial conditions, dependencies between the number of hidden solitons and material parameters as well as initial wave parameters are established.

An orthotropic constitutive model for fibre reinforced materials based on the orientation distribution function of fibres has been proposed.

SELECTED PUBLICATIONS

1. Berezovski, A., Engelbrecht, J., Salupere, A., Tamm, K., Peets, T., Berezovski, M. (2013). Dispersive waves in microstructured solids. *Int. J. Solids Structures*, 50, 1981–1990.
2. Peets, T., Kartofelev, D., Tamm, K., Engelbrecht, J. (2013). Waves in microstructured solids and negative group velocity. *Europhys. Letters – EPL*, 103, 16001 (6pp).
3. Mandre, J., Kalda J. (2013). Efficient method of finding scaling exponents from finite-size Monte-Carlo simulations. *European Physical J. B*, 86(2), 56-1-6.
4. Suuronen, J.-P., Kallonen, A., Eik, M., Puttonen, J., Serimaa, R., Herrmann, H. (2013). Analysis of short fibres orientation in steel fibre-reinforced concrete (SFRC) by X-ray tomography. *Journal of Materials Science*, 48(3), 1358–1367.
5. Chen, Y., Lochegnies, D., Defontaine, R., Anton, J., Aben, H., Langlais, R. (2013). Measuring the 2D residual surface stress mapping in tempered glass under the cooling jets: the influence of process parameters on the stress homogeneity and isotropy. *Strain*, vol. 49, 61–67.

CONTACT: Prof, Jüri Engelbrecht, e-mail: je@ioc.ee

WAVE ENGINEERING

Wave Engineering group has competence in nonlinear wave theory and modelling of fluids with the focus on applications in the marine and coastal environments. Attention is to wave excitation and propagation over the sea surface; impact of waves in coastal regions; unified framework for wave-driven phenomena.

Main results in 2013:

It was shown that the pattern of most frequently hit coastal sections, the probability of hit to each such section and the time the pollution spends offshore are almost insensitive with respect to the absence or presence of eddy-diffusivity effects.

Analytical theory of tsunami generation by submarine landslides was extended to the case of narrow bays and channels of various geometries.

The possibility of rogue wave formation due to the modulational instability has been demonstrated in a basin of intermediate depth.

Wind wave climatology in the eastern part of the Baltic Sea has been extended back to 1946.

A novel method making use of spectrogram analysis has been applied to quantify the duration, intensity and frequency distribution of wake waves from high-speed ferries.

The maximum wave set-up forms >50% of the all-time maximum water level and thus serves as a substantial source of marine hazard for low-lying regions of the City of Tallinn.

SELECTED PUBLICATIONS

1. Delpeche-Ellmann, N. C.; Soomere, T (2013). Investigating the Marine Protected Areas most at risk of current-driven pollution in the Gulf of Finland, the Baltic Sea, using a Lagrangian transport model. *Marine Pollution Bulletin*, 67(1-2), 121 - 129.
2. Didenkulova, I.I.; Nikolkina, I.F.; Pelinovskii, E.N. (2013). Rogue waves in the basin of intermediate depth and the possibility of their formation due to the modulational instability. *JETP Letters*, 97, 194 – 198.
3. Didenkulova, I.; Pelinovsky, E. (2013). Analytical solutions for tsunami waves generated by submarine landslides in narrow bays and channels. *Pure and Applied Geophysics*, 170(9-10), 1661 - 1671.
4. Soomere, T.; Pindsoo, K.; Bishop, S. R.; Käär, A., Valdmann, A. (2013). Mapping wave set-up near a complex geometric urban coastline. *Natural Hazards and Earth System Sciences*. 13, 11, 3049-3061
5. Viikmäe, B.; Torsvik, T.; Soomere, T. (2013). Impact of horizontal eddy-diffusivity on Lagrangian statistics for coastal pollution from a major marine fairway. *Ocean Dynamics*, 63(5), 589 - 597.

CONTACT: Prof Tarmo Soomere, e-mail: soomere@cs.ioc.ee

SYSTEMS BIOLOGY

Systems Biology group is focused on unravelling the intricacies behind regulation of intracellular processes in cardiac muscle cells. Efforts are mostly concentrated on studying regulatory mechanisms of metabolic processes in the heart, expanding our knowledge of cardiac energetics and contractile function, and shedding light on novel aspects of excitation-contraction coupling in rat, trout and mouse hearts. Both experimental and computational approaches are applied in investigating these topics.

Main results in 2013

In creatine-deficient mice study we demonstrate that the healthy heart is able to preserve cardiac function at a basal level in the absence of creatine kinase-facilitated energy transfer without compromising intracellular organization and the regulation of mitochondrial energy homeostasis.

We have shown that ADP potently restores calcium retention capacity in severely stressed mitochondria. This effect is most likely not related to a reduction in reactive oxygen species production.

SELECTED PUBLICATIONS

1. Branovets, J.; Sepp, M.; Kotlyarova, S.; Jepihhina, N.; Sokolova, N.; Aksentijevic, D.; Lygate, C. A.; Neubauer, S.; Vendelin, M.; Birkedal, R (2013). Unchanged mitochondrial organization and compartmentation of high-energy phosphates in creatine-deficient *GAMT(-/-)* mouse hearts. *American Journal of Physiology-Heart and Circulatory Physiology*, 305(4), H506 - H520..
2. Kalda, M.; Peterson, P.; Engelbrecht, J.; Vendelin, M. (2013). A cross-bridge model describing the mechanoenergetics of actomyosin interaction. In: *Computer Models in Biomechanics : From Nano to Macro: (Toim.)* Holzapfel, Gerhard A.; Kuhl, Ellen. Dordrecht: Springer, 2013, 91 - 102..
3. Sokolova, N., Pan, S., Provazza, S., Beutner, G., Vendelin, M., Birkedal, R., Sheu, S.-S. (2013). ADP protects cardiac mitochondria under severe oxidative stress. - *PLOS ONE*, 2013, 8, 12, e83214, 1-12.

CONTACT: Dr Marko Vendelin, e-mail: markov@sysbio.ioc.ee

NONLINEAR CONTROL THEORY

Nonlinear Control Theory group has competence in dynamical control systems on time scales. Attention is focused on novel algebraic methods and symbolic software tools for solving fundamental problems for nonlinear control systems towards unification of discrete- and continuous-time control.

Main results in 2013

Computational aspects of realization of a set of higher-order nonlinear input/output equations in the state space form were studied. Instead of the algorithmic solutions, provided in earlier works, the explicit formulas, based on the concept of adjoint polynomials, were obtained.

The disturbance decoupling problem by the dynamic measurement feedback for discrete-time nonlinear control systems was studied. To address the problem the algebraic approach, called the algebra of functions, was applied, which allows the system description also depend on non-differentiable functions. A necessary and sufficient condition was given in terms of controlled and (h, f)-invariant functions. Also, algorithms were derived, which find invariant functions and the required feedback.

SELECTED PUBLICATIONS

1. Bartosiewicz, Z.; Kotta, Ü.; Pawluszewicz, E.; Tönso, M. (2013). Algebraic formalism of differential p -forms and vector fields for nonlinear control systems on homogeneous time scales. Proceedings of the Estonian Academy of Sciences, 62 (4), 215-226
2. Bartosiewicz, Z.; Kotta, Ü.; Pawluszewicz, E.; Tönso, M.; Wyrwas, M. (2013). Reducibility condition for nonlinear discrete-time systems: behavioral approach. Control and Cybernetics, 42(2), 329 - 347
3. Kaldmäe, A.; Kotta, Ü.; Shumsky, Al.; Zhirabok, A. (2013). Measurement feedback disturbance decoupling in discrete-time nonlinear systems. Automatica, 49(9), 2887 - 2891.
4. Kaparin, V.; Kotta, Ü.; Mullari, T. (2013). Extended observer form: simple existence conditions. International Journal of Control, 86(5), 794 - 803.
5. Kotta, Ü.; Tönso, M.; Shumsky, A. Y.; Zhirabok, A. N. (2013). Feedback linearization and lattice theory. Systems & Control Letters, 62(3), 248 - 255.

CONTACT: DSc Ülle Kotta, e-mail: kotta@ioc.ee

SOFTWARE SCIENCE

The software department conducts research into language and automata theory, programming languages and software engineering.

Main results in 2013:

Language and automata theory:

The partial atomaton of a given nondeterministic finite automaton, using its partial atoms as states, was studied.

Bartholdi's characterization of amenable groups as those where surjective cellular automata preserve the product measure was sharpened.

Programming languages:

A new class of monads - update monads - relevant for mathematically structured functional programming was identified.

The core of Cockett and Lack's theory of restriction categories was formalized in the dependently typed programming language Agda.-

First steps were made towards developing a framework for programming with rational datatypes in Agda.

Abstract and concrete process categories were studied as semantic domains for functional reactive programming.

A new syntactic type system was devised for recursive types, type parameters and abstract types.

Software engineering;

A semantic interoperability framework for developed for big data.

SELECTED PUBLICATIONS

1. Ahman, D., Uustalu, T. (2013). Distributive laws of directed containers. *Progress in Informatics*, v. 10, pp. 3-18.
2. Capobianco, S., Guillon, P., Kar, J. (2013). Surjective cellular automata far from the Garden of Eden. *Discr. Math. And Theor. Comput. Sci.*, v. 15, n. 3, pp. 41-60.
3. Maigre, R., Grigorenko, P., Haav, H.-M., A. Kalja, A. (2013). A semantic method of automatic composition of e-government services. In: A. Caplinskas, G. Dzemyda, A. Lupeikiene, O. Vasilecas, (Eds), *Databases and Information Systems VII*, v. 249 of *Frontiers of Artificial Intelligence*, pp. 204-217. IOS Press.
4. Ojamaa, A., Kotkas, V. Spichakova, M., Penjam, J. (2013). Developing a lean mass customization based manufacturing. In *Pro.c. of 16th IEEE Int. Conf. on Computational Science and Engineering, CSE '13 (Sydney, Dec. 2013)*, pp. 28-33. IEEE.
5. Rafnsson, W., Nakata, K., Sabelfeld, A. (2013). Securing class initialization in Java-like languages. *IEEE Trans. on Dependable and Secure Computing*, v. 10, n. 1, pp. 1-13.

CONTACT: Dr Tarmo Uustalu, tarmo@cs.ioc.ee

SPEECH TECHNOLOGY

Laboratory of Phonetics and Speech Technology is focused on experimental studies of Estonian phonetics and research and development of methods and prototypes for Estonian speech recognition.

Main results in 2013

The role of Estonian orthography on the L2 production of Estonia quantity contrasts has been studied. The results showed that L2 subjects with Finnish-language background are able to produce quantity contrasts only in words where the contrasts are explicitly expressed in the orthography. The comparative study of the acoustic features of contrastively accented words in Finnish and Estonian showed that in two closely related languages duration and F0 act as primary cues to manifest contrastive accent, however, significant differences in the two languages exist. A phone duration model applied to speech recognition has been developed. The model is based on a decision tree that finds clusters of phones in various contexts that tend to have similar durations. Experiments on two Estonian recognition tasks show a small but significant improvement in speech recognition accuracy.

A new neural network language model was developed that jointly models the language of many related domains. It is implemented by training a vector of factors for each domain that is used to modulate the connections between the layers of the model. The model is found to outperform simple neural network language models in speech recognition experiments

Adaptor Grammars is a framework for learning non-parametric Bayesian models in the setting where the data generation can be described with a probabilistic context-free grammar. We proposed a model selection method for Adaptor Grammars that enables to choose automatically the best grammar for the given task using a small set of labeled data. We applied the method to the task of natural language morphological segmentation and showed that it yields state-of-the-art results

SELECTED PUBLICATIONS

1. Alumäe, T. (2013). Multi-domain neural network language model. In: Interspeech 2013 : 14th Annual Conference of the International Speech Communication Association, Lyon, France, 25-29 August, Proceedings: Lyon, France: International Speech Communication Association, 2013, 2182 - 2186. .
2. Alumäe, T., Nemoto, R. (2013). Phone duration modeling using clustering of rich contexts. In: Interspeech 2013 : 14th Annual Conference of the International Speech Communication Association, Lyon, France, 25-29 August, Proceedings: Lyon, France: International Speech Communication Association, 2013, 1801 - 1805.
3. Meister, E., Meister, L. (2013). Production of Estonian quantity contrasts by native speakers of Finnish. In: Interspeech 2013: 14th Annual Conference of the International Speech Communication Association, Lyon, France, 25-29 August, Proceedings: Lyon, France: International Speech Communication Association, 2013, 330 - 334.
4. Sirts, K., Goldwater, S. (2013). Minimally-supervised morphological segmentation using adaptor grammars. Transactions of the Association for Computational Linguistics, 1, 255 - 266.
5. Suomi, K., Meister, E., Ylitalo, R., Meister, L. (2013). Durational patterns in Northern Estonian and Northern Finnish. Journal of Phonetics, 41(1), 1 - 16.

CONTACT: Dr Einar Meister, e-mail: einar@ioc.ee

APPLIED MATHEMATICS

Applied mathematics group is focused on fast methods for solving integral equations, inverse problems to determine properties of complex materials and multi-objective and convex optimisation.

Main results in 2013:

Uniqueness for the solution of an inverse problem for 1D linear model of microstructure with multiple scales using Gaussian wave packets was proved. An analytical-numerical method to study the uniqueness of solutions to inverse problems to determine coefficients of 5th order KdV and 6th order generalized Boussinesq equation was elaborated.

SELECTED PUBLICATIONS

1. Kangro, I., Kangro, R., Vaarmann, O. (2013). Some approximate Gauss-Newton-type methods for nonlinear ill-posed problems. Proceedings of the Estonian Academy of Sciences, 62(4), 227-237.
2. Riismaa, Tiit (2013). A method for description and optimization the structure of multi-level selection procedure. In: OAS 2013 : Proceedings of the 2nd International Conference Optimization and Analysis of Structures, Tartu, Estonia, August 25-27, 2013: (Ed) Lellep, J.; Puman, E.. Tartu: University of Tartu Press, 2013, 135 - 140.
- 3.

CONTACT: Prof Jaan Janno, e-mail: janno@ioc.ee

3.2.2 Loetelu struktuuriüksuse töötajate rahvusvahelistest tunnustustest.

Tarmo Soomere sai Balti Teaduste Akadeemiate medali silmapaistvate tulemuste eest Eesti, Läti ja Leedu mereuuringute alases koostöös.

3.2.3 Loetelu struktuuriüksuse töötajatest, kes on välisakadeemiate või muude oluliste T&A-ga seotud välisorganisatsioonide liikmed.

Tanel Alumäe

International Speech Communication Association (ISCA) - liige

Jüri Engelbrecht

ICSU Peaassamblee liige

Euromech liige

ERAWATCH nõukoja liige

RP7 „Peoples Programme“ nõukoja liige

ERA-NET Complexity juhtkomitee liige

Academia Europea, liige

World Academy of Arts and Sciences liige

Bulgaaria Teaduste Akadeemia välisliige

Budapesti Tehnikaülikooli audoktor (Dr. h.c.)

Ungari Teaduste Akadeemia, auliige

Göteborgi Kuningliku Teadus- ja Kunstiühingu välisliige

Lissaboni Teaduste Akadeemia liige

Läti Teaduste Akadeemia, välisliige

Euroopa Teaduste ja Kunstide Akadeemia liige

Accademia Peloritana dei Pericolanti, välisliige

Hele-Mai Haav

Baltic Journal of Modern Computing- toimetuskolleegiumi liige

Proceedings of Riga Technical University - toimetuskolleegiumi liige

European Coordinating Committee for Artificial Intelligence (ECCAI) liige ja Eesti koordinaator

Jaan Janno

Abstract and Applied Analysis - toimetuskolleegiumi liige

Mathematical Modelling and Analysis – toimetuskolleegiumi liige

The Open Acoustics Journal - toimetuskolleegiumi liige

Baltimaade ülikoolide konverentsivõrgustiku MMA liige

Jaan Kalda

Advisory Board of the International Physics Olympiads – liige

International Jury of the World Physics Olympiad – liige

European Academy of Sciences and Arts – liige

Ahto Kalja

Baltic Journal of Modern Computing- toimetuskolleegiumi liige

Einar Meister

International Speech Communication Association (ISCA) - liige

Lya Meister

International Speech Communication Association (ISCA) - liige

Sven Nõmm

Rahvusvaheline Automaatjuhtimise Föderatsiooni (IFAC) Eesti rahvusliku komitee kontaktisik
IFAC Technical committee "Human - Machine Systems" - liige.

Jaan Penjam

EL 7. Raamkava IST programmi programmkomitee Eesti delegatsiooni ekspert
ACM – Association for Computing Machinery – liige

Ewald Quak

Journal of Mathematics in Industry, Springer, toimetuskolleegiumi liige
EL RP7 programmi „People“ Marie Curie Industry-Academia Partnerships and Pathways (IAPP)
taotlusi hindava paneeli aseesimees

Arvi Ravasoo

Euroopa Mehaanikaühingu Euromech liige
Euroopa Eksperimentaalmehaanika Alalise Komitee liige

Andrus Salupere

IUTAM (International Union of Theoretical and Applied Mechanics) peaassamblee liige
Eesti Rahvusliku Mehaanika Komitee esimees
Euroopa Mehaanikaühingu Euromech liige

Tarmo Soomere

Euroopa Teadusfondi Merekomitee aseesimees
Journal of Marine Systems toimetuskolleegiumi liige
Boreal Environment Research toimetuskolleegiumi liige
Oceanologia toimetuskolleegiumi liige
Euroopa Geoteaduste Liidu liige
Euroopa Akadeemiate Nõuandva Kogu Keskkonnapaneele liige

Enn Tõugu

IEEE liige
IEEE Computer Society, liige
Academia Europea, liige
Computing and Informatics /Slovak Acad Sci) toimetuskolleegiumi liige
Knowledge Based Systems (Elsevier) toimetuskolleegiumi liige

Tarmo Uustalu

International Federation for Information Processing (IFIP), WG 2.1 „Algorithmic Languages and Calculi“ liige
Journal of Universal Computer Science toimetuskolleegiumi liige
Association for Computing Machinery (ACM), liige
European Association for Programming Languages and Systems (EAPLS) liige
European Association for Logic, Language and Informationn (FoLLI) liige
European Association for Computer Science Logic (EACSL) liige
European Association for Theoretical Computer Science (EATCS) liige
Interest Group in Pure and Applied Logic (IGPL) liige
Formal Methods Europe (FME) liige

Otu Vaarmann

The European Working Group *Multiple Criteria Decision Aiding*, liige

The European Working Group *Financial modelling*, liige

Töörühma EUROPT – The Continuous Optimization (Association of European Operations Research Societies) liige

3.2.4 Soovi korral aruandeaastal saadud TjaA-ga seotud tunnustused

Andrus Saluperet autasustas Vabariigi President Valgetähe IV klassi teenetemärgiga

Jaan Kaldat autasustas Vabariigi President Valgetähe V klassi teenetemärgiga.

Tarmo Soomere pälvis Eesti Vabariigi 2013. aasta teaduspreemia tehnikateaduste valdkonnas tööde tsükli "Merelt lähtuvate ohtude kvantifitseerimine ja minimeerimine Läänemere ranniku kontekstis" eest

Tarmo Soomere sai 2013. aasta teadusajakirjanduse sõbra auhinna Ökul, mida annab välja Eesti Teadusajakirjanike Selts.

Jaan Kalda pälvis Vabariigi Presidendi kultuurirahastu nõukogu otsusel presidendi reaalteaduste eripreemia.