Research Laboratory for Proactive Technologies

Department of Computer Control

Tallinn University of Technology

Annual Report 2008

1918 TALLINNA TEHNIKAÜLIKOOL

February 2009

Tallinn

Abstract

This report is a combination of a white paper explaining the research plans of the lab, and the results obtained in 2008. In the long run we are looking for a symbiosis of computer science, systems science and complexity science. More specifically we discuss theoretical and practical problems in the domain of networked proactive, pervasive computing systems – e.g. collecting situational information, developing models of interactive computation, interfacing nodes with different ontology, handling networks with dynamically changing connectivity of nodes.

Keywords: autonomy and proactivity of components, pervasive computing, ad hoc networks, mediated interactions, multi-stream interaction machines, agent technologies, multi-agent systems, emergent behaviour, fuzzy and multi-rate control systems, situation-aware interaction-centred models of computation

Kokkuvõte

Käesolev aruanne tutvustab labori uurimisprogrammi ja -kavatsusi ning 2008. aastal saadud tulemusi. Labori kaugem eesmärk on leida arvutiteaduse, süsteemiteaduse ja komplekssüsteemide teaduse sümbioos, mis võimaldaks lahendada ja selgitada paljusid teoreetilisi ja praktilisi probleeme ja on seotud tajumatute proaktiivsete arvutisüsteemide võrkudega – näiteks, situatsiooniinfo kogumine, interaktiivsete arvutusmudelite arendamine, erineva ontoloogiaga võrgusõlmede liidestamine, spontaanvõrkude haldamine.

Võtmesõnad: komponentide autonoomsus ja proaktiivsus, tajumatud arvutisüsteemid, spontaanvõrgud, vahendatud interaktsioon, agenditehnika, agentsüsteemid, multi-voo interaktsioonimasin, ilmnev käitumine, hägusad ja mitmekiiruselised juhtimissüsteemid, situatsiooniteadlikud interaktsioonikesksed arvutusmudelid.

Editors of the Report 2008: L. Motus, M. Meriste, J.-S. Preden

Disclaimer

This report has resulted from a voluntary effort of a research team in order to promote exchange of its research results and applied hypotheses for feedback in the form of advice and comments from the other researchers.

This report has no intention to interfere with the research report regulations -- introduced by the Estonian Ministry of Education, and adopted by Estonian universities -- which have been developed by civil servants and serve solely their needs.

Synopsis of the Research Laboratory for Proactive Technologies in 2008

The laboratory (http://www.proactivity-lab.ee) focuses on theoretical and practical study of networked systems built from stationary and/or mobile software-intensive (proactive) components. Typical components are pervasive computing systems. The research is partitioned into three threads -- modelling and verification of situation-aware interaction-centred computation, methods and technologies for acquiring situational information, and methods for interpretation of situational information for (proactive) decision making. The long-term goal of the laboratory is the ability to detect and partially control the emergent behaviour in pervasive computing systems.

Staff of the laboratory includes 1 DSc, 8 PhD-s, 4 PhD students, plus a varying number of MSc level students and assistants. The researchers of the laboratory are closely cooperating with The Centre for ICT at Institute of Technology, University of Tartu in the areas of interaction-centred computation and multi-agent technologies; IB Krates (Estonian SME working internationally in the area of tools for, and development of embedded systems' software), Smartdust Solutions (Estonian SME working internationally in the area of wireless sensor networks). The laboratory is a member of CENS (Estonian Centre for Nonlinear Studies, http://cens.ioc.ee/cens).

The laboratory was established in 2007 by a decree of Senate (Tallinn University of Technology), stems from the Real Time Systems group at the Department of Computer Control, Tallinn University of Technology, and has inherited its theoretical results and experience.

Researchers in the Research Laboratory for Proactive Technologies (2008)

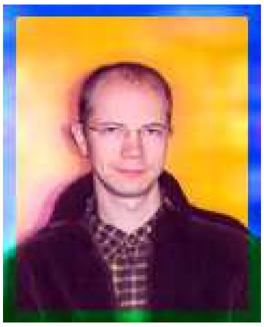

Astrov Igor

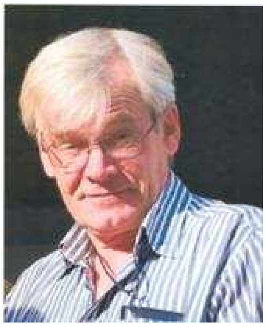

Kangilaski Taivo


Karpištšenko Andre


Kimlaychuk Vadim


Kull Andres


Lints Taivo


Meriste Merik


Motus Leo


Naks Tonu


Pahtma Raido


Pedai Andrus


Pikk Priit


Preden Jürgo-Sören


Rannat Kalev


Riid Andri


Rüstern Ennu


Petlenkov Eduard


Savimaa Raul


Serg Risto


Udal Andres


Tenno Ander

Content

1. Preface.. 8
2. Research directions in the Laboratory... 10
    - 2.1 Abstract research object.. 11
    - 2.2 Supporting technologies and pilot applications................... 12
    - 2.3 Situation-awareness of computing..................................... 16
    - 2.4 Situation-aware models of interactive computing............... 18
    - 2.5 Pervasive proactive computing and emergent behaviour.... 20
3. Researchers of the Lab and some of their interests.................................... 23
4. Formal research commitments.. 29
    - 4.1 Grants from Estonian Ministry of Education................................. 29
    - 4.2 Grants from the Estonian Science Foundation............................... 29
    - 4.3 International contracts and collaboration...................................... 31
    - 4.4 Other contracts and collaboration... 33
5. Applications for collaboration and/or projects, still pending....................... 35
6. Participation in, and organising conferences, summer schools, reviewing papers, etc... 37
    - 6.1 Organising conferences, etc, and reviewing papers................... 37
    - 6.2 Attended conferences, summer schools, seminars, etc............. 38
7. Teaching activities of the lab's staff... 40
8. Supportive personal grants applied/received.. 40
9. Longer visits, lectures, fellowships, etc in 2008.. 40
10. Collaboration partners.. 41
11. Foreign and domestic visitors in the lab.. 41
12. PhD theses in progress carried out by the lab's staff or supervised by them... 42
13. Conclusions.. 44
14. Publications of the lab in 2008 and manuscripts submitted for 2009............ 46
15. References.. 51

1. Preface

Prehistory of the Lab

The laboratory was officially launched in 2007 by a decree of the Senate of Tallinn University of Technology (TUT), based on an application of a group of enthusiastic researchers from the Computer Control department, with a background in real-time systems engineering, artificial intelligence, and computer science. The idea of creating the Lab was supported by a group of researchers from the Institute of Technology, University of Tartu. The two research groups had been collaborating informally since the beginning of the 21^{st} century in the domain of situation-aware multi-agent systems and interactive models of computation. The latter models are believed to foster understanding the essence and ability to control of, hitherto slightly mystical, emergent behaviour observed in situation-aware multi-agent systems (as well as in many networked pervasive computing systems, and in networked embedded real-time systems and, of course, in practically all biological and social systems).

Partners of the Lab

This is the first activity report of the laboratory – the first year (2007) was spent on (partially) solving organisational and urgent financial problems, and on attempts to elaborate feasible research plans for the future. The collaboration of the Tallinn and Tartu research groups was partially formalised in 2007 – some members of the Tartu group are now part-time researchers at the Lab -- and the originally planned research scope of the Lab was slightly extended to include other researchers from the TUT Department of Computer Control. Extending the research scope also invoked closer contacts with the Estonian Centre for Nonlinear Studies (CENS, http://cens.ioc.ee/cens, Institute of Cybernetics, TUT) -- that is the leading centre in Complexity Science studies in Estonia. Today the Lab is a member of CENS. This status broadens perspectives for the laboratory in studying emergent behaviour. The emergent behaviour (and its control) has become a major practical problem in networked pervasive computing systems and is increasingly observed in synthesised symbiotic mixtures of artificial and natural systems. Additional working contacts in 2007 were established with Department of Mechatronics and Department of Machinery (both from TUT) – those contacts have turned out to be mutually useful and several joint ventures are being planned for 2009.

Today the Lab has several industrial and governmental contracts and grants as discussed further in this report. We also appreciate immediate feedback from the real world in the form of informal discussions and personal contacts with several Estonian SME-s – e.g. IB Krates, Smartdust Solutions, and Elvior. We believe that such feedback helps to keep the research on the right track.

Background of the research

In the daily research the Lab strives to start from the unsolved practical problems, stemming from applications of networked pervasive computing systems embedded into natural and artificial world, and proactively attempting to influence the behaviour of ambience. This does not quite conform to the mainstream research practice which usually departs from the ruling theories, and attempts to stretch domains of definition for those theories to include the problem at hand. Our experience indicates that characteristic features of networked pervasive computing systems (e.g. loosely composed autonomous components, dynamically changing interactions, self-organising capability, incomplete information about the systems structure, and proactive behaviour) cannot be handled with sufficient precision by the conventional computing theories. Therefore we are looking for extensions to Turing computing.

In a way, our situation is reverse to that in the 1950-s – i.e. the period before many separate (and (partially) independently evolving) research disciplines, such as computer science, artificial intelligence, theory of complex systems, systems engineering, robotics, and others were canonised. Then the researchers faced many fascinating unsolved problems and a few theories that could fit for handling those problems. Today we have a multitude of theories that study and describe separate aspects of a complex phenomenon – e.g. problems related to a networked pervasive and situation-aware computing system – but we cannot convincingly verify that the particular system satisfies all the axioms and constraints imposed by those theories, and more often we know exactly that many of those axioms are not satisfied.

Unfortunately, many essential features of pervasive computing systems – for instance subtle behavioural details invoked by self-organisation, proactive operation, and emergent behaviour of the system components – remain out of the scope of those theories. Some aspects of listed features can be observed (and partially studied) by theories related to automation, mechatronics, computer science, software engineering, distributed artificial intelligence, cognitive engineering, systems biology, and many disciplines in natural and social sciences.

The practice of building pervasive computing systems is still ahead of the capability of researchers to explain theoretically why and how the systems behave as they do, *therefore we follow the methodology applied in natural science – analyse the existing artefacts, understand the essential computing processes required for the artefact to function properly, develop models and theories that fit for analysing and forecasting the artefact's behaviour, build a new artefact based on the developed models and theories, verify that the artefact's actual behaviour matches with the constraints, requirements and goals used when building it.*

We are very clearly at the beginning of the road, and would appreciate readers' comments, critics and advice -- after you have digested the content of this report. Please use the *Contact Us* button at http://www.proactivity-lab.ee/ for your response.

2. Research directions in the Laboratory

The ever increasing complexity of (pervasive) computing systems and their networks, plus constantly increasing strictness of user and dependability requirements (both functional and non-functional requirements) have highlighted a distinct mismatch between the capabilities of the available design and analysis tools and essential properties of novel computing systems. Increasing number of novel computer applications can be characterised by the following features:

- rapidly increasing complexity of the artefacts,
- intensifying symbiotic interactions between the artefacts, and with the natural world processes,
- increasing strictness of user requirements to quality of service of the artefacts,
- necessity to decrease the cost and time of artefacts' development and maintenance

Essential features of those computing systems cannot be verified nor validated (with the required details and/or precision) by applying commercially available tools and existing theories and methods.

The researchers in the Lab are convinced that the existing conflicts between the evolution trends of, requirements to, and resources for building networked pervasive systems can be mollified by adopting the novel research results regarding the essential building and functioning principles of the natural world, to the artificial world -- in particular to building networked (and proactive) pervasive computing systems. Hence the Lab researchers have decided to focus on the following domains:

- learn to build autonomous proactive components (and their models) that interact with their environments, i.e. primitive artefacts, that exhibit cognitive, learning and adaptability capabilities
- learn to build more complex artefacts (with self-organisation capability) from autonomous proactive components and their models
- learn to forecast and, if possible, to control the emergent behaviour, inevitably generated by the interactions between autonomous proactive components

In order to manage with these ambitious goals – i.e. in order not to deviate from the right track and avoid getting (too early) lost in the myriad of interesting (and challenging) application details -- we decided, at this stage, to formulate a generic research object that enables us to study all the three topics within the same framework of abstract notions.

2.1 Abstract research object

The research program of the Lab has been inspired by three observations regarding the evolutional trends in the artificial world:

- *The functionality of an artefact is increasingly determined by software* that operates on pervasive computer systems embedded into that artefact. This enables dynamic modification of the functionality – a feature that is clearly new with respect to the traditional „hard-wired" artefacts whose functionality is in-built „once and forever". Such new artefacts have been named software-intensive artefacts (devices). Computing, applied in software-intensive artefacts is called "ubiquitous computing", or "pervasive computing", sometimes even "invisible computing", since those artefacts exhibit non-terminating (on-going) computational process – quite often not visible to a human operator manipulating the artefact, or collaborating with it. As such, the pervasive computing violates many restrictions imposed by the conventional model of computation based on the Church-Turing thesis (see Wegner and Eberbach 2004). Similar issues are also considered in a discussion by Milner (sketched in Milner 2006a, and 2006) on ubiquitous computing and by Lee (Lee 2006 and 2008); see also (Stepney *et alii* 2004) for further details on Grand Challenges for Computing Research.
- *The artefacts are increasingly being networked and their behaviour is coordinated with each other* – either directly via network connection to the other artefact, or indirectly via the natural environment with which the artefacts are jointly interacting. Networking has a twofold effect on the designers of the artificial world. First, the networked artefacts can provide remarkably better quality of service and solve many tasks that have been hitherto unsolvable, or economically not feasible to solve. Second, the networked systems with prefixed constraints imposed upon their behaviour are more complex to build and maintain – the share of emergent behaviour in networked (autonomous) systems cannot be neglected any more, they are also more sensitive to security risks (due to potentially hostile interactions over the network).
- *New type of computer networks* is required to network autonomous software-intensive artefacts (e.g. ad hoc mobile networks, as discussed by Chlamtac (2003), which can comprise heterogeneous and mobile nodes, can have a dynamically changing topology of interactions, and are energy sensitive.

Among the existing common abstract research objects the closest to our needs – i.e. that embed all the three above listed evolution trends -- seem to be abstract intelligent agents and their dynamically evolving networks (a.k.a. multi-agent systems). We need to extend the definition of an autonomous agent – in addition to a variety of pretty loose agent definitions -- we add a requirement that an agent is explicitly situation-aware. Situation-awareness is an essential feature that explicitly enables an agent (and system of agents) to efficiently manage in dynamically changing, incompletely known environments. At the same time this poses the problem of dynamic definition of new situations and dynamic detection of situations.

Situation-aware autonomous (proactive) agents and their networks are believed to be the best available abstraction for modelling and analysing networked (proactive) pervasive computing systems. This choice infers that we face the necessity to consider computations that do not satisfy the strictly defined restrictions to methods conventionally applicable to Turing computable functions.

Eventually, this choice will enable us to model, in addition to autonomous proactive computing systems, also other natural phenomena, and social structures (e.g. organisations, institutions, etc) as multi-agent systems.

Accepting situation-aware multi-agent systems as the abstract research object that unifies the handling methods of problems invoked by different applications we have organised the following substantial (i.e. non-statistical and non-bibliometric) discussion presented in the report, into four sections:

- Supporting technologies and pilot applications
- Situation –awareness of computing
- Situation-aware models of interactive computing
- Proactive pervasive computing and emergent behaviour

2.2 Supporting technologies and pilot applications

This section covers studies in properties of technology platforms and tools applicable for developing pervasive computing systems and their networks, including both hardware and software platforms and tools, and to certain extent also the technology used to interact with the (non-computer based) environment. This section also covers study and assessment issues of implemented pilot projects – the tools and methods used for acquiring and synthesising situational information, for testing a uniform interface between the components of proactive systems (e.g. machine-machine, human-machine, and human-human interface), for status monitoring and control of mechanical devices. Studies described in this section will provide, in the long run, feedback information supporting the development and or improvement of methods and tools applicable for analysing, evaluating, verifying and implementing networked pervasive computing systems. Special experimental laboratory is in the process of being furnished for implementing, testing and assessing the pilot applications.

2.2.1 Technologies for simulating and implementing agents

This research topic continues the on-going work on elaboration of KRATT – the testing and development environment for individual agents and multi-agent systems. The KRATT is based on agent-based middleware which supports the development of prototype applications in different application areas. The middleware contains a generic architecture for situation-aware agents, basic components for constructing various classes of agents required for building application-specific situation-aware multi-agents. Agents, and consumers that use services provided by agents, are not in one-to-one stationary relationship; one agent can concurrently work for different consumers or use services provided by other agents. KRATT can also support some stages of design, implementation, and testing of situation-aware multi-agent systems. In addition, the test-bed will serve as an experimental base for developing the analysis, validation and verification tools that are to estimate properties of the design, and implementation, and to check the satisfaction level of functional and non-functional requirements, including those regarding the emergent behaviour. KRATT related research was initiated in Tartu in 2000. Consult also Motus et alii (2002), (2003), (2004), and Meriste et alii (2005).

2.2.2 Interface technologies for exchanging situational information

Interactions play central role in situation-aware networked pervasive computing systems – only information is being exchanged in majority of those interactions. Dynamically adjustable exchange of situational information assumes introduction of a new type of interaction into message exchange mechanisms that has been widely used computing. In addition to commonly used direct and indirect interactions, we suggest to apply mediated interaction (see, Motus and Meriste, 2009). Mediated interaction enables the information consumer to subscribe to information from specific situations only.

In the case of interacting autonomous proactive components one may encounter with the problem of disparate (or slightly inconsistent) ontology of interacting partners – since many interactions change dynamically during operations, and not all the producers of autonomous components follow the same standard. This means that one cannot completely fix (standardise) the interfaces through which the informational interactions take place – the use of smart interfaces (that interactively match the partners' ontology) would be preferable. However, today the interactive ontology is not yet available. Therefore the Lab's team has pragmatically divided the interfacing problem into three:

- Development of *a class of unified interfaces* supporting human-human, human-machine, and machine-machine communication. The communication is based on exchanging (fragments of) digital maps via an agent-based situation-aware map server. The map server is also responsible for checking the consistency of exchanged information and from the point of view of interaction partners operates as a mediated interaction. Digital maps, their fragments, or digital schemas can be accessed by all the autonomous, mobile and/or stationary network components on subscription basis (moderated by the footprint of the subscriber). Humans are identified as mobile and proactive components of the system (or network of systems). A map server collects, processes, and verifies situational information from the (autonomous and distributed) providers, updates information on the maps, and distributes the maps (map fragments) that have been dynamically updated and personalised according to subscriptions, to the subscribers. Such an *interactive map* is constructed by generic situation-aware agents by fusing maps or their complementary layers, collecting information from vehicles cooperating with map agents, linking collected photos, video-recordings and other information structured into specific attributed objects on the interactive map - *points of interest*. A prototype system to customise interactive digital maps (Kaardikratt) has been developed and tested in close-to-real conditions. See for details Meriste et alii (2005), and Motus et alii (2006).

- Thin compo*nents, not able to process* digital maps, exchange information in conventional way by exchanging alpha-numeric messages (e.g. by using one of the existing agent communication languages). This sounds nice and simple, but may involve a non-trivial mapping from the situational information as presented in the map to alpha-numeric message (and reverse), and/or matching ontology by applying a set of available alternative ontologies with interpretation rules to enable the matching negotiations.
- The research for interactive ontology has not been started yet.

2.2.3 Smart dust and sensor networks for acquiring situational information

Smart dust denotes a collection of smart motes. Motes are expected to have a self-organising capability, e.g. they form multi-hop ad hoc networks. A mote comprises a set of sensors, adequate processing capability, data storage, radio-communication equipment, and local power source. Each mote may have a unique design and is functionally a node of an ad hoc network. Smart dust and sensor networks are often considered to be identical although *a hair-splitter* may claim that a node in a sensor network need not be as smart and autonomous as a mote of smart dust. In sensor networks, the nodes may also be communicating in multi-hop mode along *ad hoc* routes, but sensors, processors, and communication devices may not be as compactly packaged and sensor networks may not have a complete self-organising capability.

A conventional computing system is interfaced to the real world (natural or artificial) by means of sensors, actuators, processors, filters, etc that enable the collection of situational information and are capable of directly monitoring and/or influencing the real world. Such interface is sometimes called a cyber-physical system. However, quite often the notion of "cyber-physical systems" is used to denote a pervasive computing system, together with the attached sensing and actuating devices. In principle, cyber-physical systems are expected to transform artefacts interaction with each other, with the natural world, and with the humans to the same extent as internet has transformed the way humans interact with each other.

We use the motes of smart dust as (in some cases mobile) nodes of multi-hop ad hoc network (MANET). Ad hoc networks are used in our theoretical and experimental work as:

- one of the sources of primary and secondary (i.e. synthesised) situational information in a larger system
- subnet of a larger heterogeneous computer network, with dynamically changing topology and limited self-organising properties; such subnets can be used for implementing proactive components, proactive systems, and networks of proactive systems
- test-cases for analysis and verification methods (and tools) developed for proactive systems that exhibit complex, self-organising, and adaptive topology of connections between nodes; the actual behaviour of such systems cannot be simulated sufficiently precisely by applying conventional modelling methods because of the presence of emergent behaviour.

In 2008 the lab studied the following issues related to collecting situational information:

- methods for periodic positioning of moving nodes,
- methods for (adaptive) positioning of stationary nodes deployed at random
- methods for preliminary interpretation of sensor readings, e.g. attaching time and location labels, pre-processing the readings before uploading, etc.
- formal methods for interpreting and verification of situational information, and for fusion of situational information
- communication patterns and communication security in MANET
- monitoring and maintaining the operation of MANET.

For details see Preden (2006), Preden and Helander (2006), Helander and Preden (2006), Preden et al (2007), Preden and Helander (2007), Preden et al (2007b), Preden (2008)

2.2.4 Pilot applications and assessment of methods

Pilot applications and assessment of research results is an on-going activity that can be divided into three categories:

- **Based on MATLAB/Simulink models**
    - *Neural network usage*, e.g. multi-rate hybrid Kohonen neural nets based fingerprint recognition method, and multi-rate neural net based control system

for autonomous vehicles, see for details Astrov et alii (2008), Pedai and Astrov (2008), Astrov and Pedai (2008)

- *Automatic code generator* for real-time embedded system, comparison of the manual and generated code from MATLAB/Simulink models – Gene-Auto project; the test and assessment was made on a physically built case-study (autonomously navigating mobile toy-robot). For details, see Toom et alii (2008)

- **Based on real-world environment and physical devices**
  - *Autonomous mobile platforms* equipped with sensor motes, positioning beacons, and other necessary instrumentation and actuators – for testing autonomous navigation, positioning, and collecting situational information
  - *Uniform methods for interfacing components* in a situation-aware pervasive computing system, based on digital map server and distribution of customised maps – the technology has been tested in pilot application and needs now a scaling test and careful study of operational properties – e.g. bandwidth requirements, sensitivity to processing ability, data storage and displaying requirements of the terminal; *pilot applications have been:*
    - *monitoring and* maintenance systems for engineering communications in towns, groundwater sources and their status
    - *automated post-processing of information* collected b*y UAV, linking the aerial pho*tos and videos to digital map and detection of changes
    - *monitoring and diagnosis of machinery by using motes – jointly wi*th Department of Machinery, see Preden et al (2007) and (2007b)
- **Preparation the set-up for future experiments in verification**
  - Developing the requirements and guidelines for validation and verification of network enabled capabilities (a teamwork in NATO RTO SCI Task Groups)
  - Analysis of verification and qualification experience obtained from ITEA project no. 05018 "Gene-Auto: Automatic Software Code Generation for Real-time Embedded Systems", preparations for testing the multi-stream interaction machine that is being developed under the topics of "Situation-aware models of interactive computation"

2.3 Situation-awareness of computing

Situation-awareness is a pragmatic property, not directly related to computation proper (e.g. verification of algorithms). A simple example of situation-awareness is a distributed braking system in a car (or in the landing gear of an airplane) -- each wheel has its own processor, that controls the braking power so that none of the wheels is blocked and all the wheels cover (more or less) equal distance in a time-unit. To achieve such behaviour one applies situation-aware interaction between sensors, processors and actuators in the braking systems. One may say that situation-awareness is used in control and modelling to cope with complex nonlinear problems by applying “divide and rule” approach that in many cases substitutes a major complex problem with a series of less complex problems – e.g. sliding mode control (Utkin et al, 1999).

Situation-awareness in computing systems fosters the capability to synthesise data (e.g. data fusion) in a distributed systems and to verify the behaviour in specific (e.g. pervasive) computer applications where the evolutionary or intentional changes in the environment influences (i.e. partially controls) the processes within the computing system (or within components of that system). Situation-awareness of a computing system enables to capture and study the joint behaviour of computing system and its environment even if properties and/or topology of the system, or its environment change unexpectedly. In the other words, situation-awareness supports monitoring and due response to changes in the incompletely known environment, as well as enables partial control of system’s emergent behaviour that is caused by joint evolution, adaptation, learning, and (potential) self-organisation of the computing system and its environment during the simultaneous computation and interaction processes.

Situation-awareness of a computing system (or its component) is enabled by its access to information that characterises essential (dynamic) properties of the environment (and states of neighbouring components within the computing system). Typically the variable value that characterises situation is to be equipped with a tag that determines its belonging to a particular situation (e.g. time of measuring/computing this particular value, validity period of that value, position of the measuring point, etc). Situation-related information is used by the computing system for proving consistency of data before fusion, for (proactive) planning of its future actions, and for checking the validity of its behaviour in a specific situation.

It should be stressed that “situation-awareness” and “context-awareness” are approximately coinciding notions. Researchers departing from computer science and human-machine interfaces tend to prefer context-awareness, whereas researchers with systems engineering and computer application background tend to use the notion of situation-awareness.

One of the preconditions for applying situation-aware computing is system’s ability to subscribe to certain type of information, e.g. information related to a particular situation, as characterised by time-based, location-based, etc. properties. Such capability is provided by cyber-physical systems, research in this domain focuses on how people and computers interact with the physical world and, to certain extent, with each other. The research in cyber-physical systems has generated many new computer applications that pose still not quite resolved problems – e.g. how to control the behaviour of *ad hoc* networks, which sensors to use, how to positioning moving objects (without GPS access), fusion of situation-sensitive information, etc. For further details, see Lee (2008).

Another essential precondition for situation-aware computing is the ability of (a component of) a system to control and (proactively) select the forthcoming path of computing – e.g. algorithms that are to be executed, interactions that are to be performed, information that is to be transmitted and/or accepted, etc -- depending on the available situation-sensitive information.

To provide a situation-aware computing system with the capability to monitor and dynamically control its own behaviour efficiently, the designer of the system may need to implant mediated interactions (see Motus and Meriste 2009) in-between essential subsystems and/or components of the systems. Such a capability enables to extend the scope of verifiable properties, e.g. from stationary properties of systems with static structure to emerging properties of situation-aware systems with (self-)adapting parameters and (self-)evolving structures. To assist the designer in implanting mediated interactions one needs a model of interactive computing that is more expressive and describes the system's behaviour more precisely than conventional models of Turing computing.

2.4 Situation-aware models of interactive computing

Researchers from different areas have observed that analysis and verification of pervasive computing systems require more expressiveness and analysing power than provided by the conventional models and theories based on Turing computing models. Turing himself (see, for instance Turing (1936)) has pointed out the limitations of Turing a-machine. The research for extending the capabilities of Turing machine paradigm was resumed in the 1970-es by R. Milner (see Milner 1980 and 1993). Milner's work opened new perspectives to the old ideas of interaction-centred computing, expressed by Turing already in 1940-es.

Wegner (1998) and Eberbach (2001) have elaborated the concepts of interaction-centred computing and have stated a concept of natural hierarchy for models of computation – Turing Machine, Sequential Interaction Machine (SIM), and Multi-stream Interaction Machine (MIM) – whereas SIM cannot be modelled by Turing machines only, and MIM cannot be modelled by SIM only. Motus et al. (2005) extended this conceptual hierarchy with a special case of models for situation-aware interaction-centred computation.

The first step of up this hierarchy was a development of a Persistent Turing Machine (PTM), as published in Goldin et al. (2004). This was followed by alternative approach to definition of interaction machines, described in Dosch et al. (2007). Persistent Turing machine can be considered as a model for Sequential Interaction Machine. Multi-stream Interaction Machine has not been understood as thoroughly as the Sequential Interaction Machine.

A prototype of a multi-stream and situation-aware interaction model of computation (the Q-model) has been described in Lorents et al (1986) and in Motus and Rodd (1994). The prototype model stems from the idea suggested by Quirk and Gilbert (1977) and has been tested on pilot projects for analysing the behaviour of distributed real-time systems in laboratory conditions (see, for example, Motus and Naks (1998), Naks and Motus (2001)). The problem with this prototype is that it did not evolve smoothly from Turing machine based theories. Although the correspondence of the Q-model to a weak second-order predicate calculus has been demonstrated, a remarkable semantic gap remained to be bridged.

The central idea in the Q-model is the use of situational information for controlling/guiding the computation, and applying mediated interaction for exchanging this information between components of the computing system – e.g. between the elements of a single stream of computation (as used in PTM for introducing memory), and/or between simultaneously executed streams of computation (as potentially required in MIM). The researchers in the Lab are working on elaborating those ideas to reach a working prototype of a multi-stream interaction machine.

Intuitively, a MIM receives multiple input streams, processes the input streams simultaneously (in a forced concurrent mode, a.k.a. truly concurrent mode, or applying non-algorithmic parallelism), and produces (possibly a different number of) output streams whereas the input streams may interact with each other during the computation process.

In the general case we cannot assume any restriction on the input and/or output streams (e.g. complete synchronism or complete asynchrony of those streams). At the same time, we should accept application dependent restrictions on the inter-stream interactions during the operation of a MIM. At least some of those inter-stream interactions should be implemented as mediated interactions. The mediated interaction, as explained in (Motus and Meriste 2009), may need further elaboration to qualify for describing of a general-purpose situation-aware inter-stream interaction.

Each of the streams, simultaneously executed in MIM can be implemented as persistent Turing machines aware of their own history. In order to manage (and process) inter-stream interactions between simultaneously executing sequential interaction machines we need to develop different type of PTM-s – that would elaborate the above described channel concept. The hypothesis is that there is no algorithmic way to implement those situation-selective interactions that take place between streams in a multi-stream interaction machine.

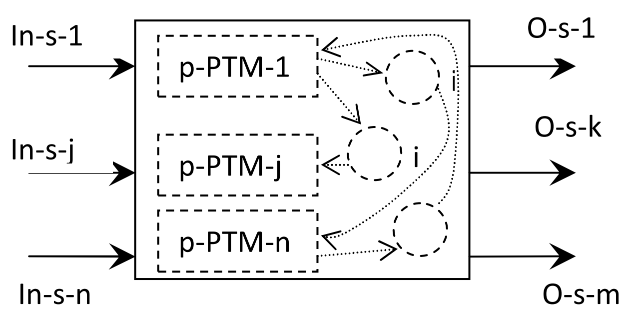


Figure 1 Multi-stream interaction machine with n input streams and m output streams; during the processing of the streams by p-PTM-s, they interact with each other via i-PTM-s

Figure 1 presents one possible inner structure of a generic MIM that has n input streams and m output streams. The processing PTM-s (p-PTM-j, $1 \leq j \leq n$) are described in Goldin et al (2004) and Dosch et al (2007). The situation-selective mediated interactions between input streams are implemented by interaction PTM-s (i-PTM-r, $1 \leq r \leq u$); the formal description for i-PTM is still to be developed.

The researchers in the Lab are convinced that interactive computation, as a sample case of super-Turing computation, suffices for describing and analysing the behaviour of (networked) pervasive computing systems, provided explicit situation-awareness capability is added to interactive computation.

2.5 Pervasive proactive computing and emergent behaviour

The term "proactive" (introduced to sociology by Frankl (1946)) has come to use for describing the behaviour of artefacts comparatively recently (in the 1980-es), probably due to influence of research in human behaviour in groups and organisations. Some examples of such research can be found in Bateman and Crant (1993), Crant (2000), and in Parker et al (2006). Quite naturally, the term has become essential for characterising the behaviour of intelligent agents (and in studying the behaviour of multi-agents) whose decisions are required to optimise their goal function. Hence, achieving proactive behaviour has become an essential goal in building (networked) autonomous artefacts. Those artefacts have been designed following the multi-agent paradigm that, in its turn, has been inspired by new understanding of operating principles of the biological world.

In a nutshell, proactivity (i.e. ability to initiate a change) can be contrasted to conventional use of the term "adaptivity" (i.e. ability to respond to changes), and expands the notion of proficiency to cover unpredictable requirements (i.e. in addition to the ability to fulfil perfectly the predictable requirements of one's job). Hence, proactivity is about being anticipatory and taking care of dynamically occurring (not necessarily *a priori* predicted) situations. A proactive system acts to influence the joint evolution of the system itself and its environment, in order to improve the satisfaction of its goal functions rather than reacts to (a priori defined) detected situations in the environment – as conventional (networked) artefacts do.

An intuitive expectation that (limited) autonomy is a precondition to proactivity is supported by Hornung and Rousseau (2007) that describes their behavioural studies of employees in an organisation. Autonomy in artificial systems is often used to loosen the rules of interactions, and also to reduce intensity of interactions between autonomous parts of a system, as well as between the system and the human operator – without reducing performance, reliability, fault-tolerance, etc.

As a visible side effect of autonomy and proactivity, a human operator may feel his/her reduced control ability over the system. Consequently, a mediocre leader of an organisation may feel loss of control over the organisation if the members of the organisation are too autonomous, and/or too proactive. In reality, the central capability to control the behaviour of a (distributed) proactive system is reduced due to delegation of responsibilities and decision making to autonomous components of the system.

The reduction of central control may lead to increased agility, viability and resilience of the system with regard to changes in the environment. At the same time, autonomy of components combined with presence of proactive components, and presence of indirect and/or mediated interactions in the system invokes the occurrence of *emergent behaviour* – i.e. the behaviour that cannot be deduced (or predicted) from the properties and goals of individual components of the system. In addition to potential good aspects of emergent behaviour it also increases the risk of not reaching the *a priori* prefixed goals of the system. Neglecting (temporarily) the possibility that the prefixed goals were not reasonable this leads us to a new problem for artificial (computer controlled) systems – how, and to what extent, is possible to control a system under the reduced central control capability (due to incomplete information and emergent behaviour)?

Due to autonomy of simultaneously processed interacting streams and due to the use of situation-selective inter-stream interactions in real life systems, Turing computation paradigm cannot provide a sufficiently precise behavioural description of those systems. Salient part of multi-stream interaction machine's behaviour is generated dynamically during its operations – and cannot be deduced from the behaviour of separate single stream processing subsystems. Such behaviour corresponds to the definition of "emergent behaviour" that was first observed in physics and is today a central research topic for complexity science.

Feasible models for such computing systems have multiple levels (i.e. multi-scale modelling), whereas at different levels of models one uses theories that may be logically inconsistent -- see for instance the taxonomy of models for computation in Motus et al (2005). This may be one of the many causes for occurrence of the emergent behaviour. Another explanation for emergent behaviour follows from the Anderson (1972) statement -- "*the ability to reduce everything to simple fundamental laws does not imply the ability to start from those laws and reconstruct the universe*" – that basically criticises the analysis only approach (i.e. excessive use of "divide and rule" principle) that typically abstracts away some interactions (as of negligible importance for the component of interest). Those interactions of "negligible interest" may be of decisive importance during the synthesis when we try to reconstruct the (part of) universe with well-defined properties.

Complexity science stems originally from physics and has been expanded later to cover and to partially unify the research into the essence of a variety of domains (e.g. nonlinear mechanics, mathematics, chemistry, biology, social sciences, computer science, artificial intelligence, and systems science/engineering). Most of the complexity study so far has been based on the analysis of natural phenomena, or on behavioural patterns occurring in social life of biological creatures. The research in the complex artificial systems adds a new, hitherto missing, possibility to observe and experiment with the occurrence of emergent behaviour in the synthesis process of a (networked) artefact. This may reveal some essential features regarding the complexity and methods of its (partial) control.

A vague analogy to the potential relation of complexity science and synthesis of networked proactive pervasive computing systems might provide unexpected benefit, e.g. it has become possible to correct some inaccuracies in analytical description of natural language grammar based on the experimental feedback obtained by building a speech synthesiser departing from the rules of grammar of language, and comparing the synthesised speech with speech provided by a native speaker.

During the synthesis of, and experimenting with a simple networked proactive pervasive computing system we can, at least in principle, detect the conditions under which the emergent behaviour appears. These conditions can be studied thoroughly; the experiments can be repeated with slightly modified conditions, etc – until we have understood the phenomenon sufficiently to (partially) control the emergent behaviour in this system. Then the scalability of this knowledge can be checked by well planned and partially repeatable experiments – this can be easier to perform in the artificial world than in the natural and/or social worlds.

3. Researchers of the Lab and some of their interests

3.1 PhD level researchers

Astrov Igor (MSc 1992, PhD 2000)

PhD in automatic control theory

Senior researcher of the Research Laboratory for Proactive Technologies, Department of Computer Control, TUT, e-mail: igor.astrov@dcc.ttu.ee

Research interests: Adaptive control, animation, continuous-time systems, decentralisation, decomposition, discrete- time system, fuzzy logic, hybrid control, modelling, multi-rate systems, multivariable, neural networks, neuro-fuzzy networks, nonlinear, simulation, state equations, stochastic systems.

Kangilaski Taivo (MSc 1997, PhD 2004)

PhD in control engineering

Senior researcher of the Research Laboratory for Proactive Technologies, Department of Computer Control, TUT, e-mail: taivo.kangilaski@dcc.ttu.ee

Research interests: Virtual Organizations, Virtual Enterprises (VO/VE).

Virtual Organizations are temporary alliances of enterprises that cooperate to share skills and resources in order to better respond to business opportunities. The cooperation is heavily dependent on Information and Communication Technology and the organisational performance is affected with ICT and business alignment in virtual organisations.

About 35% of Estonian energy market is liberalised in the beginning of 2009, and the liberation is to be completed by 2013. Energy market participants can be modelled as VO collaborators. Taivo has studied the energy market liberalisation process and the way it impacts on existing businesses in the context of ICT and business alignment.

Meriste Merik (MSc 1973, PhD 1984)

PhD in computer science

Senior Researcher of the Research Laboratory for Proactive Technologies, Department of Computer Control, TUT, merik.meriste@ut.ee

Professor, proactive systems, Institute of Technology, University of Tartu

Research interests: Merik’s interests include foundations of interactive computing, formal models of situation-aware multi-interactive computations, agent-based models, simulation of situation-aware proactive systems, user-oriented and self-organising interactive maps *pro* spatial/geographic interactive systems. The focus of research is on mediated interactions – on its models, methods and implementation.

Motus Leo (MSc 1965, PhD 1973, DSc 1990)

PhD in Stochastic control, DSc in real-time software engineering

Head of the Research Laboratory for Proactive Technologies, Department of Computer Control, TUT, leo.motus@dcc.ttu.ee

Professor, real-time systems, TUT

Research interests: Leo's research is focused on studying the behaviour of networked proactive real-time systems (a.k.a. situation-aware multi-agent systems) – studying the process of enabling situation-awareness, detecting and partial control of emergent behaviour, and developing interactive model of computation required to handle subtle behavioural details of such systems.

Leo was 7 years Editor-in-Chief and is still the Consulting Editor of an Elsevier journal on Engineering Applications of Artificial Intelligence. He is also member of the editorial boards for Springer Journal of Real-time Systems and IOS Journal for Integrated Computer-Aided Engineering. Leo has had 7 years of administrative experience as president of the Estonian Association of Engineers, and 6 years in IFAC (International Federation of Automatic Control) -- as Chairman of TC on Computers in Control, and member of the IFAC Technical Board. He has also served 7 years as dean for the faculty of Systems Engineering at Tallinn University of Technology and is currently Secretary General of the Estonian Academy of Sciences. Occasionally he serves as a member of different advisory councils in Estonia.

Rannat Kalev (MSc 1994, PhD 2007)

PhD in geophysics

Senior researcher of the Research Laboratory for Proactive Technologies, Department of Computer Control, TUT, kalev.rannat@dcc.ttu.ee

Research interests: Kalev's main research topics have been adaptive multi-sensor surveillance systems, double-diffusion in the ocean waves and nonlinear effects, applications of GPS-method in meteorology and marine rescue service. He is also interested in climatology processes, variability of tropospheric water vapour as a greenhouse gas.

In 2008 Kalev has been busy with preparing the launch of an ECO-NET project "Ship hull deformation monitoring" and investigating the feasibility of Crossbow motes as a communication and monitoring platform for a synchronised multi-sensor network and its integration with the GPS/INS technology.

Riid Andri (MSc 1997, PhD 2002)

PhD in control theory

Senior researcher of the Research Laboratory for Proactive Technologies, Department of Computer Control, TUT, andri@dcc.ttu.ee

Research interests: Andri's main interest is in theoretical research of computational intelligence, fuzzy logic, properties of fuzzy systems, fuzzy modelling and control algorithms. In 2008 he developed a new algorithm for error-free simplification that does not remove parameters that contribute to system's behaviour of a class of Mamdani fuzzy systems. A concluding paper in a series of papers on fed-batch fermentation was completed that described an interactive evolutionary algorithm for a fuzzy controller optimisation.

Savimaa Raul (MSc 1995, PhD 2005)

PhD in proactive modelling

Senior researcher of the Research Laboratory for Proactive Technologies, Department of Computer Control, TUT, raul.savimaa@dcc.ttu.ee

Research interests: Raul researches modelling of time-sensitive emergent behaviour of multifunctional organisations that operate in dynamic environment, by applying multi-agent systems and/or their components, and time-aware interactive computation; he studies the methodology for modelling emergent behaviour by working with pilot models for time-critical organisations.

Udal Andres (MSc 1992, PhD 1999)

PhD in modelling semiconductor devices

Senior Researcher of the Research Laboratory for Proactive Technologies, Department of Computer Control, TUT, andres.udal@dcc.ttu.ee

Research interests: Andres's main interests are in numerical modelling of complex non-linear processes in semiconductor devices and materials, especially in modelling of carbon nano-tube based structures. In 2008 he studied modelling of quantum well semiconductor nanostructures, graphene and carbon nano-tube based structures, theoretical comparison of Fourier-Heisenberg uncertainties in quantum mechanics and signal processing. He is also interested in philosophical basis of quantum mechanics, paradoxes of quantum mechanics, superluminal tunnelling microwave experiments, and achievements in nano-infotechnology.

Tenno Ander (MSc 2000, PhD 2004)

PhD in modelling electrochemical processes in accumulators

Senior researcher of the Research Laboratory for Proactive Technologies, Department of Computer Control, TUT, ander.tenno@dcc.ttu.ee

Research interests: Ander is interested in software engineering – e.g. prediction of optimal software project length based on estimated effort, calibration of use-case points and other effort-prediction methods, software usability and quality vs. invested effort. In 2008 Ander has been reloading his batteries.

3.2 PhD student level researchers

Kimlaychuk Vadim (MSc 2001)

MSc in microprocessors and -systems; information security

Researcher of the Research Laboratory for Proactive Technologies, Department of Computer Control, TUT, vadim.kimlaychuk@dcc.ttu.ee

Research interests: Agents' ontology, semantics and pragmatics, transfer of knowledge from one agent to another; communication of agents, security issues in agent communication; experimentation with Java beans as the pilot case of shared knowledge security network; service-oriented architecture in conjunction with agent oriented systems design

Kull Andres (MSc, 1985)

MSc in distributed data processing

Researcher of the Research Laboratory for Proactive Technologies, Department of Computer Control, TUT, andres.kull@dcc.ttu.ee

Research interests: Model-based testing of reactive software, model-checking in model-based testing, requirements driven model-based testing; telecommunication systems

Lints Taivo (MSc, 2005)

MSc in multi-agent models for bacterial cell functioning

Researcher of the Research Laboratory for Proactive Technologies, Department of Computer Control, TUT, taivo.lints@dcc.ttu.ee

Research interests: the concepts of adaptivity, designing highly adaptive complex systems; modelling, simulation and visualisation of complex adaptive systems, emergent behaviour; artificial life; natural life, etc. In the first half of 2008 Taivo compiled an interdisciplinary overview of adaptivity and adaptation, including methods for quantifying adaptivity. The second half of the year was devoted to understanding which properties of a system facilitate or impair adaptivity. Taivo's theoretical study has been combined with experimental work on pilot case-studies.

Naks Tonu (MSc, 1998)

MSc in object-oriented modelling of hard real-time systems

Researcher of the Research Laboratory for Proactive Technologies, Department of Computer Control, TUT, tonu.naks@dcc.ttu.ee

Research interests: Software engineering, processes and models, modelling time-critical systems, automatic code generation and model verification for real-time systems

Pedai Andrus (MSc, 2002)

MSc in multi-rate subsystems design

Researcher of the Research Laboratory for Proactive Technologies, Department of Computer Control, TUT, andrus.pedai@dcc.ttu.ee

Research interests: developing new schemes for proactive multi-rate control applications, including proactive multi-rate expert systems for simulation models.

Preden Jürgo-Sören (MSc, 2005)

MSc in heterogeneous and ad hoc networks

Researcher of the Research Laboratory for Proactive Technologies, Department of Computer Control, TUT, jurgo.preden@dcc.ttu.ee

Research interests: computation and communication in ad-hoc networks, situation-aware models of interactive computation; sensors and actuators in multi-hop ad hoc networks, positioning of nodes, data fusion and verification at the node

3.3 MSc level researchers

Pahtma Raido (BSc, 2007)

BSc in sensors on motes of smart dust

Engineer of the Research Laboratory for Proactive Technologies, Department of Computer Control, TUT, raido.pahtma@dcc.ttu.ee

Research interests: sensing, communication and data storage in wireless sensor networks, node and phenomena localisation

Pikk Priit (BSc, 2006)

BSc in nodes positioning in ad hoc networks

Engineer of the Research Laboratory for Proactive Technologies, Department of Computer Control, TUT, priit.pikk@gmail.com

Research interests: Positioning in sensor networks, data communication in mobile and stationary *ad hoc* networks; current research is related to positioning sensors with moving platforms.

3.4 Associate research staff from the Department of Computer Control

Rüstern Ennu (MSc 1970, PhD 1976)

PhD in analysis and identification of linear systems

Professor, in automatic control and systems analysis; Ennu has served 12 years as head of the department of Computer Control and is currently dean of the Faculty of Information Technology, TUT, ennu.rystern@dcc.ttu.ee
Research interests: Dynamic systems' modelling and control, computational intelligence, fuzzy modelling and control, adaptive control, robust control.

Petlenkov Eduard (MSc 2003, PhD 2007)
PhD in neural networks based identification and control
Senior lecturer, chair of Automatic Control and Systems Analysis, Department of Computer Control, TUT, eduard.petlenkov@dcc.ttu.ee
Research interests: modelling by and application of neural networks in control applications; for instance, detection and tracking of surgeon's motions during endoscopic surgery, organ recognition in endoscopic images; adaptive fault detection in embedded self-test environment; feedback linearization in nonlinear control systems.

Risto Serg (MSc 1999)
MSc in local networks of smart sensors
Assistant: chair of Real-time systems, Department of Computer Control, TUT, risto.serg@dcc.ttu.ee
Research interests: Risto is *de facto* a member of the Lab and participates in many projects, although he formally works at the Department of Computer Control. Risto is studying power-efficient and computationally efficient embedded systems, sensor networks, operating systems, and resource management. His special interest is in design and implementation of scalable cyber-physical systems.

4. Formal research commitments of the Lab

4.1 Grants from Estonian Ministry of Education

The Lab participates in a joint research project SF 014 0113s08 “Proactivity in the artificial world”, principal investigator L. Motus; the financing decision has been made by the Research Council for the period 2008 – 2013. The joint project comprises two symbiont subprojects:

- SF 014 0113A s08 “Proactivity and situation-awareness”, principal investigator L. Motus, carried out by the Research Lab for Proactive Technologies, Department of Computer Control, TUT, and
- SF 014 0113B s08 “Mechatronic and production systems’ proactivity and behavioural models”, principal investigator M. Tamre, carried out by Department of Mechatronics and Department of Machinery, TUT

Synopsis of subproject SF 014 0113A s08:

Three simultaneously on-going and interacting research threads are followed - proactive modelling, technology platforms and tools, and pilot applications and assessment methods. The emergent behaviour in proactive systems and its relationship to complex systems theory are of special interest. Research in proactive modelling focuses on models of situation-aware interactive computing, emergent behaviour in enterprises and organisations, self-learning and adaptation methods in control systems, and nano-components. Research in technology and tools covers agent-based and smart-dust technologies, plus tools and methods for interface technologies for exchanging situational information. Pilot applications and study of methods for their assessment are divided into three parts - cases applying MATLAB/Simulink models, cases applying real world environment and physical devices, and preparatory work on set-up of verification studies.

4.2 Grants from the Estonian Science Foundation

Grant ETF 6182

Title: “Research of multi-agent systems in heterogeneous environment with dynamic structure”, and duration of the grant 01.01.2005 – 12.31.2008.

Principal investigator: L. Motus

Synopsis:

The goal of this project was to study possibilities for merging into a united framework the innovative developing methods, new emerging theoretical ideas (e.g. super-Turing, and interaction-centred models of computation), requirements for pervasive computer applications (e.g. proactivity, autonomy, situation-awareness, mobility of nodes, dynamically evolving interaction structure, etc), new developing paradigms (agent-based design, model-based development and verification), and new technological platforms (e.g. ad hoc networks, smart dust, mobile nodes, cyber-physical systems based interfaces).

The project combines experimental and theoretical methods. Experimental part of the project comprises integrating the evolving tools and products (agent implementation and testing environment KRATT, agent-based digital map processing system, multi-agent system based on ant-nest paradigm) developed within ETF grant no. 4860 (2001-2004), conventional agent development tool JADE, and some motes of intelligent dust into Hopadhoc environment, and building applications in this environment. Theoretical part aims at stating and resolving problems discovered during experimental work -- e.g. methods for guaranteeing correctness of situation-aware computations, methods for secure communication between agents and coalitions of agents, viability of operation in the environment with dynamically changing structure, navigation without GPS, assessing and/or testing properties of new applications, etc.

Grant ETF 6837

Title: Robust methods for complex systems control: and integrated approach", and duration of the grant is 01.01.2006 – 31.12.2009.

Principal investigator: E. Rüstern

Synopsis:

The goal of the project is investigation of control system design methods for complex dynamical systems by integrating classical control theory with fuzzy logic and neural networks. Theoretical goals are:

- Generalization of the robust output controller design method for SISO systems to obtain a robust state controller and state observer design method for MIMO systems;
- Elaboration of effective and reliable control algorithms for complex systems (e.g. car navigation, autonomous mobile robots) by integrating control theory, fuzzy logic, multi-rate and neural network based methods;
- Software development for fuzzy modelling.

Application of the research results is planned in Eesti Energia and/or AS Silmet.

Grant ETF 6914

Title: "Modelling of semiconductor quantum well nanostructures and carbon nano-tubes", duration of the grant is 01.01.2007 – 12.31.2009.

Principal investigator: A. Udal

Synopsis:

This project is dedicated to development and application of models and software for two types of novel nano-objects: semiconductor quantum well in nano-hetero-structures and carbon nano-tube (CNT) based structures. The models and new software are developed for analysis of semiconductor nanostructures in cooperation with University of Leeds (U.K.). The main attention is focused on GaAs/GaAlAs quasi-parabolic quantum well structures for terahertz region optoelectronic applications. For research of CNT structures the available *ab initio* software packages (e.g. VASP) will be used to analyse the different types of graphene lists, CNT and relevant possible nano-devices with hetero-junctions. The cooperation with a high-tech company in the area of atomic force microscopy is planned.

Grant ETF 7693

Title: "Modelling of time-sensitive processes and emergent behaviour in multi-functional and virtual organisations", duration of the grant is 01.01.2008 – 31.12.2011

Principal investigator: R. Savimaa

Synopsis:

The project focuses on the modelling and analysis of time-sensitive processes and detection of emergent behaviour in multi-functional human organizations and enterprises. The project strives to integrate results from four research threads:

- Modelling of emergent behaviour in time-sensitive organizations that operate in dynamic environment with focus on elaboration of detailed modelling methodology and its supporting tools
- Revisiting life-cycle modelling and team composition studies in the context of virtual enterprises
- Estimating risks, necessary amount of resources, and the required overall work-effort to complete large software projects is the major problem in software engineering. We study the usability of approaches and results from previous threads in software engineering. The potential synergy allows us to prognosticate time and resources necessary for development a suitable information system for virtual enterprises.
- The above-described threads need to be linked together based on common theoretical foundations that are, at least partially, based on the emerging understanding of the essentials regarding embedded, real-time, proactive, pervasive computing systems, and multi-agent systems. For instance, situation-aware, interaction-centred models of computation, multi-stream computing, persistent Turing Machines, multi-stream interaction machines, and multi-agent systems.

4.3 International contracts and collaboration

ITEA project 05018

Title: Gene-Auto: Automatic Software Code Generation for Real-time Embedded Systems, duration of the project 01.01.2006 – 31.12.2008

Principal investigator in Estonia: T. Naks

Principal investigator in TUT: L. Motus

Partners: Continental Automotive France SAS, Airbus France, EADS Astrium SAS (France), Barco Avionics (Belgium), Israel Aircraft Industries, Tallinn University of Technology (Estonia), FéRIA (Federation of Research in Computer Science and Control Theory, France), INRIA Rocquencourt (National Institute for Research in Computer Science and Control, France), IB Krates (Estonia), Cril Technology (France), Thales Alenia Space (France).

As usual for ITEA projects, all the partners were financed through the respective national members of EUREKA programme -- the Estonian partners were finance through Enterprise Estonia.

Synopsis:

The Laboratory for Proactive Technologies participated in the project with two case studies - high-level robot control, and positioning of a mobile robot. The aim of the case studies was validation and verification of the code generator. We were able to complete our tasks in the project although funding for the project (by Enterprise Estonia) for the lab ended in June of 2008 (i.e. six months before the project completed).

The case studies were publicly demonstrated at the ITEA symposium 2008 in Rotterdam, merged into an autonomous mobile robot. The robot control algorithms were designed and implemented in Matlab as a Simulink/Stateflow model from which the code for robot was generated using Gene-Auto tools. The Matlab model for the case study was based on fuzzy logic control (designed by Andri Riid to which Jürgo Preden added the strategic control in Stateflow). The lower-level controls for the robot were done by Risto Serg and the software for indoor positioning system was developed by Raido Pahtma who also did some of the robot's integration work. Rait Kapp, a master student, integrated generated code with the existing robot code and performed generated code comparison with hand-written code. The final reports for the project will be prepared and sent to the project management in January 2009.

T. Naks (representing the Lab and IB Krates) was the leader of WP 2 (Development of model analyser and code generator), whereas IB Krates was the major developer of the code generator. L. Motus compiled a survey of formal verification methods for integrated systems for WP 5 (Formal Methods for Verification and Validation).

COST – European Cooperation in Science and Technology

COST action 295 – *Dynamic Communication Networks: Foundations and Algorithms*

Duration: 27.01.2005 – 26.01. 2009

Objectives: to provide foundations, models, algorithms, and general tools for dynamic communication networks; efficient design of applications for networks of decentralised interacting and evolving entities, experiencing possibly brutal modifications of their environments.

Members of the management committee – M. Meriste and L. Motus

J.-S. Preden participated in the work of the Action 295

COST action IC0603 *– Antenna Systems & Sensors for Information Society Technologies* (ASSIST)
Duration: January 2007 – January 2009
Objectives: Cooperation towards a deeper understanding of antenna operation in new complex environments and for the corresponding development of adequate modelling and measuring tools are the main scientific objective of the action. Whereas traditional antenna areas still demand research, new unforeseen and challenging problems are appearing – e.g. antennas in consumer electronics, health care, biology, radio astronomy, earth sciences, and earth resources monitoring.
Member of the management committee is J.-S. Preden.

4.4 Other contracts and collaboration

Network enabled capabilities (NEC) and ad hoc networks
Duration: September 2008 – December 2011
Principal investigators: J.-S. Preden and M. Meriste
Objectives: This is a joint project with Institute of Technology (University of Tartu) for studying the feasibility and developing networked enabled capabilities for collecting, pre-processing, fusion, and redistribution of the situational information, and assisting in decision-making in a semi-autonomous platoon. The project has been approved by the Estonian Ministry of Defence. The project assumes that the underlying network comprises smart dust motes, unmanned mobile devices, handheld devices and back-end databases, all operating together in providing relevant personalised data to the network agents.

ELIKO competence centre -- Smart space project
Duration: July 2008 – July 2009
Principal investigators: J.-S. Preden, R. Pahtma
Objectives: Development of a smart space where the entities in the smart space are provided context-sensitive information depending on their location and expressed interests. The network of smart dust motes performs environment monitoring, position estimation of mobile entities; it behaves as data store and data provider for network clients.
Project partners: Smartdust Solutions, Eliko competence centre

Power-line monitoring devices
Duration: August – September 2008
Objective: The objective of this two-phase project was to provide the Estonian electric power transmission systems' operator OÜ Põhivõrk with a power-line monitoring system that satisfies the requirements of OÜ Põhivõrk. During the first phase of the project (an overview of existing powerline monitoring equipment) it was determined that suitable

commercial equipment exists. If such equipment would not have existed the second phase of the project would have started in which a new power-line monitoring device prototype (interfaced to an existing SCADA system) for use on 400 kV power-lines would have been developed.
Partners: Smartdust Solutions, TUT Department of Electrical Engineering

Neural Networks for HVAC applications
Duration: June 2008 – December 2009
Principal investigator: E. Petlenkov
Contract no. 8068 between TUT and OÜ Yoga
Objectives: Develop a self-learning and self-tuning neural net based algorithm that can be integrated into large intelligent building control system.

Participation in NATO RTO Task Groups

SCI-TG-181 ”Design Considerations and Technologies for Air Defence Systems”,
Participant L. Motus
SCI-ET-206 ”System Design Considerations and Technologies for Safe High-Tempo Operations in Degraded Visual Environments”
Participants: M. Meriste and J.-S. Preden

5. Applications for collaboration and/or projects, still pending

CUES – Cognitive-Data-Fusion for Urban Environment Sensing and Threat-Detection proposal
Date of submission: September 10, 2008
Duration of project: 2009 --2012
The CUES (Cognitive-Data-Fusion for Urban Environment Sensing and Threat-Detection) proposal was submitted to the European Defence Agency answering a joint investment programme call on force protection (A-0444-RT-GC JIP-FP Call 3). The objective of the project is to develop a monitoring system for urban environments which would be capable of threat detection and notification using monitoring devices embedded into the environment.
Project partners: D'Appolonia S.p.A., Genoa, Italy; French-German Research Institute of Saint-Louis, France and Gammatech and the project leader is D'Appolonia S.p.A.
The project was not approved by European Defence Agency (January 2009)

Eliko competence centre -- Smart space project (II) proposal
Duration: July 2009 – July 2012
Principal investigators: J.-S. Preden, R. Pahtma
Objectives: Development of a new networking layer (involving routing, synchronization, and clustering) for ubiquitous computing environments. The proposed networking layer allows for temporal multiplexing of radio bandwidth by clustering network nodes into synchronized cells and providing limited synchronization between cells, resulting in reduced power consumption and better network performance. The decision for acceptance of the proposal will be available in March 2009.
Partners: Smartdust Solutions, Eliko competence centre
Financing decision will be made by Enterprise Estonia before September 2009.

Innovative Manufacturing Engineering Systems Competence Centre (IMECC)
Duration: September 2009 – September 2015
Status: application submitted for the competition organised by Enterprise Estonia, the competition results will be announced by August 2009
Objective: To improve the competitiveness of Estonian engineering industry and to develop cultural, ethical, and social values on increasing integrated industrial use of new technologies for optimal product life-cycle management (PLM) and e-manufacturing, emerging manufacturing technologies and process automation techniques, and new forms of self-organising systems with on-line monitoring and diagnostics in order to gain

competitive advantages and assure economic success in global economy; to rise the effective use of knowledge in product engineering and manufacturing planning for small series production in distributed and networked organisations of Estonian engineering industry.

Structure:

The IMECC activities cover three Strategic Development Areas:

- Integration of business and manufacturing planning based on e-manufacturing and Product Lifecycle Management Systems, two sub-projects (R. Küttner)
- Development cost and time-efficient solutions for SMEs for process automation and innovative emerging manufacturing technologies, two sub-projects (P. Kulu)
- Self-organising systems with on-line monitoring and diagnostics, three sub-projects (L. Motus)

IMECC unites:

16 industrial partners (OÜ Alise Technic, Norcar BSB Eesti Ltd, Robomente OY, AQ Lasertool OÜ, Favor Ltd, Sumar Instrument OÜ, AMS Elektronic LLC, Bestnet Ltd, Hanval Metall OÜ, AS Datel, AS Paide Masinatehas, AS Ferreks TT, Federation of Estonian Engineering Industry (EML), AS Fujitsu Services, Metso Minerals Inc., ELI OÜ), and

4 scientific partners from Tallinn University of Technology (Laboratory for Proactive Technologies, Department of Computer Control; Department of Mechatronics; Department of Materials Engineering; Department of Machinery).

6. Participation in and organising conferences, summer schools, reviewing papers, etc

6.1 Organising conferences, summer schools, reviewing papers, projects

Reviewing papers, member of IPC, organising

- IEEE Swarm Intelligence Symposium, Sept 21-23, 2008, St. Louis, USA (T. Lints)
- International Conference on Knowledge Generation, Communication and Management, June 29- July 02, 2008, Orlando, USA (I. Astrov)
- International Multi-Conference on Engineering and Technological Innovation, June 29-July 02, 2008, Orlando, USA (I. Astrov)
- 10th WSEAS International Conference on Mathematical methods of Computational Techniques in Electrical Engineering, October 26-28, 2008, Corfu, Greece (I. Astrov)
- 7th WSEAS International Conference on Non-Linear Analysis, Non-Linear Systems, and Chaos, October 26-28, 2008, Corfu, Greece (I. Astrov)
- 4th WSEAS International Conference on Wavelet Analysis and Multi-rate Systems, October 26-28, 2008, Corfu (I. Astrov)
- 4th WSEAS International Conference on Educational Technologies, October 26-28, 2008, Corfu, Greece (I. Astrov)
- 4th WSEAS International Conference on Dynamical Systems and Control, October 26-28, 2008, Corfu, Greece (I. Astrov)
- 2009 World Congress on Computer Science and Information Engineering, March 31- April 02, 2009, Los Angeles, USA (I. Astrov)
- 2nd International Multi-Conference on Engineering and Innovation, July 10-13, 2009, Orlando, USA (I. Astrov)
- IEEE 2009 Toronto International Conference – Science and Technology for Humanity, September 27-29, 2009, Toronto, Canada (I. Astrov)
- COST DC-ICT, open call projects reviewing, spring and fall of 2008, (M. Meriste, L. Motus)
- 6th International Conference on Software Engineering Research, Management and Applications, SERA 2008, August 2008, Prague, Czech (L. Motus)
- IEEE International Conference on Communications, June 14-18, 2009, Dresden, Germany (L. Motus)
- 2nd IFAC International Conference on Intelligent Control Systems and Signal Processing, September 21-23, 2009, Istanbul, Turkey (L. Motus)
- The 3rd Annual Conference of the National Graduate School in Information and Communication Technologies, April 25-26, 2008, Voore, Estonia (E. Petlenkov)

6.2 Attended conferences, summer schools, seminars, etc

- Estonian Summer School on Computer and Systems Science (J.-S. Preden, T. Lints)
- Estonian Winter School in Computer Science (J.-S. Preden, T. Lints)
- 34th Estonian Spring School in Theoretical Biology: Laws of Biology (T. Lints)
- 12th Estonian Computer Science Theory Days (T. Lints, L. Motus)
- EU-China Summer School on "Internet, Sciences, and Society, Warsaw, Poland (T. Lints)
- 12th IASTED Conference on Artificial Intelligence and Soft Computing, Spain, 2008 (T. Lints)
- IEEE Swarm Intelligence Symposium, 2008, St. Louis, USA (T. Lints)
- Artificial Life XI: 11th International Conference on the Simulation and Synthesis of Living Systems, Winchester, UK (T. Lints)
- GPS/INS Multi-sensor Kalman filter navigation, May 19-22, 2008, Paris, France (K. Rannat)
- 3rd International Workshop on technologies for Search and Rescue, and other Emergency Marine Operations, October 14-16, Brest, France (K. Rannat, R. Serg)
- ECO-NET workshops in Brest (July 8, October 20-21) and Tallinn (December 1, 2008), K. Rannat
- International Seminar on Defence R&D, September 26, 2008 Tartu K. Rannat, L. Motus
- 13th WSEAS International Conference on Applied Mathematics, December 15-17, 2008, Puerto de la Cruz, Spain (K. Rannat)
- ARIS Process Days, November 5-6, 2008, Stockholm, Sweden (T. Kangilaski)
- IBM Rational Software Development Conference June 10-14, 2008, Orlando, USA (T. Kangilaski)
- Oracle Nordic Application Days, March 12-13, 2008, Stockholm, Sweden (T. Kangilaski)
- ebIX forum 2008, April 16-17, 2008, Tallinn (T. Kangilaski)
- ARIS Process world Europe, June 17-18, 2008, Berlin, Germany (T. Kangilaski)
- Model-based testing in Street lighting Case Study, D-Mint project Plenary meeting, September 9, 2008,Bilbao, Spain (A. Kull)
- ITEA 2 Symposium, 21-22 October 2008, Rotterdam, the Netherlands (T. Naks, J.-S. Preden, R. Pahtma, A. Kull)
- Wireless Applications for Machines and Systems, WAMS2008, November 18-19, 2008, Ylivieska, Finland (R. Pahtma)
- IADIS International Conference, April 9-11, 2008, Algrave, Portugal (V. Kimlaychuk)

- IEEE 6th Conference on Computational Cybernetics, November 27-29, 2008, Stara Lesna, Slovakia (V. Kimlaychuk)
- 6th International Conference on Pervasive Computing, May 19-22, 2008, Sydney, Australia, (R. Serg)
- IEEE World Congress on Computational Intelligence, International Joint Conference on Neural Networks, June 6-11, 2008, Hong Kong (E. Petlenkov)
- American Control Conference, July 11-13, 2008, Seattle, USA (E. Petlenkov)
- 17th IFAC World Congress, July 6-11,2008, Seoul, Korea (E. Petlenkov)
- 10th International Conference on Control, Automation, Robotics, and Vision, December 17-20, 2008, Hanoi, Vietnam (E. Petlenkov)
- 4th International Conference on Wireless Communications, Networking and Mobile Computing, October 12-17, 2008, Dalian, China (A. Pedai)
- International Conference on Audio, Language, and Image Processing, July 7-9, 2008, Shanghai, China (I. Astrov)
- World Congress on Science, Engineering and Technology, July 25-27, 2008, Prague, Czech (I. Astrov)
- International Conference on Control, Automation, and Systems, October 14-17, 2008, Seoul, Korea (I. Astrov)
- 5th International Conference on Electrical and Computer Engineering, December 20-22, 2008, Dhaka, Bangladesh (I. Astrov)
- 7th WSEAS International Conference on Computational Intelligence, Man-Machine Systems and Cybernetics, December 29-31, 2008, Cairo, Egypt (A. Pedai)

7 Teaching activities of the lab's staff

The following examples illustrate the teaching activities at the undergraduate and MSc levels:

- **T. Naks** and **R. Savimaa** share lecture course ”Introduction to Real-time Software Engineering” (code ISP 0011) for undergraduate students
- **T. Naks** supervises course projects in “Real-time systems” (code ISP 0020) for MSc students
- **L. Motus** delivers lectures in “Software dynamics” (code 0012) for MSc students
- **L. Motus** delivers lectures in “Multi-Agent Systems” (code 0030) for MSc students
- **R. Serg** supervises practical exercises in ISP 0011, ISP 0012, ISP 0030 , and ISP 0040 (Computer Networks)

L. Motus has courses for PhD students for individual study, e.g. Artificial Intelligence and Real-time (ISP 9010), Foundations of Multi-agent System (ISP9030)

A. Udal (together with **E. Velmre**, Department of Electronics) delivers a course for MSc students “Optoelectronics and Integrated Optics”

8 Supportive personal grants applied/received

T. Lints has been successful in applying and receiving supportive grants:

- IEEE Swarm Intelligence Symposium 2008 Student Travel Grant awarded by IEEE Computational Intelligence Society (800 USD)
- ICT PhD student scholarship from Estonian Information Technology Foundation (3900 EUR)
- A travel and accommodation bursary awarded by the organisers of A-LIFE XI. Taivo's bursary was from one of the conference sponsors – a company called ProtoLife (500 GBP)
- Participation in EU-China Summer School on “Internet, Science, and Society” was sponsored by the Estonian Doctoral School in ICT

J.-S. Preden has been successful in applying and receiving the following supportive grant:

- ICT PhD student scholarship from Estonian Information Technology Foundation (3900 EUR)

9 Longer visits, lectures, fellowships, etc in 2008

Visits

Preden J.-S (2008) Microsoft Research at Redmond

Lecture

Udal, A. (2008). Simulation of electro-thermal and thermoelectric interactions in SiC material and devices, Proceedings of Advanced Materials Summer School PAM2 (Vilnius, Lithuania, May 19-23, 2008), lecture material on CD-ROM, 80 pp., http://www.pam2.mtmi.vu.lt

10 Collaboration partners

Brown University
Ecole Nationale Supérieure d'Electrotechnique, d'Electronique, d'Informatique, d'Hydraulique et des Télécommunications (ENSEEIHT), Toulouse
Leeds University
Microsoft Research, Redmond
Microsoft Innovation Center in Aachen, Germany
University of Lübeck
Vilnius University

11 Foreign and domestic visitors in the lab

Alex Gammerman, Professor of Computer Science, and Director of the Computer Learning Research Centre (CLRC), Royal Holloway, University of London

A Gammerman studies algorithmic randomness theory, and its applications to machine learning, development of inductive/transductive confidence machines, and intelligent data analysis.

Johannes Helander, Architect and Chief Scientist at Microsoft Innovation Center in Aachen, Germany

J. Helander is a specialist in the area of Embedded Systems. His current interests include embedded web services, communication middleware, component-based real-time systems, consumer centric security, context history based prediction and modelling, and automatically scalable parallelism

Gabriel Jakobson, Chief Scientist, Altusys Corp; IEEE Communications Society, Board of Governors

G. Jacobson is an expert in developing advanced information technology and applied artificial intelligence solutions for managing complex networks and systems.

12 PhD theses in progress, carried out by the lab's staff or supervised by them

T. Lints "Adaptivity"

PhD thesis with a working title "Adaptivity", which will consist of an interdisciplinary overview of adaptivity in general, and of the description of some practical methods and software-intensive prototypes (mostly related to evolutionary and developmental robotics), inspired by the theoretical work; expected completion -- fall 2009.

A. Kull "Model-Based Testing of Reactive Systems"

The thesis focuses on developing a model-based testing tool for reactive systems that can be used for testing industrial scale reactive systems, and is reasonably simple to use by test engineers. The novel test generation methods suggested in the thesis are:

- Iterative test generation from deterministic models (departing from the model-checking approach)
- Reactive planning of the test generation from non-deterministic models.

The thesis presents reasoning for development of those methods and discusses the problems related to developing and experimenting with the tool MOTES that implements the novel methods of test generation. The MOTES tool, and its applicability has been demonstrated on several industrial-scale case-studies. Planned completion time of thesis – August 2009.

J.-S. Preden „Situation-awareness of interacting computing agents“

One of the emerging fields in computer science is ubiquitous computing systems. A characteristic implementation platform for ubiquitous computing systems is multi-hop *ad hoc* network comprising heterogeneous devices. Due to the complexity, dynamic nature and openness of such networks the applications built on top of such networks can't be described, implemented, and analysed using traditional theoretical and practical methods. In my PhD thesis I model *ad hoc* network nodes as agents interacting with other agents and with the physical world. Agents interpret the incoming data in a situation-aware manner, while situation-awareness is achieved through interactions with the physical world and with the other agents. The thesis studies situation-awareness concepts considering the applicability of these concepts in pervasive computing systems. A set of potential formalisms are reviewed in the context of their applicability for achieving situation-awareness of computing systems. The thesis also presents some practical examples of situation-aware pervasive computing systems. Expected completion of the thesis – the end of 2009

R. Serg "Design of scalable embedded systems based on high level model"

My thesis will focus on aspects of high level system description and analysis. The aim is to tailor and elaborate methodologies currently used for MDD (Model Driven Development) to fit the pervasive computing and cyber-physical systems' area. Applicability of the theoretical results is demonstrated on a case study. Expected completion time autumn 2010

A.Karpištšenko "Model driven development and simulation platform for networked systems"

The thesis focuses on software development tools and methodologies that ease the debugging and detection of failure scenarios before networked systems are deployed in the environment. Architecture for a prototype tool is proposed that reuses and integrates existing technologies allowing:

- Executable code generation from high-level models described in a domain specific language
- Simulation of the networked system's behaviour and pre-set scenarios with high degree of environment configurability

The implementation of the prototype takes inspiration from MIT *proto* language and toolkit, while extending its possibilities with a simulation environment that allows control of the simulation environment and network topology. The main contribution of the work are the design principles for development platforms of networked systems, the choice and integration of existing technologies to demonstrate the effectiveness of those principles and comparison of data propagation algorithms. Expected completion time – fall 2010

V. Kimlaychuk "Security issues in multi-agent communication system"

The thesis discusses some pragmatic problems in the agent world. I start by modelling life of a real ant colony as a set of interacting software agents. For this I use JADE agent development and testing platform. Agents are software programs written in JAVA and running on a variety of hosts. A graphical user interface shows simulated life pattern of ant's nest. Next chapter demonstrates how agent-based approach supports solving the capacity planning task on the example of "5 hungry philosopher" problem. JADE agent platform and JAVA is used for this again.

The last part of the thesis crosses the boundaries of software agents as pre-programmed components and shows the ability of agents to share knowledge, and learn from other agents' experience. Shared knowledge security model is introduced here as a paradigm for securing the behaviour of next generation software – e.g. service oriented architecture, its evolution and security is being studied. Estimated completion time – the end of 2009

13 Conclusions

Elaboration and modifying of scientific theories, or discovering new interactions between the existing theories, is an inner mechanism that invokes scientific progress. The evolution of science is triggered as usually – by feedback from the not quite successful attempts of applying the existing theories for explaining natural phenomena, or to synthesising new artefacts.

Hence, in the larger picture this report contains nothing unusual. In a smaller picture the report focuses on practical difficulties and paradoxes hindering rapid dissemination of pervasive computing systems, with special emphasis on integration and networking of component-based stand-alone systems caused phenomena. The key to resolution of observed difficulties lies, according to our belief, in better understanding the essence of the underlying computational processes, in providing the computational processes with adequate ambient information, and in enhancing self-X capabilities of the synthesised systems.

In particular, this report describes our first, and in some cases indirect, attempts to address well-known difficulties observed in everyday life, and related to:

- verifying behaviour of real-time systems since its beginning (in 1950-es)
- explaining unexpected behaviour in complex systems, e.g. multi-agent systems
- forecasting and controlling behaviour of networked pervasive computing systems (and real-time systems)

These difficulties have been amplified by persistently more stringent user requirements to new computer applications which the researchers'/designers' strive to satisfy by enhancing proactive and self-X capabilities in the designed systems. Self-X capabilities are often accompanied by increased autonomy of system's components that in its turn fosters the temptation and necessity to apply dynamically changing interactions between autonomous components, and to build proactive behaviour into autonomous components.

The results obtained in 2008 leave us with the following statements on which to build the future research:

- the new pervasive computing systems violate, strictly speaking, the axioms and restrictions imposed by Turing computing paradigm, hence the Turing computing paradigm based models provide too approximate description of systems' behaviour;
- the previous statement matches with the observations pointed out at the events of Grand Challenges for Computing Research (e.g. Stepney et al 2004), that leads us to search a solution within non-classical computation paradigms – in our case within situation-aware interaction centred models of computation;
- simultaneous and interacting research threads (models of computation and proactive models of applications, proactivity, autonomy and situation-awareness

of systems, and technological platforms for implementation) -- as practiced in the lab -- have turned out to be fruitful and symbiotic, although not very easy to coordinate and to synchronise;

- systems comprising of autonomous (and may be proactive) components with dynamic structure of interactions have secured their position among novel computer applications and the related impacts and unsolved problems cannot be overlooked
- autonomy and proactivity in artificial (as well as natural) systems assume the existence of dynamic structure of inter-component interactions and inevitably cause the level of emergent behaviour that cannot any more be neglected
- for (partial) control of emergent behaviour one needs to understand the essence of the underlying computations – Turing machine paradigm cannot explain the computations in networked pervasive computing systems with sufficient details, and completely neglects many essential features
- properties of the pilot multi-stream interaction machine (as a case study of a tool for reasoning about interaction-centred computation) look promising for detection of many dynamically emerging features and enables to embed into the computing system instruments (e.g. mediated interactions) for partially controlling the emergent behaviour
- the experiments with detection and partial control of the emergent behaviour in artificial systems will provide better insight into the essence of emergent behaviour observed in the natural and/or social systems

The Lab for Proactive Technologies has started a research programme that eventually will lead (hopefully) to symbiosis of computer science, systems science and complexity science with minor influence from artificial intelligence, and artificial life. Such symbiosis provides the theoretical basis for, and practical capability to design artificial, natural, and social systems; to develop methods and tools for analysing the behaviour of such systems, and ability to partially control the emergent behaviour in such systems. Simultaneously we try to keep an eye on the progress of technological platforms for collecting situational information, for communication between nodes of ad hoc networks, smart interfacing of nodes with different ontology, and computing in the nodes and in the network.

14 Publications in 2008, and submitted for 2009

14.1 Books, and PhD theses

J.-S. Preden (2008) “Smart dust”, Eds. Dudziak, R.; Köhn, C.; Sell, R., Integrated Systems and Design Kaunas University of Technology Press, 47 – 53

I. Astrov and A. Pedai (2008) “Enhancing situational awareness through neural regulation of take-off and landing manoeuvres in unmanned helicopter”, in: Recent Advances in Computational Intelligence, Man-Machine Systems and Cybernetics (Eds. A. Zaharim, N. Mastorakis, and I. Gonos), WSEAS Press, ISBN: 978-960-474-049-9, 29-34

14.2 Conference proceedings

I. Astrov and A. Pedai (2008) “Enhancing situational awareness by means of hybrid adaptive neural control of vertical flight in unmanned helicopter”, International Conference on Automation and Systems, Seoul, Korea, ISBN: 978-89-93215-01-4-98560, 329-332

I. Astrov, S. Tatarly, S. Tatarly (2008) “Fingerprint recognition for varied degrees of image distortion using three-rate hybrid Kohonen neural network”, Proc. 2008 International Conference on Audio, Language and Image Processing, ISBN: 978-1-4244-1723-0, vol.1, 363-369

I. Astrov and A. Pedai (2008) “Situational awareness based on neural control of an autonomous helicopter during hovering manoeuvres”, Proc. 5th International Conference on Electrical and Computer Engineering, Dhaka, Bangladesh, IEEE Catalogue number CFP0868A-PRT, 857-869

I. Astrov and A. Pedai (2008) “Enhancing situational awareness through neural regulation of take-off and landing manoeuvres in unmanned helicopter”, Proc. 7th WSEAS International Conference on Computational Intelligence, Man-Machine Systems and Cybernetics, 29-34

J. Belikov, E. Petlenkov, “Calculation of the Control Signal in MIMO NN-based ANARX Models: Analytical Approach,” *Proc. of 10th International Conference on Control Automation Robotics & Vision (ICARCV 2008)*, Hanoi, Vietnam, December 17-20, 2008, pp. 2197-2201.

J. Belikov, K. Vassiljeva, E. Petlenkov, S. Nõmm, “A Novel Taylor Series based Approach for Control Computation in NN-ANARX Structure based Control of Nonlinear Systems,” *In Proc. of the 27th Chinese Control Conference (CCC2008)*, Kunming, China, July 16-18, 2008, vol. 2, pp. 474-478

T. Kangilaski (2008) “ICT and Business Alignment in Virtual Organization”, July 13-16, 2008, Proc. 6th International Conference on Industrial Electronics, INDIN 2008, Daejeon Korea, pp.1251 – 1256

T. Kangilaski (2008) “Implementing EU directive 2003/54/EC for Electricity Market in Estonia”, IADIS International Conference Information Systems 2008, April 9 -11, 2008, Algarve, Portugal, pp. 246-250

V. Kimlaychuk (2008) “Integrating Oracle enterprise service bus with JADE agents”, IEEE 6th International Conference on Computational Cybernetics, November 27-29, 2008, IEEE Computer Society Press, 59-61

V. Kimlaychuk (2008) “SOA Integration Aspects for Large Companies”, In: Proceedings of the IADIS International Conference Information Systems 2008: IADIS International Conference, Algarve, Portugal, APRIL 9-11, 2008. (Eds.) Nunes, M.B.; Isaias, P.; Powell, P. Algarve, Portugal: IADIS Press, 2008, 99-105

T. Lints 2008, *"FlockHeadz: Virtual Flock in a Room Used as a Controller"*, IEEE Swarm Intelligence Symposium 2008, Sheraton Westport Lakeside Chalet, St. Louis, Missouri, US, September 21-23. 5p.

T. Lints 2008, *"Let AI Learn from Web 2.0. Tag Co-Occurrence based Text Categorization as an Example"*, IASTED International Conference on Artificial Intelligence and Soft Computing 2008, September 1-3, Palma De Mallorca, Spain. ACTA Press. 5p.

P. Miidla, K. Rannat (2008) “Thermohaline fields monitoring model”, Proc. 13th WSEAS International Conference on Applied Mathematics, 188-192.

L. Motus, Meriste, M., Preden, J.-S. (2008) NNEC Technologies Focused on use by Semi-Autonomous Groups”. In: Proceedings, SCI-187 Symposium on Agility, Resilience and Control in NEC: SCI-187 Symposium on Agility, Resilience and Control in NEC; Amsterdam; North Atlantic Treaty Organization, 2008, 1 - 16.

S. Nõmm, E. Petlenkov, J. Vain, F. Mijawaki, K. Yoshimitsu and J. Belikov, „Recognition of the Surgeon’s Motions During Endoscopic Operation by Statistics based Algorithm and Neural Networks based ANARX Models“, *In proc. of the 17th IFAC World Congress*, Seoul, Korea, July 6-11, 2008, pp. 14773-14778.

A. Pedai and I. Astrov, "Demand and supply chain simulation in telecommunication industry by multi-rate expert systems", *2008 World Congress on Science, Engineering and Technology* (WCSET 2008, Prague, Czech Republic, July 25-27, 2008), CD-ROM, paper No 47, pp. 268-270.

A. Pedai and I. Astrov, "Multi-rate expert systems in supply chain simulation for telecommunication industry", *Proceedings, 4th International Conference on Wireless Communications, Networking and Mobile Computing* (WiCOM 2008, Dalian, China, October 12-17, 2008), CD-ROM, IEEE Catalogue Number: CFP08WNM-CDR, ISBN: 978-1-4244-2108-4, Library of Congress Number: 2008900673, vol. 6, paper No 06-02-015, pp. 1-4.

E. Petlenkov, “Model Reference Control of Nonlinear Systems by Dynamic Output Feedback Linearization of Neural Network based ANARX Models,” *Proc. of 10th International Conference on Control Automation Robotics & Vision (ICARCV 2008)*, Hanoi, Vietnam, December 17-20, 2008, pp. 1119-1123.

E. Petlenkov, I. Artemchuk, F. Miyawaki, K. Yoshimitsu, "Restricted Connectivity Neural Network Structure for Organ Recognition by Analysis of Endoscopic Images during Surgical Operation," *In Proc of the* 11*th Biennial Baltic Electronics Conference (BEC2008)*, Tallinn, Estonia, October 6-8, 2008, pp. 261-264.

E. Petlenkov, J. Belikov, S. Nõmm, M. Wyrwas, "Dynamic Output Feedback Linearization Based Adaptive Control of Nonlinear MIMO Systems," *In proc. of the 2008 American Control Conference (ACC2008)*, June 11-13, 2008, Seattle, Washington, USA, pp. 3446-3451.

E. Petlenkov, A. Jutman, S. Nõmm, R. Ubar, "A Novel Artificial Neural Networks based Automatic Adaptive Fault Detection Technique for Analog Circuits," *In Proc. of the* 11*th Biennial Baltic Electronics Conference (BEC2008)*, Tallinn, Estonia, October 6-8, 2008, pp. 167-170.

E. Petlenkov, A. Jutman, S. Nõmm, R. Ubar, "Towards Artificial Intelligence based Automatic Adaptive Response Analyzer for High Frequency Analog BIST," *In Proc. Of the IEEE International Conference on Computational Intelligence for Measurement Systems and Applications (CIMSA2008),* Bogazici University, Istanbul, Turkey, July 14-16, 2008, pp. 99-104.

E. Petlenkov, S. Nõmm, J. Vain, F. Miyawaki, "Application of Self Organizing Kohonen Map to Detection of Surgeon Motions During Endoscopic Surgery," *In proc. of the 2008 International Joint Conference on Neural Networks (IJCNN2008), the 2008 IEEE World Congress on Computational Intelligence (WCCI2008)*, June 1-6, 2008, Hong Kong, pp. 2807-2812.

A. Riid, Saastamoinen, K., Rüstern, E. (2008) "Error-free Simplification of Transparent Mamdani Systems", In: Proceedings of the IEEE International Conference on Intelligent Systems: 4th IEEE International Conference on Intelligent Systems; Varna, Bulgaria, September 6-8, 2008, Eds. Yager, R.R.; Sgurev, V.S.; Jotsov, V.S. IEEE, 2008, 2-8 - 2-13

A. Riid, Saastamoinen, K., Rüstern, E. (2008) "Redundancy Detection and Removal in Mamdani Fuzzy Systems", In: Proceedings of the Eighth International Conference on Applications of Fuzzy Systems and Soft Computing: Eighth International Conference on Applications of Fuzzy Systems and Soft Computing (ICAFS 2008), Helsinki, Finland, September 1-3, 2008, b-Quadrat Verlag, 2008, 131 - 140.

A. Riid, Rüstern, E. (2008) "Fed-Batch Fermentation Controller Design with Evolutionary Computation" In: Proceedings of the 5th International Conference on Soft Computing as Trans-disciplinary Science and Technology (CSTST 2008), Cergy-Pontoise, Paris, France, October, 28-31,. ACM, 2008, 371-377

R. Serg, J. Helander (2008) " Using XML Web services for Embedded Systems Interoperability; World's smallest Web 2.0 Server Demo", Advances in Pervasive Computing adjunct proc. 6th International Conference on pervasive Computing, Sydney, Australia, Austrian Computer Society (OCG) Press, 111-114

A. Toom, T. Naks, M. Pantel, M. Gandriau, I. Wati (2008) "Gene-Auto: an Automatic Code Generator for a safe subset of Simulink/Stateflow and Scicos", Proc. 4th European Congress on Embedded Real-Time Software, R-2008-01-10C02

A. Udal, Kukk V., Velmre E., Klopov M.: Quantum mechanical transforms between x- and k-space as a signal processing problem. Proc. of the Baltic Electronics Conf. BEC2008 (Tallinn, Oct. 6-8, 2008), 2008, pp. 71-74

E. Velmre, Klopov M. and Udal A.: Modeling of carbon nanotube junction with ab-initio software VASP. Proc. of the Baltic Electronics Conf. BEC2008 (Tallinn, Oct. 6-8, 2008), 2008, pp. 75-78

14.3 Journal papers

P. Miidla, K. Rannat, P.Uba (2008) „Simulated studies of water vapour tomography“, WSEAS Transactions on Environment and Development, Issue 3, volume 4, 181-190

P. Miidla, K. Rannat (2008) „Tomographic approach for tropospheric water vapour detection“, Computational Methods in Applied Mathematics, vol. 8, no.3, 1-16

A. Pedai and I. Astrov (2008) "Demand and Supply chain simulation in telecommunication industry by multi-rate expert system", Proc. World Academy of Sciences, Engineering and Technology, ISSN: 1307-6884, vol.31, 268-270

R. Reeder, Ikonic Z., Harrison P, Udal A., and Velmre E.: Laterally pumped GaAs/AlGaAs quantum wells as sources of broadband Thz radiation. Journal of Applied Physics, 2007, Vol. 102(7), 6 p

14.4 Abstracts

No published abstracts listed

14.5 Submitted journal and conference papers for 2009

T. Lints (2009), "*Relation Learning with Bar Charts*", 2009 IEEE Symposium on Intelligent Agents, within the IEEE Symposium Series on Computational Intelligence 2009, March 30 - April 2, Sheraton Music City Hotel, Nashville, Tennessee, USA. 7p -- accepted

A. Riid, J.-S. Preden, R. Pahtma, R. Serg, T. Lints (2009) "Automatic Code Generation for Embedded Systems from High-Level Models", journal of Electronics and Electrical Engineering -- submitted

J.-S. Preden, R. Pahtma (2009) "Smart Dust Motes in Ubiquitous Computing Scenarios", journal of Electronics and Electrical Engineering -- submitted

R. Pahtma, R. Agar, J.-S. Preden (2009) "Utilization of Received Signal Strength Indication by Embedded Nodes", journal of Electronics and Electrical Engineering -- submitted

L. Motus and M. Meriste (2009) "On Mediated Interactions", submitted

M. Meriste, L. Motus, T. Kelder, J. Helekivi, M. Polikarpus (2009) "Interactive maps for knowledge based guidance of UAV", NATO RTO SCI Symposium on Intelligent Uninhabited Vehicle Guidance Systems, 2009, accepted

J.-S. Preden, R. Serg, A. Riid, L. Motus, R. Pahtma, (2009) "Vehicle guidance system in NEC context", NATO RTO SCI Symposium on Intelligent Uninhabited Vehicle Guidance Systems, 2009, accepted.

14.6 Popular science papers, and local papers

J.-S. Preden (2008) "Situation awareness of computing agents", Proc. Estonian Doctorate School Information and Communication Technology, April 25-26, 2008 Voore Tallinn: Tallinn University of Technology, 11-13

T. Lints, 2008, "*What is Adaptation?*" Proc. Estonian Doctorate School Information and Communication Technology, April 25-26, 2008 Voore Tallinn: Tallinn University of Technology, 133-135

14.7 Verbal presentations at seminars, lectures in other institutions, etc

J.-S. Preden, "Situation awareness of computing agents" at the Estonian Winter School in Computer Science

P. Uba, K. Rannat, P. Kukk, „Meteo-data from GPS-signal", International Seminar on Defence R&D, Tartu, Estonia

A. Udal, Kukk V., Velmre E., Klopov M., „Quantum mechanical transforms between x- and k-space as a signal processing problem", Baltic Electronics Conf. BEC 2008 http://www.elin.ttu.ee/bec

T. Lints „ My first steps towards general AI", 7th Estonian Summer school on Computer and Systems science, in co-operation with the Nordic Network on Dependable Systems

T. Lints "Defining Adaptivity – a short review", 13th Estonian Winter School in Computer Science

L. Motus, M. Meriste, "Towards proactive computing systems", Final Workshop of the Estonian Centre of Excellence for Dependable Computing 2002-2007, Tallinn Jan 2008

M. Meriste, L. Motus, "Teadmistepõhise Eesti alus – proaktiivne võrgustamine, E-eesti konverents, Tallinn, in Estonian "Knowledge-based Estonia – proactive networking"

M. Meriste, J.-S. Preden, "Interacting entities in dynamic networks", COST Action 295 regular workshop, Freiburg, Feb 2008

M. Meriste "Arukas maja -- isekorralduv süsteem", Kinnisvaramagnaadid MTÜ korraldatud seminar "Keskkonnasõbralik ehitamine - Eesti tulevik", in Estonian "Intelligent building as a self-organising system"

M. Meriste, "Interactive maps", to German SME delegation visiting TU Institute of Technology, Sept 2008

L. Motus "Proactive technologies and their applications", seminar Intelligent Building 2, TUT, organized by IEEE Estonia, May 2008

L. Motus "Transparency of Interactions", Seminar on Complexity, in conjunction with the Complexity-NET meeting in Tallinn, May 15, 2008

A Udal „Quantum mechanical coordinate-momentum transforms and the Heisenberg's uncertainty as a classical Fourier' signal processing problem: philosophical and practical conclusions", Center of Nonlinear Studies CENS (Inst. Of Cybernetics TUT)

R Pahtma "A Cricket based positioning system for the TUT Robotics Club robot", Robotex 2008

Seminars in the Lab

19.09.2008 L. Motus "Verification of embedded software – modules versus systems"
02.10.2008 V. Kimlaychuk "Shared knowledge security in agent network"
09.10.2008 J. Preden &M. Meriste "Network enabled capabilities and ad hoc networks"
16.10.2008 A. Riid "Error-free simplification of fuzzy systems"
30.10.2008 A. Udal "Quantum mechanical coordinate-momentum transforms and the Heisenberg's uncertainty as classical Fourier' signal processing problem"
06.11.2008 M. Meriste "Interactive digital map – a multi-agent system"
R. Serg "Adapting futures: scalability for real-world computing"
13.11.2008 R. Pahtma "Intelligent dust and positioning of motes"
20.11.2008 T. Naks "Model based development and qualification of software process"
27.11.2008 J. Preden "Aspects of situation-awareness"
04.12.2008 R. Savimaa "Modelling time-sensitive behaviour in organisations – possibilities and practice"
11.12.2008 A. Kull "Model-based testing of Embedded Systems"
18.12.2008 A. Karpištšenko "Design of "Canvas" for networked systems"
08.01.2009 T. Lints "Adaptation: concepts, processes, applications"

15. References

P.W. Anderson (1972) "More is different", Science, vol. 177, no. 4047, 393-396

T.S. Bateman, and Crant, J. M. (1993) "The proactive component of organizational behaviour: A measure and correlates", Journal of Organizational Behaviour, 14(2), 103-118.

I. Chlamtac, Conti M., Liu J.J.-N (2003) "Mobile ad hoc networking: imperatives and challenges", Ad Hoc Networks, vol.1, 13-64, www.elsevier.com/locate/adhoc

J-L. Colaço, B. Pagano, M. Pouzet (2005) "A Conservative Extension of Synchronous Data-flow with State Machines", Proc. of the ACM Embedded Systems Software Conference (EMSOFT'05), ACM 1-59593-4/05/0009, 173-182

M. J. Crant (2000), "Proactive behaviour in organizations", Journal of Management, vol. 26, no. 3, 435-462

W. Dosch, M. Meriste, L. Motus (2007) "Enriching Interactive Components with AGAIN Commands", Proc IEEE International Conf. Electro/Information Technology, IEEE Computer Society, 200 – 205, ISBN 1-4144-0931-1

E. Eberbach (2001) "Challenges Facing Computer Science in the 21st Century", in (ed. J.C. Misra) Applicable Mathematics: Its Perspectives and Challenges, Narosa Publishing House, New Dehli, 565-573

M. Endsley (1995) "Towards a theory of situation awareness in dynamic systems" Human Factors, vol. 37, no.1, 32-64

V. Frankl (1946/1984) "Man's Search for Meaning", Washington Square Press, 221 pp.

T. Frűhwirth and S. Abdennadher (2003) "Essentials of Constraint Programming", Springer, 145 pp

N. Halbwachs (1998) "Synchronous Programming of Reactive Systems: A Tutorial and Commented Bibliography" Springer, Lecture Notes in Computer Science no. 1427, 1-16

J. Helander, Preden, J. (2006) "Adapting the Auto to a New Tune", 1st Workshop on Models and Analysis for Automotive Systems / RTSS 2006 : The 27th IEEE Real-Time Systems Symposium: 1st Workshop on Models and Analysis for Automotive Systems : Held in conjunction with RTSS 2006, 5-8 December 2006, Rio de Janeiro, Brazil. , 2006, pp 21 - 24

W. Hohmann (2004) "Supporting Model-Based Development with Unambiguous Specifications, Formal verification and Correct-by-Construction Embedded Software", SAE (Society for Automotive Engineering) 2004 World Congress, session on In-vehicle Software, paper no. 2004-01-1768, 6 pp.

S. Hornung and D.M. Rousseau (2007) "Active on the Job—Proactive in Change", Journal of Applied Behavioural Science, Vol. 43, No. 4, 401-426

D. Goldin, S. Smolka, P. Attie, and E. Sonderegger (2004)"Turing Machines, Transition Systems, and Interaction" Information and Computation Journal, 194, no.2, 101-128

D. Goldin and P. Wegner (2005) "The Church-Turing Thesis: Breaking the Myth", LNCS 3526, Springer, 152-168

E.A. Lee (2006) "Cyber-Physical Systems – Are Computing Foundations Adequate?", Position paper at NSF Workshop on Cyber-Physical Systems: Research Motivation, Techniques and Roadmap, 9 pp

E.A. Lee (2008) "Cyber Physical Systems: Design Challenges", International Symposium on Object/Component/Service-Oriented Real-Time Distributed Computing (ISORC), Orlando, FL, 7 pp

P. Lorents, L. Motus, J. Tekko (1986) "A language and a calculus for Distributed Computer Control Systems Description and Analysis", Proc. Software for Computer Control, Pergamon/Elsevier, 159-166

M. Meriste, L. Motus, T. Kelder, J. Helekivi (2005) "C# templates for Time-aware Agents", *In: Proceedings of the 7th International Conference on Enterprise Information Systems : ICEIS2005: 7th International Conference on Enterprise Information Systems; Miami, USA; 24-28 May, 2005.* Miami, 247 - 250

M. Meriste, L. Motus, T. Kelder, J. Helekivi, A. Marandi, J. Preden (2005) „Location awareness of information agents", Advances in Databases and Information Systems, Springer Verlag, Lecture Notes in Computer Science, vol.3631, 199-208

R.A. Milner (1980) "A Calculus of Communicating Systems" *LNCS*, Vol.92, Springer Verlag, 171p

R.A. Milner (1993) "Elements of Interactions", Communications of the ACM, vol.36, no. 1, 78-89

Milner R. (2006a) "Transcription of the presentation "Scientific Foundation for Global Computing"", Springer, Trans. on Computational Systems Biology IV, LNBI 3939, 1-13

R.A. Milner (2006) "Pure bigraphs: structure and dynamics", Information and Computation, vol. 204, no.1, 60 - 122

L. Motus and M.G. Rodd (1994) „Timing Analysis of Real-time Systems", Elsevier/Pergamon, 1994, 212 pp

L. Motus and Naks T. (1998), "Formal timing analysis of OMT designs using LIMITS", *Computer Systems Science and Engineering*, vol.13, no.3, 161-170

L. Motus, M. Meriste, T. Kelder, J. Helekivi (2002) "An architecture for a multi-agent systems test-bed", *In: Preprints: 15th Triennial World Congress of the International Federation of Automatic Control; Barcelona, Spain; 21-26 July, 2002.* Oxford: Pergamon, 69

L. Motus, M. Meriste, T. Kelder, J. Helekivi, V. Kimlaychuk (2003) "A test-bed for time-sensitive agents – some involved problems", 9th IEEE International Conference on Emerging Technologies and Factory Automation, Portugal, vol. II, 645-651

L. Motus, M. Meriste T. Kelder, J. Helekivi (2004) „Agent-based templates for Implementing Proactive Real-time Systems", Proc. International Conference on Computing, Communications, and Control Technologies, ISBN 980-6560-17-5, August 2004, Texas, USA, vol.1, 199-204

L. Motus, M. Meriste, W. Dosch (2005) "Time-awareness and Proactivity in Models of Interactive Computation", Electronic Notes in Theoretical Computer Science, vol. 141, 69-95, www.elsevier.com/locate/entcs

L. Motus, M. Meriste, J-S. Preden (2006) "Network Enabled Capabilities -- Grassroots Perspectives". NATO RTO/IST Symposium on "Dynamic Communication Management", North Atlantic Treaty Organization, (16-1 - 16-13)

T. Naks and Motus L. (2001) "Handling Timing in a Time-critical Reasoning System – a case study", *Annual Reviews in Control*, vol.25, 157-168

S. K. Parker, Williams, H.M., and Turner, N. (2006) “Modelling the antecedents of proactive behaviour at work”, Journal of Applied Psychology, 91(3), 636-652

J. Preden, (2006) "Communication area based positioning", Proc. The 3rd IEEE International Conference on Mobile Ad-hoc and Sensor Systems, ISBN 1-4244-0507-6, October 2006, pp 336 - 347

J. Preden, Helander, J (2006) "Auto-adaptation Driven by Observed Context Histories", UbiComp workshop ECHISE 2006: Exploiting Context Histories in Smart Environments

J. Preden, Sarkans, M.; Otto, T. (2007) “Diagnostics of Machining and Assembly Systems by Networked Motes”. J. Machine Engineering, 2007, 7(1-2), 68 - 77

J. Preden, Helander, J, (2007) "Situation aware computing in distributed computing systems", Proceedings of the 10th Symposium on Programming Languages and Software Tools 2007, Budapest, 14th-16th of June, 2007. (Edit.) Horvath, Z.; Kozma, L.; Zsok, V., Eötvös Lorand University, Faculty of Informatics: Eotvos University Press, 280 - 292.

J. Preden, Sarkans, M; Otto, T, (2007b) "Smart dust based modular laboratory kit for monitoring workshop machinery", 8th International Workshop on Research and Education in Mechatronics

W. Quirk. and Gilbert R. (1977) ´”The Formal Specification of the Requirements of Complex Real-time Systems” AERE, Harwell, rep. No. 8602

Stepney S., Clark J.A., Tyrrell A., Johnson C., Timmis J., Partridge D., Adamatzky A., Smith R.E. (2004) “Journeys in Non-Classical Computation; A Grand Challenge for Computing Research”, 20 pp

A. Turing (1936) “On computable numbers with an application to the Entscheidungsproblem”, Proc. London Mathematical Society 42:2 230-265; ibid 43 (1937), 544-546

V. Utkin, J. Gulder, M. Shijun (1999) “Sliding Mode Control in Electromechanical Systems”, CRC Publ., 338 p

P. Wegner (1998) “Interactive foundations of computing” Theoretical Computer Science, **192**, 315-351

P. Wegner and E. Eberbach (2004) “New models of Computation”, The Computer Journal, vol. 47, no.1, 4 - 9