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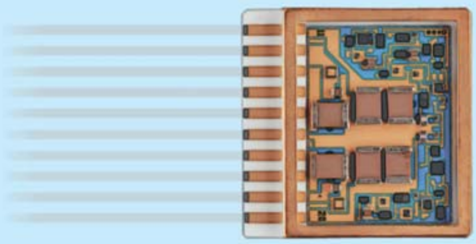
Networked Embedded and control Systems Technologies for Europe and Russia

NESTER



Networked Embedded and Control Systems Technologies: Opportunities for EU-Russia Cooperation

International Workshop

July 4-5, 2009, Milan, Italy

Networked Embedded and Control Systems Technologies: Opportunities for EU-Russia Cooperation

Materials for the International Workshop on
“Networked embedded and control system technologies: European and Russian R&D cooperation”

4-5 July, 2009, Milan, Italy

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NESTER consortium members:

inno TSD,
a strategic management consulting company (FR),

European Embedded Control Institute (EU)

Russian Technology Transfer Network, a network of research and innovation centres (Russia)

LANIT-TERCOM, (Russia)

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1. NETWORKED EMBEDDED AND CONTROL SYSTEMS – TOWARDS A CLOSER EU-RUSSIAN COLLABORATION

Software and electronics are now embedded in various devices and objects. At the same time pervasive data changes how these intelligent objects dynamically pool information, cooperate under numerous constraints and reliably interact and control the physical world. The networked control system, i.e. distributed hierarchical system of co-operating controllers and computing elements which are connected together, cope with failures and uncertainties with recovery through reconfiguration or self-restructuring. At the same time they use more and more new sensors and sensor networks, emerging from micro and nano-systems technologies, leading to further improvements in performance and efficiency. These complex engineering systems, situated on the edge between several domains with 3 key elements (3"C") – communication, computer and control, are known under the name of Networked Embedded and Control Systems (NECS).

One of the key elements of the research in the area of NECS is its multidisciplinarity. While individual contributions in the research and advances in the different application domains are at high level, there is very small interaction between the principal elements (3"C") and not enough of transversal research used in parallel in different domains. A better integration is required both at the technological level in order to avoid fragmentation and at the scientific level, where thorough and principled system-theoretic view is still missing. Even the meaning of the term "NECS" is ambiguous and still requires better definition, people coming from communication, computer and control communities have different understanding of NECS.

For example, despite the recent intersection between the application domains of network theory (communication) and control engineering (control), the necessary links for the transfer of ideas and tools between the two fields have yet to be established. This situation is largely due to fundamental differences between the methodologies and goals of the two communities. While control engineers build feedback systems to satisfy closed loop design specifications, network theorists seek models to explain the observed behaviour of existing networks. In fact, the starting points and objectives of a complex-network theoretician and a control engineer are reversed, even though they face the same problems in trying to understand their target systems. Despite the use of different analysis tools, network properties such as connectivity, efficiency, and robustness are critical to both control design and complex-network modelling.

Research on NECS have major strategic relevance for the European industry and society, since these systems form a key growth area in information and communication technologies with a broad range of applications that will affect the citizen in all aspects of their lives. Existing and emerging areas include, for example, automotive industry, energy management, biomedical and health care industries, environmental monitoring, factory automation, personal communication, process industry and transportation. But other information – based industries – such as telecommunications – are likely to benefit from advanced procedures for embedded decision making. Contrary to desktop computing where a few major players dominate the scene, NECS is still open field with enormous potential in the future markets of ambient intelligence.

In this situation, Europe should position itself as a major player, leading the development of intelligent and networked systems. Addressing these ambitious objectives requires merging of different system sciences and engineering as well as the mobilization of resources on a large scale. One of the urgent needs in the emerging area of embedded and networked control systems is to reinforce insufficient dialogues between the various NECS research groups. Indeed, one of the consequences of the present fragmentation of efforts undertaken in different countries positioning in the NECS technologies is the situation where the methodologies are rediscovered from one area to another with more or less difficulties and more or less knowledge of the available or promising fundamental tools that can be used. Russia is the "old" scientific partner of the European Union. Traditionally very strong in the fundamental physic and mathematic research, the Russian researchers have outstanding competences in "hot" ICT topics such as software architecture, nanoelectronics components, robotics, infrastructures, embedded systems design. Even though the area of the NECS is quite new for Russian researchers, it is expected that NECS fields will be developed rapidly in the nearest future.

That is why the European Commission decided to support the NESTER project, aimed to propose the collaboration priorities between Russia and Europe in the field of NECS, to bring closer the European and Russian researchers in the field of NECS and to foster joint collaboration opportunities driven by industrial demands.

The NESTER project

NESTER www.nester-ru.eu is an International cooperation support action on Networked Embedded and Control Systems, one of the key priority ICT areas defined in Work Programme (FP7-ICT-2). The NESTER project is funded by the European Commission under the 7th Framework Programme.

The general objective of the NESTER project is to identify constituencies and opportunities for deeper strategic cooperation between Europe and Russia in the field of NECS. This might therefore have great impact on future policies, trends, practices and projects led by the European Commission.

The NESTER project is implemented by a consortium led by inno-TSD (France), the three other partners are EECI – European Embedded Systems Institute, RTTN –

Russian Technology Transfer Network (Russia) and Lanit-Tercom (Russia). The consortium work closely with the NECS expert group composed of 5 European and 5 Russian NECS high-level specialists, each expert being closely linked to one of the four industrial sectors. The objective of the NECS expert group is to provide the NESTER consortium with a strategic vision on the European-Russian collaboration in the field of NECS and to help detecting collaboration opportunities between NECS players from Russia and Europe.
Throughout the 18-month project duration (April 2008 – September 2009), the NESTER project aims to:

- Identify opportunities for deeper strategic cooperation between Russia and the European Union in the field of NECS technologies
- Contribute to the definition of NECS EU-Russian cooperation strategy in at least four industrial sectors
- Promote common development of NECS technologies involving research and industry from EU and Russia.

The project bases its analysis on industrial sector needs in order to identify the four industrial sectors most propitious for cooperation. Developing common NECS classification, the NESTER project has screened Russian and European competences in the field of NECS technologies and mapped collaboration opportunities.

The building of the European and Russian NECS Network opened to researchers, industrials, and policy makers supports a constructive dialogue between Russia and the European Union. This creates new ideas, concepts and technologies that will catalyse knowledge transfer and allow to progress beyond the current NECS technological state-of-the-art. Thus, NESTER is a great opportunity to build industrial and research partnerships between Europe and Russia in the NECS field.

Identification of four industrial “locomotive” sectors with highest potential for European-Russian NECS collaboration

The objective of the consortium was to analyse ten industrial sectors in order to select those with highest EU-Russian NECS collaboration potential.
The methodology of selection of 4 industrial “locomotive” sectors with highest potential to European-Russian NESC collaboration includes five main steps:

1. Constitution of the preliminary list of industrial sectors;
2. Organisation of 20 interviews with European and Russian specialists;
3. Analysis of over 20 relevant documents (reports, research agendas…);
4. Cross-mapping of the results obtained,
5. Selection of four “locomotive” sectors and their further analysis.

The following industrial sectors were analysed: (1) Telecommunication; (2) Smart manufacturing and logistics; (3) Bank and finance; (4) Transport (sea, land, public…); (5) Navigation; (6) Security; (7) Aerospace and avionics; (8) Energy production and distribution; (9) Health; (10) Multi-Media (game, photo, video), (11) Home centric design /smart home.

The analysis took into account the current status of the NECS technologies development and market trends in each of these sectors, as well as current scientific challenges, such as (1) Modelling, analysis and control design for multi-rate and multi-dimensional systems with structured interaction and large uncertainties; (2) Design of error correction codes for control purposes; (3) Event driven sensing and control for a more efficient energy management; (4) Concept of cooperative control in systems constituted by complex networks of autonomous agents; (5) Dynamic optimisation of actuators and sensors positioning for performance optimisation; (6) Multi – agent and dynamic aspects of the systems; (7) Generalization of problems arising in different application domains and their treatment on more fundamental level; (8) Big uncertainties in the systems description both for system identification and handling.

As a result of this work, the highest potential for EU-Russian NECS collaboration has been identified in the following four sectors: (1) Transport; (2) Energy; (3) Telecommunication; (4) Public infrastructure security (Fig. 1).

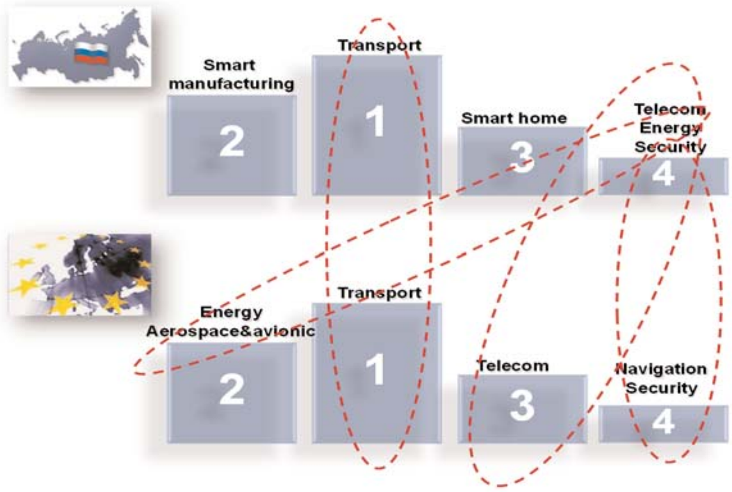

Fig.1. Identification of four sectors with highest NECS EU-Russian collaboration potential: Russian and European visions.

Analysis of four industrial "locomotive" sectors with highest potential for European-Russian NECS collaboration

Transport

The current state of practice exhibits the following weaknesses:

- Safety and Quality of service are considered separately;
- Model based design is performed but the information flow between abstraction levels is not standardized;
- Conflicting requirements are detected manually;
- Modular certification is not yet done;
- Product time-to-market pressure does formal methods not applicable in practice;
- Academia programs target low educational skills in formal methods (scientific vs. engineering approach).

Part of the gap existing between the current state-of-practice and state-of-the-art will be filled by the following achievements:

- New integrated platforms combining functional and non-functional properties
- New concepts of robustness and diagnosability
- Methodologies and tools coping with increasing system complexity

- Integration of formal methods and tools in development environments at different levels of detail according to domain/problem safety constraints.
- Modification of existing training practice

The European-Russian NECS cooperation should be structured in order to address these needs and shall provide techniques, methods and tool to improve safe mobility, to integrate diagnosability aspects in order to optimise life cycle costs and cover all transportation domains (e.g. advanced driver assistance systems, advanced braking systems, flight management systems; power management systems, cost-efficient implementation…).

Main challenges include: (1) Improvement of cross fertilisation between transport domains to leverage globally the excellence of engineering of NECS for transportation; (2) Development time reduction despite increase of systems and software complexity; (3) Increasing quality and reliability of products and services with novel functionalities for end user.

Energy
Expected impact from EU-RU collaboration includes:
- Energy saving (low energy consumption)
- Distributed energy management & optimisation
- Energy efficiency
- Higher performances with reduced energy consumption (Energy/performance trade-off)

Main challenges include:
- Energy management especially for sensors, actuators and wearable or portable devices
- Design of energy autarkic mobile embedded devices
- Reduce emission and energy consumption through better situation awareness and improved vehicle global efficiency
- Reduce energy consumption of home, office and mobile equipment by reducing energy consumption
- Increased requirements for energy consumption for supporting security functions especially in battery-constrained embedded devices.
- Low energy/power electronics design with various requirements.

Telecommunication
The telecommunication sector is one of the most active in the Russian market. It is sufficiently financed and the use of NECS technologies and ICT in general, in this sector is really high and has excellent potential.

Expected impact from EU-RU collaboration includes:
- Development of new network interconnections which will allow better interoperability of services and forester the reduction of telecommunication costs and the introduction of new technologies.
- Creation of new software network applications which will enable interoperation across the EU-Russia ICT community

- Contributing to the promotion of common standards and certification methods
- Joint projects will help to increase efficiency and productivity of software development; therefore they will contribute to increasing the level of software technologies profitability
- Research and education networks: integrating Russian researchers into European research community

The main challenge in the area of telecommunication is the provision of ubiquitous wireless connectivity under the constraints of minimum power consumption and limited bandwidth for real-time, secure and reliable communication. A particular focus appears in the development of systems with advanced properties:

- Development of both network architectures and protocols to enable connectivity and secure and dependable communications
- Tracking and wireless identification systems: These systems allow application and services based on the location of users and objects.
- Wireless Control Networks: These networks are constituted by sensors and actuators providing the infrastructure necessary for the realisation of ambient intelligence.
- Autonomous systems with context sensitive self properties that enable the efficient construction of self-organising embedded systems
- Interoperable service oriented architectures play an important role in order to get full interoperability among heterogeneous resulting in fully autonomous plug and play behaviour
- Integration of heterogeneous communication technologies.

Public infrastructure security

Expected impact from EU-RU collaboration includes:

- Provide interconnected ES based solutions satisfying new needs (financial, medical, public safety, …)
- Create common standards for devices and protocols approaching the homeland security market
- Increase the market of Critical Infrastructure Protection
- Advanced security of the common transport system increasing business opportunities in all market domains
- Increase the market of methods ,tools and services to support cost effective processes for designing secure and dependable applications

Research challenges for joint European-Russian research in the domains include:

- Development of secure NECS at node level (secure software, scalability of the management of a large number of interacting devices, integrated security techniques that use modulation, encoding, encryption and interleaving technologies..)
- Secure real -time networking for NECS and critical infrastructures and secure, trusted, dependable and efficient data transfer (frequency agility and flexible transmission, flexible communication protocols providing trade off between performance (latency, jitter, throughput...), and security parameters (determinism, reliability, security....)

- Secure NECS services and applications (enhanced intrusion detection and prevention, large scale secure, dependable and resilient distributed NECS, continuous and upgradeable security assessment of large scale distributed NECS, automatic security management in presence of limited resources of embedded nodes)
- Design tools and methodologies for large scale distributed NECS(support for security as built -in feature, develop generic modelling, simulation and analysis methodologies, develop tools to evaluate security, privacy and dependability/ composability)
- Architectures, designs and processes (security/privacy specs: common framework, completeness evaluation, architectures: intrusion proof, upgradeable, trusted, dependable, architectures for reliable fault tolerant and resilient ES

The following scientific topics are common for all of these sectors:
- Energy consumption management
- Development of dynamically reconfiguring architectures
- Languages and algorithms for the control of evolvable, distributed and adaptable systems
- System-level model-based tools and design processes
- Development of new test, validation and verification tools

All these R&D topics are transversal and are relevant for most of application sectors and therefore can be considered as priority R&D topics for European-Russian NECS collaboration.

Establishing partnership

The workshop “Networked embedded and control systems technologies: European and Russian R&D cooperation” is taking place as a satellite event at ICINCO conference (Milan, July 2-5, 2009), where European and Russian researchers will have the opportunity to present their scientific results and discuss collaboration opportunities.
The workshop is aimed at strengthening R&D collaboration between the European Union and Russia in the field of Networked Embedded and Control System Technologies (NECS). Representatives from both the research and industrial communities will be brought together to share experiences, present and discuss recent scientific and technological achievements, and identify areas of common interest and potential R&D collaboration in the field of NECS, namely within the scope of upcoming calls of the European Union’ 7th Framework Programme.
Workshop participants will have the opportunity to:
- meet with European and Russian leading NECS players
- get an insight into the latest technical developments presented by researchers with first-hand experience
- Take advantage of networking opportunities to establish new research-research and research-business contacts

NESTER team prepared this publication, in order to increase the visibility of Russian NECS competences for European partners.

In chapters II and III of this paper, we are pleased to present the catalogue, containing profiles of Russian organizations interested and active in identified technological NECS areas. In this catalogue, we collected the profiles of 22 organisations that expressed interest for collaboration with EU partners of 80 covered by NESTER mapping. It gives an overview of Russian potential in the mentioned areas. Chapter IV includes the articles prepared by the Russian participants for NESTER workshop. These articles discover in detail, the competences of Russian partners in the NECS fields.

We hope that the presented information will enable you to find the most appropriate partners from Russia for further cooperation in European R&D projects.

2. RUSSIAN NECS COMPETENCES MAPPING

This table shows competences of 22 Russian organizations in accordance with the classification of Networked Embedded and Control Systems technologies elaborated by NESTER. It is a two-dimensional classification based on research and technology development of applications. The NECS technologies classification was used for the exercise of technological screening and cross-mapping of technological offers (“NESC R&D offer”) and industrial needs (”NESC users”).
The table is based on self-estimations provided by representatives of these organizations. More detailed information about the organizations is presented in chapter III of this paper.

	R&D Institutes and Universities														R&D Companies							
Four domains within application context ("NESC users"):	Bauman Moscow State University	Institute for system programming of the Russian Academy of sciences	Institute of Automation and Electrometry Siberian Branch of Russian Academy of Sciences	International Institution of Cybernetics and Artonics	Moscow State University/Computational Mathematics and Cybernetics Faculty, Laboratory for CS	Moscow Power Engineering Institute	Moscow Institute of Electronic Technology	Novosibirsk State Technical University/ Department of Production Automation in Machine Building	Saint-Petersburg State University / Laboratory of stochastic computing	Saint-Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences	Saint Petersburg State University / Institute for Information Technologies	Saint Petersburg State University of Information Technologies, Mechanics and Optics	Saint Petersburg State University of Aerospace Instrumentation	Ulyanovsk State Technical University	Cybernetic systems development	ELVEES RnD Center	Karza LLC	LMT Ltd	Modular System Tornado	NTK SciDeCo Ltd	Siemens Corporate Technology	VEK-21 Ltd
1. Industrial applications (both transport and manufacturing)		●	●		●				●	●			●	●	●			●		●	●	
1.1. Transport		●			●				●	●		●			●				●	●		
1.1.1. Automotive (on board and part of the roadside infrastructure)		●		●	●			●	●	●	●	●		●	●		●			●		
1.1.2. Air transport		●		●	●					●		●		●	●							
1.1.3. Rail (on board and interlocking systems)		●	●	●	●				●		●	●			●		●	●		●		
1.1.4. Sea transport		●		●	●						●				●		●					
1.1.5. Localization		●			●						●	●			●		●					
1.2. Smart manufacturing (including industrial process control)	●	●	●	●	●	●		●	●		●				●		●	●		●		
1.3. Logistics		●			●				●						●					●	●	
1.5. Bank and finance		●			●									●	●							
2. Nomadic environments – "Walk, Talk, Hear, See"		●	●		●			●	●	●				●	●			●		●	●	
2.1. Wireless communications		●	●		●		●		●	●		●			●			●		●		
2.1.1 Personal area network (PAN) < 10m		●	●	●	●		●		●	●	●	●			●		●	●		●		
2.1.2 Local area networks (LAN) < 100 m		●	●	●	●		●		●		●	●			●			●		●		
2.1.3 Metropolitan area networks (MAN) < 50 km		●		●	●		●		●			●			●							
2.1.4 Wide Area networks (WAN) global		●			●				●	●					●							
2.2. Navigation		●			●										●							
2.3. Distant control & monitoring		●	●		●		●				●				●	●	●	●	●	●	●	
2.4. Multimedia (TV, radio).		●		●	●		●			●		●		●	●						●	
3. Private spaces – "Efficiency, safety and pleasure in the home"		●			●			●		●					●					●		
3.1. Healthcare sector: from 'health care' to health management'		●			●		●	●		●										●	●	
3.2. Domestic electronics and appliances (Home centric design /smart home etc…)		●		●	●		●	●			●	●			●	●	●			●	●	
3.3. Multi-Media (game, photo, video…)		●		●										●	●							
4. Public infrastructure – "Secure and dependable environment"		●			●			●	●	●	●	●	●		●	●		●			●	
4.1. Urban infrastructures (electricity, gas, water production and distribution networks)		●		●	●	●	●	●			●		●		●	●						
4.2. Public health (hospitals, health centers, etc.)		●		●	●		●			●		●	●			●		●	●		●	
4.3. Education and leisure (schools, parks, sport centers, etc.)		●		●	●		●	●				●				●		●				
4.5. Security services (police, military, emergency services, etc.)		●			●							●	●			●		●				
4.6. Optimisation of transport systems in urban areas, etc.		●			●			●		●		●				●		●	●		●	

Three transversal areas within research and technology development ("NESC R&D offer"):	R&D Institutes and Universities														R&D Companies							
	Bauman Moscow State University	Institute for system programming of the Russian Academy of sciences	Institute of Automation and Electrometry Siberian Branch of Russian Academy of Sciences	International Institution of Cybernetics and Artonics	Moscow State University/Computational Mathematics and Cybernetics Faculty, Laboratory for CS	Moscow Power Engineering Institute	Moscow Institute of Electronic Technology	Novosibirsk State Technical University/ Department of Production Automation in Machine Building	Saint-Petersburg State University / Laboratory of stochastic computing	Saint-Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences	Saint Petersburg State University / Institute for Information Technologies	Saint Petersburg State University of Information Technologies, Mechanics and Optics	Saint Petersburg State University of Aerospace Instrumentation	Ulyanovsk State Technical University	Cybernetic systems development	ELVEES RnD Center	Karza LLC	LMT Ltd	Modular System Tornado	NTK SciDeCo Ltd	Siemens Corporate Technology	VEK-21 Ltd
5. Heterogeneous distributed networks		●	●		●			●	●	●			●		●			●		●		
5.1 Design	●		●	●	●	●		●		●			●	●	●	●			●			
5.1.1 Safety	●	●			●	●			●				●					●	●	●		
5.1.2 Security	●	●			●	●	●			●				●								
5.1.3 Dependability		●	●		●			●			●			●	●	●		●				
5.1.4 Cost and energy efficiency			●	●	●	●			●		●	●					●					
5.2 Architectures		●		●	●				●	●	●		●			●		●	●	●		
5.2.1. Composability	●					●		●			●			●				●				
5.2.2. Modularity (Plug & Play)	●				●				●		●	●		●	●				●	●		
5.2.3. Programmability		●										●	●		●	●				●		
5.2.4. Scalability		●	●		●		●		●				●	●			●					
5.2.5. Standardisation and interoperability	●			●	●					●	●	●		●	●		●	●				
5.3 Hardware/Software platforms				●	●	●							●			●			●			
5.3.1. Lightweight OS and kernels	●				●	●	●	●		●				●	●	●	●			●		
5.3.2. Radio interfaces	●			●			●	●			●			●	●	●	●	●				
5.3.3. Sensors					●	●			●		●								●			
5.3.4. Actuators		●			●					●		●	●		●							
5.4. Engineering methods			●	●	●						●		●			●						
5.4.1. System-level model-based tools and design processes for fault adaptation & recovery	●			●	●	●								●			●					
5.4.2. Unification of approaches from computer science, electronic engineering and control	●	●	●		●	●	●	●	●	●					●				●	●		
5.4.3. Advanced model-driven development for platform based design	●	●	●	●	●		●	●	●	●					●	●	●			●		
5.4.4. Test, validation and verification tools.	●	●	●	●	●	●		●	●	●				●		●	●	●				
6. Seamless connectivity	●	●	●	●	●	●	●		●		●	●					●	●	●			
6.1. Cross domain connectivity (multi-homing)	●		●	●		●	●	●				●	●		●				●	●		
6.2. Roaming			●	●			●		●							●						
6.3. QoS awareness	●		●	●	●																	
6.4. Privacy, security and trust				●	●																	
6.5. Predictable connectivity					●																	
6.6. Management of temporal and spatial uncertainties					●		●	●														
7. Large scale dynamic system control and middleware	●				●			●	●								●					
7.1. Network centric algorithms					●				●	●												
7.1.1. Resources discovery					●					●		●								●		
7.1.2. Resources management					●					●	●		●	●		●	●					
7.2. Object/service	●	●			●		●				●			●	●			●				
7.2.1. Definition				●	●			●				●	●		●	●		●	●			
7.2.2. Instantiation					●			●	●					●			●			●		
7.3. Configuration and decision making		●		●	●		●			●					●	●	●	●				
7.3.1. Ad-hoc cooperation					●	●				●	●	●			●	●	●	●	●			
7.3.2.Robustness	●				●		●					●								●		
7.3.3. Predictability	●	●	●		●	●	●			●			●	●		●						
7.4. Abstraction and virtualisation		●	●		●							●		●			●					

3. CATALOGUE OF RUSSIAN R&D ORGANIZATIONS AND THEIR PROPOSALS FOR COLLABORATION

R&D Institutes and Universities 16
- Bauman Moscow State Technical University 16
- Institute for system programming of the Russian Academy of sciences 18
- Institute of Automation and Electrometry Siberian Branch of Russian Academy of Sciences 20
- International Institution of Cybernetics and Artonics 22
- Moscow State University / Computational Mathematics and Cybernetics Faculty, Laboratory for Computer Systems 23
- Moscow Power Engineering Institute (Technical University) 24
- Moscow Institute of Electronic Technology (Technical University) 25
- Novosibirsk State Technical University 27
- Saint-Petersburg State University / Laboratory of stochastic computing, Institute of Information technology, Department of Mathematics and Mechanics 30
- Saint-Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences / Laboratory for Information Technologies in Systems Analysis and Integrated Modeling 31
- Saint Petersburg State University / Institute for Information Technologies 34
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- LMT Ltd 48
- Modular System Tornado 49
- NTK SciDeCo Ltd 50
- Siemens Corporate Technology, Ltd. 51
- VEK-21, Ltd 52

R&D Institutes and Universities

Bauman Moscow State Technical University

Acronym: BMSTU
Type: R&D organization/University/Laboratory
Size: > 80 employees

Founded in 1830 BMSTU is a research-led University ranked #1 among Russian technical universities. It combines profound fundamental schooling and research with practical application knowledge. It is made up of 7 Research & Educational Complexes, 18 faculties, 9 research institutes. It has around 20000 students, incl. 1000 postgraduates and 800 internationals. It offers a wide range of undergraduate and postgraduate programmes of different levels. Since 1997 top Russian technical university for highest employment rates of graduates. It is constantly involved in different international programmes and projects. R&D activities are carried out at the following Research & Educational Complexes:

- Fundamental Sciences;
- Manufacturing Engineering;
- Special-purpose Engineering;
- Power Engineering;
- Robotics & Integrated Automation;
- Information Science & Control Systems;
- Radioelectronics, Laser & Medical Technology.

R&D activities in NESC sphere suggested for international cooperation with European partners

In the area of embedded systems Information Science & Control Systems Faculty of BMSTU has a profound expertise in automatic control theory and applications to embedded control systems, multivariable feedback, $H\infty$, robust, model predictive, adaptive, self-organizing, nonlinear, linear, impulse, self-oscillations, automatic search control systems, μ-analysis, identification, adaptive state estimators for complex distributed dynamical plants, vast and diverse experience in analysis, design, optimization, mathematical modelling and implementation of real-time high temperature plasma control systems in fusion on tokamaks and open magnetic traps. Submitted two FP7 proposals: DYNCON (Dynamics Control of Large-Scale Complex Distributed Plants, 2007), HYSOCON (Hierarchic Self-Organizing Control Systems for Complex Nano- & Multi-Dimensional Production Processes, 2008).

Specific areas of R&D interests: control of dynamical plants with uncertainties; embedded control systems design for production processes in particular pipeline valves control systems and their diagnostics; methods of robust and adaptive systems design; plasma control and investigation in thermonuclear installations in particular tokamaks.

Relevant publication of the workshop participant

See page 56

Hierarchical Control System for Complex Dynamical Plants
Yuri V. Mitrishkin, Rodolfo E. Haber

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Institute for system programming of the Russian Academy of sciences

Acronym: ISP RAS
Type: R&D organization/University/Laboratory
Size: > 50 employees

The Institute for System Programming (ISP) of the Russian Academy of Sciences (RAS) was founded on January 25, 1994. ISP RAS has three main components of its activity that have strong influence on each other:
- Academic Research
- Industrial Development
- Education

The Institute has more than 120 highly skilled researchers and software engineers, 11 of them have Doctor degree, 35 of them have Ph.D. degree. Many employees of the Institute are professors in classical and technical universities at the same time.
The Institute participated in various international projects, including commercial projects with Intel, Microsoft, Klockworks, Telelogic, Sun and others, pilot and joint research projects, FP6 and FP7 projects.

R&D activities in NESC sphere suggested for international cooperation with European partners
Main R&D directions of the Institute are:
- Software and hardware verification and validation;
- Technologies and systems architectures for the Future Internet
- Architectures, platforms, technologies, methods and tools
- Strategies and technologies enabling mastery of complexity, dependability, and behavioural stability
- Mathematical Models and Methods in Information Security
- Cognitive Systems, Interaction, Robotics
- Suites of interoperable design tools for rapid design and prototyping of embedded systems

Relevant publication of the workshop participant

See page 63

Early Creation of Cross Toolkits for Embedded Systems
Nikolay Pakulin, Vladimir Rubanov

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Proposal for cooperation

Title: Open framework for cross-tools development

Project idea: Cross toolkits (assembler, linker, debugger, simulator, and profiler) play a key role in the development cycle of embedded systems. Early creation of cross toolkits and possibility to quickly adapt them allows using them as early as at the hardware/software codesign stage, which becomes an important success factor for the entire project. Challenging issues for cross toolkits development is efficiency of simulation and CPU instruction set alterations at the design phase. Developing cross toolkits in C/C++ produces highly efficient tools but requires extensive rework to keep up with instruction set changes. Approaches based on automatic toolkit generation from some top level specifications in Architecture Description Languages (ADLs) are less sensitive to this problem but they produce inefficient tools, especially simulators. We propose to develop a flexible open framework for model-based construction of efficient cross-tools at early design phase of a System-on-Chip.

FP7 ICT Work Program and Call Identification:
Objective ICT-2009.3.4 Embedded Systems Design
Objective ICT-2009.3.5 Engineering of Networked Monitoring and Control systems

Potential project partners:
1. SoC developers and system integrators for field tests of the proposed framework.
2. CPU and hardware developers for designing the common notation for model-driven development
3. SoC development framework vendors to integrate the proposed framework into their toolchains fr productisation.

Institute of Automation and Electrometry Siberian Branch of Russian Academy of Sciences

Acronym: IAE SB RAS
Type: R&D organization/University/Laboratory
Size: 250 - 499 employees

The Institute of Automation and Electrometry of the Siberian Branch of Russian Academy of Sciences (IAE SB RAS) was founded in 1957 as a "physical-technical" research organization. Institute has 17 scientific laboratories, 11 research groups and Engineering centres.

The main research directions:
- topical problems of optics and laser physics, including physical processes in gases and condensed media induced by radiation, the nonlinear effects at interaction between radiation and structured materials, new spectral ranges and modes of radiation generation;
- fundamental problems of laser and optical technologies, including processing and modification of materials, information science, micro- and nanostructure formation, diagnostics and monitoring, and precision measurements;
- software architecture, integrated solutions, simulators and software for data processing systems of sensing, analysis, information displaying, and control systems for complex dynamic processes.

The institute currently has 370 employees, which include 134 scientists, as well as staff and technical support personnel.

The Institute contacts with more than 20 foreign universities, institutes and scientific centres in the USA, Germany, France, Sweden, China, Korea and other countries.
The Institute serves too as basis for three specialized Chairs of the Novosibirsk State University: "Quantum Optics (QO)"; "Physical-Technical Researches Automation (PTRA)"; "Informational-measuring systems (IMS)"

There have been established and act scientific educational centres on the basis of the departments and laboratories of the Institute for training of young specialists of high qualification (bachelors, under- and post-graduate students).

There are some dozens of post-graduate students getting education in the Institute. The Institute publishes periodical (6 issues per year) scientific journal "Avtometriya" which is republished in USA as "Optoelectronics, Instrumentation, and Data Processing".

R&D activities in NESC sphere suggested for international cooperation with European partners
In IA&E the following research directions have been formed: optics and spectroscopy, physics of condensed matter, development of precision optical technologies, systems and elements, integrated modern computing complexes based on optical and electronic technologies.

Implementation sphere: instrument making, electronics, robotics, energy equipment, mechanical engineering, optics and laser techniques, the chemical industry, environment protection, medicine and public health services.

Wide diversity of pioneer practical bottom lines and innovations have been carried out in the Institute, including:
- Problem-oriented computer platforms (digital image and signal processing, computer graphics and systems of virtual reality).
- Laser micro- and nanotechnology and systems.
- Equipment for remote diagnostics of volume media and processes conditions.
- Precision optical measurements technologies and instrumentation.
- Systems of sensing, analysing and imaging of information on basis of innovative electronic and optical technologies.
- Laser technologies and systems – fibre lasers,
- Elements of diffractive optics, including bifokal diffractive-refractive intraocular lens,
- High-power ion lasers,
- Modern receivers of infrared radiation,
- Laser termography technologies and systems,
- Optoelectronic system for combustion processes remote monitoring,
- Systems and new technologies for five-axis laser micro processing,
- Automated subway train dispatching system, etc.

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International Institution of Cybernetics and Artonics

Acronym: IICA
Type: R&D organization/University/Laboratory
Size: < 10 employees

Our Institution has the investigation of complex systems and we discovery the adaptational maximum phenomenon in complex developing systems. We work out the linguo-combinatorial method for simulation of poorly formolized systems in different areas of technic and science – machine tools, robots, transports and etc. We create the virtual world technology for 3-D interactive simulation.

R&D activities in NESC sphere suggested for international cooperation with European partners

We can cooperate in area of linguo-combinatorial simulation of complex systems and virtual worlds technology applications.

Relevant publication of the workshop participant

See page 77

Linguo-Combinatorial Simulation in Complex Systems for Creation of Embedded Systems and Control Systems
Mikhail B. Ignatyev

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Proposal for cooperation

Title: Linguo-combinatorial sumulation in complex systems for creation of embedded systems and control systems

Project idea: Any complex system interacts with its changing environment and its viability depends on its adaptability. The number of arbitrary coefficients in the structure of equivalent equations of complex system changes in the process of learning. In systems with more than six variables, the number of arbitrary coefficients increases first, and then, passing through the maximum, begins to decrease. This phenomenon makes it possible to explain the processes of system growth, complication and death in biological, economical and physical-engineering systems and to permit creation of high adaptability systems. We use the linguo-combinatorial method of investigation of complex systems, in taking key words for building equivalent equations. This phenomenon is able to increase the adaptability of different systems and permit to build the embedded systems and control systems.

FP7 ICT Work Program and Call Identification: NECS
Potential project partners: Lappeenranta University, Finland, Lappeenranta

Moscow State University / Computational Mathematics and Cybernetics Faculty, Laboratory for Computer Systems

Acronym: CSL CMC MSU
Type: R&D organization/University/Laboratory
Size: > 25 employees

The Laboratory for Computer Systems (CSL) at Computational Mathematics and Cybernetics Faculty of Lomonosov Moscow State University (CMC MSU) was founded in 1982. Primary activities of CSL are Research and Development projects and Education. The Laboratory has 25+ research fellows and software engineers, 8 of them have Ph.D. degree. Also CSL have more than 60 Graduate and Ph.D students, who participate in research activities.
The CSL has more than 25 completed multi-stage industrial R&D projects in fields of Embedded Systems, Computer Simulation and IT Security. Our customers are large russian and international companies ("Sukhoi" Company, Daimler AG, ST Microelectronics, RC "Module", RC "Electropribor", Sun Microsystems). In addition, CSL staff members contribute to a variety of open-source projects (GCC, GDB, KDevelop, KDE, Debian, Boost C++).

R&D activities in NESC sphere suggested for international cooperation with European partners

Main R&D directions of the CSL are:

- Real-time simulation of embedded systems
- Hardware-software co-simulation for embedded systems
- Fault tolerance, availability, performance estimation
- Real-time anomaly detection: Hardware, IT Security, Medicine
- Job-shop Data Exchange Scheduling Algorighms
- IT Security for Embedded Systems and Computer Networks
- Monitoring and simulation of worm and virus activity
- Intrusion detection for distributed networks
- Computer system behavior visualization
- Program analysis and transformation (web security, obfuscation)
- Methods and tools for verification of embedded software

Relevant publication

- V.V. Balashov, A.G. Bakhmurov, M.V. Chistolinov, R.L. Smeliansky, D.Yu. Volkanov, N.V. Youshchenko. A Hardware-in-the-Loop Simulation Environment for Real-Time Systems Development and Architecture Evaluation // In Proc. of the Third International Conference on Dependability of Computer Systems DepCoS-RELCOMEX 2008, Szklarska Poreba, Poland, June 26-28 2008.

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Moscow Power Engineering Institute (Technical University)

Acronym: MPEI
Type: R&D organization/University/Laboratory
Size: > 500 employees

The Automated Control Systems department of Moscow Power Engineering Institute (Technical University) has big experience in creating and supporting of control systems at power plants and other technology processes.
Parametric methods for the optimal synthesis of control systems and reliability calculations, research and standardization of dynamic characteristics of measurement, mathematical modelling of thermal units and creating of computer simulators developed at the Automated Control Systems department receive wide application in industry.

The main scientific goals are development of rules and control algorithms for innovation industrial enterprise processes, development and implementation of integrated automated systems for ruling and managing of industrial enterprise based on modern information technology, software and hardware systems.

R&D activities in NESC sphere suggested for international cooperation with European partners
The Automated Control Systems department of MPEI (TU) is ready to cooperate in the following areas:

- creating of new control algorithms,
- developing of controllers tuning methods,
- generation of new integrated control systems and libraries for existing systems,
- creating of mathematical models for industrial processes,
- developing of network programs for control higher level,
- improvement of measurement methods,
- creating of computer simulators,
- generation of users applications for automation purposes

Relevant publication of the workshop participant

See page 86

The automated system of monitoring and registration for technical and economic performance calculations of industrial enterprise
Alexey Chernayev

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Moscow Institute of Electronic Technology (Technical University)

Acronym: MIET
Type: R&D organization/University/Laboratory
Size: > 500 employees

MIET – Technical University is going to be Research University. MIET is one of winners of Presidental program "Innovative University". The university is proud of its graduates successfully working in well-known hi-tech companies in Russia and around the world. MIET cooperates with leading universities of Europe and the USA, takes part in exchange programs for students, postgraduates and tutors. The university implements programs of elite professional training together with a number of foreign leaders in electronics and information technologies: Microsoft, Intel, Cisco systems, Hewlett-Packard, Cadence, Synopsys, Mentor Graphics, Parametric Technology Corporation, Freescale Semiconductor, Agilent Technologies, Sun Microsystems and others.

Today, over 200 foreign students study at MIET. Besides training full-time and part-time students using the newest equipment and software, MIET was one of the first universities of Russia to provide distance education for students in Russia and abroad via the Internet using unique curriculum developed at the university.

MIET proved its status of a leading university in Russia by being listed in 2006 as one of the first 17 winners of national priority project «Education» leaving behind 200 competitors. MIET is among the universities promoting best innovative educational programs and received substantial federal funding for further development of elite professional training system.

R&D activities in NESC sphere suggested for international cooperation with Europeanpartners

MIET research and development projects are carried out in various fields and realized in the following directions:

- Fundamental research in mathematics, physics, chemistry and electronics
- Information technologies and telecommunications
- Materials for micro-, nano- and optoelectronics
- Micro- and nanoelectronic devices
- Nanotechnology in electronics
- Microsystem technology
- Devices of fibre and integrated optics
- Information control systems and complexes
- Computer simulation and image analysis
- Microelectronic radio systems and devices
- Ecology and human life-support systems
- Economics, management and marketing
- Social and philosophical problems of science and engineering
- Research on problems of general and professional education.

Joint academic & scientific departments (with foreign companies): CADENCE (USA), Mentor Graphics (USA), FreeScale Semiconductor (USA), Microsoft (USA), Cisco Systems (USA), Sun Microsystems (USA), ProCurve Networking by HP (USA), SYNOPSYS (USA) , Agilent Technologies (USA), Leipzig Universitaet (Germany) , University of Padova, University of Madrid, University of Florida , CQG (USA), etc.

Relevant publication of the workshop participant

See page 90

Optimization of Digital Wireless Transceiver Embedded System Built on Xilinx FPGA
Konstantin Tafintsev, Victor Barinov,
Alexander Bahtin and Vyacheslav Litvinov

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Novosibirsk State Technical University

Acronym: NSTU
Type: R&D organization/University/Laboratory
Size: > 500 employees

Novosibirsk State Technical University (NSTU) is famous for its scientific schools in the fields of automatics and mechanotronics, electro technologies and power energy engineering, materials science and machine-building, aircraft development and IT, radioengineering and electronics.
Nowadays NSTU is one of the major research and educational centres, as well as one of the top technical universities of Russia. NSTU's Innovation-educational program "Higher Technologies" is a winner of national competition and granted in the frame National Priority project "Education".
Currently, NSTU has 11 faculties: Institute of Social Rehabilitation, Institute for Additional Education, Pre-University Educational Centre, employing more than 1560 faculty members, including 288 professors. The total number of students is over 25000, including the students of all education forms. The Regional Centre of International cooperation in the field of engineering education was established in NSTU in 1998 by the order of RF higher education minister. There are inner university network of authorized training centres of foreign companies (DMG, Texas Instruments, National Instruments, Motorola, Schneider Electric etc) and foreign informational-educational centres (DAAD, Confucius Institute, Goethe Institute). NSTU is a member of different international associations and organizations, as: EAIE, EAU. INEER, UICEE, IEEE. IIE and others and implements about 60 interuniversity Agreements on educational and scientific cooperation.
Since 1993 NSTU has been participating in different European Programmes, as TACIS (including TACIS-EDRUS, TACIS-DELPHY, TACIS-EDSIB), TEMPUS, ERASMUS-MUNDUS, INTAS, YOUTH in ACTION and in the bilateral programs of international cooperation (as Russian-Swedish program of labour-market development in RF).

R&D activities in NESC sphere suggested for international cooperation with European partners

NSTU is an expert in the theory and practice of optimum process design of man-machine systems, hardware and software development for different industrial branches.
Among NSTU's developments there are:

- The "INTELLECT" software is invented for research, design and test of information management system in operators' activity, ergonomic design, technological processes control etc.
- An unique complex "The distributed video system for automatic monitoring in forestry" for fast detection of seat of fire with definition of its' coordinates includes video camera set combined by software and standard hardware
- System Automatic Monitoring and Control System (AMCS) is intended for manufacturing process monitoring and control, environment state monitoring (up to 1024 points temperature, humidity and barometric pressure measuring). AMCS is based on hierarchical network, contains terminal units at lower level, adapter-concentrators at middle level and concentrator at main one

- Algorithms of low-level processing and analysis of images: Filtering, Segmentation, Restoration of gray-level and colour images under linear (homogeneous and non-homogeneous) and nonlinear distortions.
- Algorithms of digital signal processing: Filtering, Detection and classifying, Estimating of parameters.
- TELMA (Temperature & ElectroMAgnetic) software system is offered for solution of various electromagnetic and heat exchange problems
- An aircraft power-supply system is based on a type «variable velocity - constant frequency» and is realized on scheme "synchronous generator with permanent magnets and semiconductor converter".

Relevant publication of the workshop participant

See page 94

New Paradigm of Context based Programming-Learning of Intelligent Agent
Andrey V. Gavrilov

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Proposal for cooperation

Title: Smart environment for elderly and disable persons

Project idea: This project aims to research and development of embedded intelligent agents to introduce into smart objects such as smart bed, chair, and table, door and so on, and development of middleware and services based on wireless sensor network and smart objects to ease life of elderly and disable persons. Smart objects and services will provide person needed information for comfortable life, including reminding about events and duties, about location of needed objects, monitoring on state of person, communication with caregiver, managing of different home equipment. Rusults of this project may be used at home and in hospitals.

FP7 ICT Work Program and Call Identification:
Challenge 7: ICT for Independent Living, Inclusion and Governance
Objective ICT-2009.7.1: ICT & Ageing

Potential project partners:
Skills in wireless sensor networks, sensors, embedded systems

Potential partners:
1) Cooperativa TEC, SME, Italy, Reggio Calabria,

2) TreeLogic, SME, Spain, Lugones - Asturias, http://idi.treelogic.com/ing
3) RoboSoft, SME, France, Bidart, www.robosoft.com
4) Democritus University of Thrace, University, Greece, Xanthi, http://robotics.pme.duth.gr
5) University of Ulster, University, UK, Londonderry, http://www.infm.ulst.ac.uk/~ulrich/CognitiveRobotics
6) CARTIF Foundation, Research Center, Spain, Valladolid, www.cartif.es
7) Istituto Dalle Molle di Studi sull'Intelligenza Artificiale (IDSIA), Research Center, Swetzerland, Bellinzona, http://www.idsia.ch

Saint-Petersburg State University / Laboratory of stochastic computing, Institute of Information technology, Department of Mathematics and Mechanics

Acronym: SpSU/LSC
Type: R&D organization/University/Laboratory
Size: 10 - 49 employees

The laboratory of stochastic computing is working on applications of randomised optimisation algorithms in multidimensional and uncertain problems. The laboratory works in collaboration with a group of Prof. Vladimir Katkovnik from Tampere Institute of Technology, Finland, in the field of image denoising, motion tracking and stereovision and compressive sensing. The specialists from the laboratory participate in the project of Inria aimed at simultaneous pattern recognition from audio and video streams. The laboratory has developed a speech recognition system using SPSA-based clustering algorithm. Adaptive scheduling of tasks in parallel and distributed computing systems is another area of interest where the laboratory collaborates with the group of Jan Duennweber from University of Muenster as well as with researchers from the Department of Physics in SPbSU. The work in this field is supported last three years by the grant of Intel Corporation. Together with Zoological Institute of RAS the group has developed a system WebKey for biological taxon identification based on stochastic optimisation (http://apps.zin.ru/webkey/). The laboratory participated in a grant by a Russian search engine Yandex.ru about Content-Based Information Retrieval, online system for image search was created. The group is interested in developing foundations for new computing paradigms based on quantum and hybrid parallel computing. In this field a theoretical book was written in the laboratory together with Professor S.L. Molodtsov, TU Dresden.

R&D activities in NESC sphere suggested for international cooperation with European partners

Stochastic optimisation applied to control problems; SPSA-based optimisation; tracking of minimum in multidimensional stochastic systems.
Signal processing with distributed sensors. Stereovision, object tracking, denoising of video, speech recognition. Clustering and stability of clustering; information retrieval using neural network learning and clustering; stochastic algorithms applied to find suboptimal solutions in NP-complete problems.
Distributed computing and GRID systems; brokering of tasks in heterogenous computing systems; load balancing in multithreaded computing.

Relevant publication of the workshop participant

See page 99

Minimum Tracking with SPSA and Applications to Image Registration
Alexander Vakhitov, Lev Gurevich, Oleg Granichin

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Saint-Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences / Laboratory for Information Technologies in Systems Analysis and Integrated Modeling

Acronym: SPII RAS
Type: R&D organization/University/Laboratory
Size: 50 - 249 employees

St. Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences was founded in 1978. Currently the Institute is the only one research entity operating within the Department of Information Technologies and Computer Systems of the Russian Academy of Sciences in the North-West of Russia. Professor Rafael M. Yusupov, Doctor of Engineering Sciences and the Honoured Scientist of the Russian Federation head the Institute. SPII RAS staff comprises 34 full professors, 57 scientists with Ph. D. degrees.
At present time the laboratory has completed following projects related to NECS: Optimal Structure Reconfiguration in a Complex Technical System (CTS). Directing organization: European Office of Aerospace Research and Development (Project # 1992p /Task#2 ISTC-EOARD), 2000-2003; Development and investigation of methodological and methodical basis for structure-functional synthesis of monitoring systems and intellectual information technologies as applied to real-time complex technical objects under dynamic conditions. Directing organization: Russian Fund of Fundamental Investigations (Project #02-07-90463), 2002-2004; Theoretical and experimental investigation of formalisms and software-based means for specification of natural-science and heuristic knowledge concerning dynamic, diagnostics and control of complicatedly structured collections of different interacting processes. Directing organization: Russian Fund of Fundamental Investigations (Project # 05-08-18111), 2005-2007; Development and investigation of intelligent information technologies of comprehensive modelling and analysis for different stages of autonomous computing systems life cycle. Directing organization: Russian Fund of Fundamental Investigations (Project # 05-07-90088), 2005-2006; Intelligent Networks for Secured/survivable power Systems. Directing organization: Civilian Research and Development Foundation (CRDF Project #RUM 2-1554-ST-05), 2005-2006.

R&D activities in NESC sphere suggested for international cooperation with European partners

Multiagent systems; distributed data mining; data fusion for decision making; ontology and context management; machine learning; multimodal user interfaces (virtual reality, speech recognition, etc.); object oriented programming; robotics; bioinformatics and telemedicine; information security and protection; steganography; intelligent geoinformation systems; immunocomputing; RFID-technology; parallel computing; real-time operating systems; models' quality estimation; vehicular ad-hoc networks; broadband wireless access; performance evaluation of telecommunication networks; intellectual transportation systems, dynamic resource allocation.

Relevant publication of the workshop participant

See page 103

Information and telecommunication intellectual monitoring technology and system for complex technical objects under dynamic conditions in real time Michael Yu. Okhtilev, Boris V. Sokolov, Alexey V. Vinel and Eugene M. Zaichik

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Proposal for cooperation

Title: Development and Investigation of New Intellectual Information Technologies of Integrated Modelling and Simulation for Structure-Functional Synthesis of Auto-reconfigurable Complex Technical Systems (ARCTS) at Different Stages of Their Life Cycle

Project idea: The scientific objective is devoted to a solution of the fundamental problem lying in common synthesis and intellectualisation of monitoring and control processes for ARCTS under dynamic conditions via multiple-model complexes and multi-criteria approaches to solving tasks. The future results of these investigations can be widely implemented in different applied areas. In our project we plan to realize these results as software prototypes for spacecrafts control-and-monitoring centres; power grid systems; virtual enterprises, and collaborative networks. The expected broader impact of the project is characterized by following attributes: the degree of automation and intellectualisation for ARCTS comprehensive modelling increases; reliability and efficiency of ARCTS control is ensured even if the controlled objects undergo structure degradation; fault detection and before-the-fact prevention of catastrophes is provided; the suggested ARCTS monitoring and control technology can be used for improvement of existing embedded and scalable software in the above-analysed application domain; implementation of the special software based on the suggested intelligent information technology looks promising for many critical applications; the proposed methods of comprehensive man-machine modelling and simulation for ARCTS monitoring and control automation allow a switch from heuristic description of the telemetry and control analysis to a sequence of well-grounded stages of monitoring and control program construction and adaptation, from unique skills to unified technologies of software design; these methods are based on a conclusion that a functional description of monitoring and control process is much less complicated than detailed examination of software realizations. Within the problem of integrated modelling for structure-functional synthesis of ARCTS two main research subtasks will accentuate: development of the methodology and the techniques basis for the formalization and solving of different ARCTS structure-dynamics problems, development of the prototype of the software tool implementing new intellectual information technologies of comprehensive modelling for structure-functional synthesis of ARCTS.

FP7 ICT Work Program and Call Identification:
Our project is connected with the main line of FP7 which has title Embedded Systems Computing and Control.

Potential project partners:
General areas: complexity management, classic control theory, operations research, artificial intelligence, systems theory and systems analysis, multiple access theory, wireless communication and intelligent transportation systems.
We are searching for a partners in the following areas: Development of models, methods and algorithms of information representation for real-time monitoring and control system functioning under dynamic conditions; Development of methods and algorithms of integrated modelling and simulation of real-time monitoring and control system for protection of power generating objects (power grids); Development of the prototype of the software implementing the proposed technology of integrated modelling and simulation of real-time monitoring and control system for protection of power generating objects under degradation process of their structures; Possible implementation: power grids, disaster tolerance and recovery systems, aerospace systems; Development of models, methods and algorithms of real-time accounting, monitoring and control systems which used radio frequency identification and mobile information technologies and implemented in the transport field; Development of the software tool prototype implementing new intellectual informational technology for real-time accounting, monitoring and control transport systems; Development of models for the performance evaluation of contemporary wireless networks and design of new communication protocols; intelligent transportation systems.

Saint Petersburg State University / Institute for Information Technologies

Acronym: RIIT
Type: R&D organization/University/Laboratory
Size: 10 - 30 employees

The Institute for Information Technology of St Petersburg State University (RIIT) has been operating on its basis since 2002. RIIT is a part of R&D Mathematics, Mechanics and Astronomy Centre Academic Senate, and trains highly qualified IT-specialists.
RIIT is involved into:

- Applied and fundamental research in the field of software development and engineering
- Data dissemination and implementation of the most efficient programming methods and technologies for the industrial needs
- Highly-intensive software development for industrial projects

RIIT core research areas:

- Information technologies algorithms
- High-speed calculations
- Software engineering
- Database development
- Real-time systems
- CASE-technologies
- Compilation technologies
- Reverse design and re-engineering
- Synchronization and control aspects

R&D activities in NESC sphere suggested for international cooperation with European partners

- Heterogeneous networks
- Programmability
- Light-weight operation systems and kernels
- Software/hardware platforms

R&D activities for the following industries: transport, wireless technologies, public infrastructure, healthcare.

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Saint Petersburg State University of Information Technologies, Mechanics and Optics / Computer Science Department

Acronym: ITMO CSD
Type: R&D organization/University/Laboratory
Size: 30 - 80 employees

St.Petersburg State University ITMO – one of the largest state universities of the Russian Federation.

The basic scientific directions of the University are: optical technologies, computer and information technologies, control systems, precision mechanics and technology, electrical technology and electronics, fundamental and applied investigations in mathematics and physics.

The basic fundamental and applied researches are conducted in fields of the scientific software engineering, grid and mobile computing, supercomputing, quantum electronics and non-linear optics, optics of biologic tissue, physical optics and spectroscopy, laser and optical technologies, power monitoring, non-centered optics, computer technologies, guidance of robots, non-linear systems theory, complex systems simulation.

The COMPUTER SCIENCE department is leading at the University in the "computer engineering" area, including embedded computer systems (ECS) design and systems on chip design.

The department carries out research works in the field of the formalized methods of designing of ECS architecture, including platform – aspect-oriented design, in the field of modelling and analysis of computer networks; a new direction - architecture design of systems on chip is being developed.

The computer department and other University specialists carry out development, pilot/small-scale production and inplementation of the embedded systems for various applications: for the distributed complexes of data gathering and automatic control, for transport systems, for measuring devices, for laboratory facilities.

R&D activities in NESC sphere suggested for international cooperation with European partners

1) Researches in the area of formalized methods of embedded systems architecture design: creation of metrics for an estimation of quality of system architecture and CAD-software for embedded systems architecture design.
2) Development of specific IP-cores (data & signal processing, network & peripheral controllers, etc.) and completed SoC for embedded control & embedded networking solutions.
3) Developments of techniques of teaching in computer architecture and NECS-areas.

Relevant publication of the workshop participant

See page 109

Problems of abstract representation of embedded systems at high-level stages design
Alexey Platunov, Pavel Kustarev

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Saint Petersburg State University of Aerospace Instrumentation / Institute of High-Performance Computer and Network Technologies

Acronym: SUAI / IHPCNT
Type: R&D organization/University/Laboratory
Size: > 30 employees

University is a multi-profile center of training, retraining and upgrading the level of skills of engineers, programmers, managers, economists and lawyers, a large R&D scientific center reputed both in Russia and abroad. We try to do our best in combining classic traditions of Universities and modern technologies of higher education. Well-known scientists and specialists of leading enterprises of Saint-Petersburg and institutes and entities of Russian Academy of Science deliver lectures at the SUAI. There are ten faculties, 42 chairs, R&D institutes and centers, over fifty directions of training, postgraduate and doctor's degree courses.

Institute of High-Performance Computer and Network Technologies
is a research department of the University, launched in 2003 on the base of Laboratory for Parallel Computers and Networks. The core team of the Institute HPCNT is in computer architectures, system software, parallel computing and networking R&D since 1974. Collaboration and R&D contracts with Intel, Nokia, Cadence, with Russian industry companies.

R&D activities in NESC sphere suggested for international cooperation with European partners

Main R&D fields:

- Embedded computing.
- VLSI architectures, Systems-on-Chip, Networks-on-Chip.
- Parallel architectures. Formal models of parallel computations.
- Parallel programming, languages, system software.
- Real-time software development.
- VHDL in digital systems design, hardware structures programming.
- High-performance network architectures and protocols.
- Digital VLSI and SoC design for embedded computing and networking.
- Development of parallel computers, software and distributed systems in avionics, in spacecraft avionics, in data processing, in network systems.

Current activities in embedded networking:

Participation in Space Wire technology (on-board high-performance real-time networking) development and standardization (in the frame of the Space Wire WG, in collaboration with ESA/ESTEC). Design of the chipset (ASIC) with Space Wire networking for aerospace applications (in collaboration with the Russian electronic industry company ELVEES). FPGA IP-blocks, firmware and software for Space Wire based chips, units and blocks.

Participation in development of the UniPro standard for embedded networking in mobile communications industry (contract with the MIPI - Mobile Industry Processor Interface, Alliance): simulation (SystemC), specification (SDL), validation; prototyping.

Current activities in embedded computing:
Parallel programming languages development and programming flow tools design for multi-core/many-core heterogeneous processors, SoC, NoC.
Adaptive high-performance libraries for heterogeneous multi-core processors.
R&D in HW/SW co-design for many-core application-specific heterogeneous SoC, NoC.

Relevant publications

- Y. Sheynin, "Parallel Programming Model for Distributed Architecture MPSoC", MPSoC-2005 Conference, Margaux (France), July 2005.
- Sheynin Y., Suvorova E., Shutenko F. Complexity and Low Power Issues for On-chip Interconnections in MPSoC System Level Design. Proceedings of the IEEE Computer Society Annual Symposium on VLSI 2006, March 2-3, Karlsruhe. IEEE Computer Society, 2006
- Yuriy E. Sheynin, Alexey Y. Syschikov. Enabling graphical notation for parallel programming. Application for United States letters patent №ITL_1662US(P26244), 2007.
- Sheynin Yuriy, Suvorova Elena. Providing guaranteed packet delivery time in SpaceWire networks. 2nd International SpaceWire Conference, Nara 2008 (Japan). Conference Proceedings. Space Technology Centre, University of Dundee, Dundee, 2008 ISBN: 978-0-9557196-1-5.

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Proposal for cooperation

Title: Automotive scable embedded real-time networking for next generation vechiles
Project idea:
Modern automotive embedded networking is based on CAN. However its bus-based architecture has limited scalabilitry that isn't approriate for next generation in-vechile embedded networking requirements. The project proposes to develop, validate, prototype and demonstarate new scalable real-time network architecture and protocols for in-vechile high-performance embedded networking.

Title: Application-specific heterogeneous many-core SoC/NoC for image processing and recognition.
Project idea: Image processing and recognition has wide application fields from intelligent consumer robotics to vehicle safety systems. Advanced image processing algorithms require high performance. To implement them in cost-efficient way the project proposes development of configurable reference many-core architecture and framework for design on its base application-specific heterogeneous SoC/NoC with specific data spaces and parallel algorithms.

Title: Multimedia embedded networking for next generation consumer electronics systems and environments.

Project idea: Next generation consumer electronics will form common spaces of devices that should actively interact and collaborate to provide multimedia-based services to a user. To support these features next generation systems and environments require embedded networking technology that could efficiently support high-quality multimedia information interchange in real time. The project proposes to develop, validate, prototype and demonstrate new scalable real-time multimedia network architecture and protocols for next generation consumer electronics systems and environments.

Ulyanovsk State Technical University

Acronym: UlSTU
Type: R&D organization/University/Laboratory
Size: > 500 employees

Ulyanovsk State Technical University was established in 1957. Now it is one of leading academic and scientific centres of the Volga region in Russia. More than 500 professors are engaged in academic, research and scientific activities. 18 000 students are currently enrolled in 81 Bachelor Degree, Master Degree and Diploma programmes at 52 departments. The main areas of scientific research are Information & Communication Technologies, Ecology, Mathematics, and Civil Engineering. UlSTU ranks the first among Russian technical universities in the number of patents assigned. Scientists of UlSTU take part in many international conferences abroad. Every year UlSTU conducts up to 5 international conferences. In ICT the University researchers have skills in Embedded Systems, Artificial Intelligent Systems, and Hybrid & Soft Computing. The University researchers successfully present their projects at prestigious international exhibitions in Brussels, Paris, Geneva, and Nuremberg. They have more than 40 gold, silver and bronze medals, including 6 medals for projects in ICT. Also they take part in joint scientific and research activities with partners from Germany, Poland, France, Bulgaria, UK, USA, Czech Republic, etc. Direct bilateral cooperation was financed by such institutions, as DAAD (Germany), Scientific fund "Kassa im. Mianowskiego" (Poland), British Council (UK), ets. The University researchers took part in 2 FP6 Projects Coordinated by the Association of Engineering Education of Russia:- RUSERA (Russia and European Research Area), FP6-502262 (2003 – 2004); - RUSERA-EXE, FP6-0043701 (2006 – 2008). UlSTU participates in the Enterprise Europe network; it is a member of the Russian Business Innovation Network (Gate2RuBIN), the Russian Technology Transfer Network (RTTN), Russian-French Technology Network (RFR).

R&D activities in NESC sphere suggested for international cooperation with European partners

In the field of embedded systems the scientists of UlSTU conduct research on development of designing patterns and hard real time operating systems. The universal system SandLIX for development of software for embedded real time systems has been developed. It ensures support of the full cycle of development of the software for embedded real time systems: compilation, debugging, preparation of weaving which includes real time operating system and application software, all-round testing. The system was rewarded with bronze medal at the International Salon of Inventions in Geneva in 2007. This scientific work group performed a number of projects according to orders of the enterprises of the Russian Federation.

In the field of soft computing scientists of UlSTU carry out theoretical and practical research of application of hybrid systems in the sphere of automation of designing, financial management and economics. One of the projects was presented at the International Salon of Inventions in 2006 and was rewarded with the silver medal.

Relevant publication of the workshop participant

See page 114

Real-time embedded system generative framework
Vadim Shishkin, Vitaly Ulybin, Denis Stenyushkin

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Proposal for cooperation

Title: Real-time embedded system generative framework

Project summary: The aim of the project is to develop the generation technology and framework for real time embedded systems design. The technology is based on the generative domain model; the design pattern language and the metaprogramming paradigm. The generative domain model allows to create and to modify the configuration knowledge base for real-time embedded systems. The framework will allow real-time embedded systems developers to significantly expedite the software development, while increasing reliability and simplifying maintenance and support.

FP7 ICT Work Program and Call Identification:
Objective ICT-2009.3.4 Embedded Systems Design
Objective ICT-2009.3.5 Engineering of Networked Monitoring and Control systems
Objective ICT 2009.2.1 Cognitive Systems and Robotics

Potential project partners:
Darmstadt University of Applied Sciences (Germany)

Title: Intelligent design repository

Project idea: The analysis of document warehouses of design repositories permits to make a conclusion that when the volume of stored information increases, its analysis for making design decisions becomes a very labour-intensive procedure. High computing complexity of algorithms of intelligent data analysis requires applying means of decomposition of the general problem into several subtasks, each of them must be executed within a separate thread of an application on the dedicated core or processor of a workstation.
Proposals: Creation of models, methods and algorithms which permit to solve problems of semistructured information resources (design documents) management at the semantic level for subsequent design decisions making.

The context of decision making is considered as dynamic and it can be represented as the ontology which changes in time. This context is presented in the repository using the language of ontologies description OWL and design documents in the XML and XML Schema format.
Generalized description of the set of information resources, for example, in the form of clusters structure, will be continuously adapted to the new state of ontology.
Clusterisation of information resources by different criteria of their similarity, taking into account their current state of knowledge domain description.

FP7 ICT Work Program and Call Identification:
Objective ICT 2009.4.1 Digital Libraries and Digital Preservation

Potential project partners:
University of Ostrava (Czech Republic)
Ghent University (Belgium)
Darmstadt University of Applied Sciences (Germany)

R&D Companies

Cybernetic systems development

Acronym: CSD
Type: Private Company
Size: < 10 employees

The CSD team has extensive experience in developing hardware and software systems on the basis of design patterns. The team completed several embedded systems developing projects. In 2008-2009 a number of mechatronic and technical diagnostic systems software developing projects for ScanMaster, Inc (Israel) were completed. The team has a wide competence in Linux technologies. The universal system SandLIX for development of software for embedded real time systems has been developed by the team. The system ensures support of the full cycle of development of the software for embedded real time systems: compilation, debugging, preparation of weaving which includes real time operating system and application software, all-round testing. The system was rewarded with bronze medal at the International Salon of Inventions in Geneva in 2007.
The project JackNyfe (http://js-kit.com) has developed by CSD programmers.
We use modern programming languages such as C/C++ (Qt), Erlang, Ruby, Haskell, Java.
CSD projects where presented at the international conference ICT-2008 (Lyon).

R&D activities in NESC sphere suggested for international cooperation with European partners
Universal system SandLIX for real time embedded systems development.

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ELVEES RnD Center

Acronym: ELVEES
Type: Private Company
Size: > 200 employees

"ELVEES" SPC (Electronic Computer and Information Systems) has been founded in 1990 from ELAS SPA that back in 1960 - 80 had been involved in development of aerospace electronic hardware, such as VLSI IC, onboard control and data processing systems being implemented in "Salyut" series on "MIR" orbital station.

At present, the accumulated research and development experience is successfully being implemented in providing public security, on of the most important areas of modern life.
ELVEES specialists worked out absolutely new security technologies, unique algorithms of artificial vision, biometric and radiometric identification.

ELVEES has its platform “MULTICORE” for the IC design, which includes a great library of IP - cores, TOOLS, Software. We have developed based on the platform tens of Multicore chips for embedded systems, proven on the silicon.

Company's major applications

- Multicore VLSI circuits, microprocessor and systems on chip 130-65 nm design for all space, communications, navigation, embedded systems;
- Mobile systems for communications;
- Embedded DSP multiprocessors systems with extra performance;
- Development, production and introduction of new generation aI security systems for: Video surveillance, access control and work time logging, personnel and vehicle traffic RFID control.

R&D activities in NESC sphere suggested for international cooperation with European partners
Chipsets and End systems for all kind embedded applications: signal and imaging processing, communications, Navigation and space applications.

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Proposal for cooperation

Title: Project#1. High performance Multicore DSP Chip with Built –in GPS / GLONASS / GALILEO navigation for space applications and other on-board embedded systems.
Project idea: High performance perspective processing Chip with real-time communication protocol SpaceWire as the Next Generation DSP Multi-core Processor for Onboard Payload Data Processing Applications for space applications, Automotive and other on-board embedded systems. Finished project of the embedded system, including Hardware & software.

Potential project partners:
Company – End embedded systems solution provider, who interesting to have partners who can solve with them together all the problems of the embedded system under the key: from chipsets up to the complete application system.

Title: Project#2. Multicore communications Chipset and subscriber terminal for professional communications (TETRA 2) for mobile and embedded systems.
Project idea: Multicore communications Chipset and subscriber terminal for professional communications (TETRA 2) with Built – in GPS / GLONASS / GALILEO navigation and Innovative smart camera for mobile and embedded systems. Finished project of the subscriber terminal or embedded system, including Hardware & software.

Potential project partners:
Company – end mobile or embedded communications systems solution provider, who interesting to have partners who can solve with them together all the problems of the perspective professional communications (for, example,TETRA-2) for mobile or embedded system under the key: from chipsets up to the complete application systems (and software), including base stations.

Karza LLC

Acronym: Karza
Type: Private Company
Size: 10-15 employees

A scientific and manufacturing company "Karza" is organized specially for realization of technical tasks in the area of electric power networks. The company develops devices for electric power networks of diferent voltage levels (0.4kV and 6/10/35kV). Most of technical decisions are made on the base of pls-modems (power line communication modem). Our devices are planned for different technical tasks such as: distance monitorning of electric power network, controlling of end power loading in power networks, protection of whole electrical power network from overloading and from all type of current leakages. These developments are in progress for two years, therefore a practical experience in usage of pls-modems is great.
We started in 2006 as a winner of competition “50 best innovative ideas of the Republic of Tatarstan”. Now all our technical developments are funded from two funds – FASIE in Moscow (http://www.fasie.ru) and Investment and Venture Fund of the Republic of Tatarstan in Kazan (http://ivf.tatar.ru)

R&D activities in NESC sphere suggested for international cooperation with European partners
Our company has two main R&D activities that may be interesting for European partners. All our engineering developments are based on pls-modem's usage (power line communication modem). The plc-modem is used in - 1. “system of monitoring and diagnostics of high voltage network” and 2."Protective and control system 0.4kV". The main idea of the usage of the first system is to automatically find out the place where open high-voltage electrical wires are broken. This system can be applied in distributed power electrical networks. The main ideas of the usage of the second system are to protect electrical network itself from current leakages, to provide a maximum current protection for the end load; to record statistics of current consumption for each load for save energy tasks; to switch load on/off according to timetable. The second system can be applied in home, offices, and shops.

Relevant publication of the workshop participant

See page 116

Intellectual systems of monitoring, protection and control in electric power networks of different voltage levels
E.Danilov, A.Smoljakov, S.Martinchuk, A.Zakirov, A.Karpov, S.Kalabanov, A. Naumov, R.Shagiev, R.Mustafin

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Proposal for cooperation

Title: Protective and control system 0.4kV; diagnostic and monitoring system on the base of intellectual PLC-modem.

Project idea: Protective and control system 0.4kV is for electrical power network with voltage level under 0.4kV. It enables to prevent weak current leaks between wires, that lead to igniting of apartments; to switch on/off electrical equipment; to automatically detect a line with unauthorized connection; to save electric power. This device is intended for end users such as a home, office, shop. Our system allows solving the whole complex of tasks of protection and control that is not realized in any competition product.
Diagnostic and monitoring system on the base of intellectual PLC-modem is for electrical power network with voltage level of 6/10/35kV. It is able to find out a place of broken wire in distributed electric power network, besides this system transfer data through electric power network.

FP7 ICT Work Program and Call Identification:
Objective ICT-2009.3.5 Engineering of Networked Monitoring and Control systems;
Objective ICT-2009.6.3: ICT for Energy Efficiency

Potential project partners:
We are looking for European partners which are in area of production and development of smart home systems. Our protective and control system would be big technical addition to the service that smart home systems provide. We plan that our partner will be able to apply our system to his own system. Our part of partnership is to make changes to our system to make both systems play correctly.
Also we'd like to find partners who produce soft and hardware systems pointed to saving of energy and monitoring of distributed power networks. Again partner apply our system to his own system, we make changes to our system to play correctly.

LMT Ltd

Acronym: LMT
Type: Private Company
Size: 10 - 30 employees

LMT Ltd. serves contract development and manufacture of embedded microprocessor equipment, multi-purpose controllers, specialised instrument controllers, control and sensor networks on the basis of wire and wireless channels. Our competence - system engineering of networks embedded control systems (NECS) , development of embedded systems hardware and software, computer networks.

R&D activities in NESC sphere suggested for international cooperation with European partners

Development of application specific software and hardware for:
- on-board transport automation;
- building and office infrastructure automation;
- automatic street light control systems;
- automatic meter systems for power and water;
- microcontroller and PLD development and training systems.

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Modular System Tornado

Acronym: MST
Type: Private Company
Size: 50-249 employees

Company "Modular Systems Tornado" has more then 17 year experience on the Industrial Automation market. “Modular Systems Tornado” is one of the Russian leaders in development and production of DCS complexes for Power Plants, Substations and others industrial objects. The company has finished more then 40 huge projects with DCS "Tornado" for boilers, turbines and energy blocks of Power Stations and more then 100 turnkey local autinmation projects. We have three classes of DCS:

- "Tornado-I" based on classic technology of MIC-controllers with VME-subbus CXC;
- "Tornado-M" based on special MIF-modules developed by the company to provide high reliability and performance of DCS.
- "Tornado-N" is based on the new technology of "one-level" architecture based on Fast Ethernet modules MIRage-N.

DCS “Tornado” technology is patented.

R&D activities in NESC sphere suggested for international cooperation with European partners
DCS for automation, IO-modules, industrial networks, CPU modules based on PowerPC technology, sensors for electrical parameters measurement, measurement of railway characteristic, system software for real-time OS;

Relevant publication of the workshop participant

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Prospects of “one-level” architecture of control systems on the basis of network Ethernet DCS "Tornado-N" with “one-level” architecture on the basis of Ethernet
Oleg V. Serdyukov

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Proposal for cooperation

Title: DCS based on idea of monogeneous network architecture, hardware CUP and I/O modules for various industrial applications.
Project idea: Cost-effective, scalable, reliable and high performance DCS, based on idea of monogeneous network architecture.

Potential project partners:
Company - complete solution provider, interested in having system integrators DCS “Tornado” and hardware.

NTK SciDeCo Ltd

Acronym: SCIDECO
Type: Private Company
Size: <50 employees

SciDeCo – A scientific/engineering company servicing domestic and international customers.
Fields of Expertise:

- Development, verification, and realization of various DSP algorithms
- Development, verification, and realization of microprocessor systems, including System-on-Chip (SoC)
- Development of digital and mixed-signal devices and systems
- PCB development
- Small scale and prototype production of developed devices.

Areas of Specialization:

- Digital signal processing
- Wireless transmission
- Telecommunication devices
- Telemetry
- Digital video processing

R&D activities in NESC sphere suggested for international cooperation with European partners
Wireless systems, telemetry, SDR, implementation as embedded systems on FPGA(s)

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Siemens Corporate Technology, Ltd.

Acronym: Siemens CT
Type: Private Company
Size: 30 - 80 employees

Siemens Corporate Technology (CT) department is present in Russia for more than 4 years, with offices in Moscow and St.Petersburg. The main directions of research and perspective development are in the areas, correlated to activities of Siemens sectors, namely:

- Industry
- Energy
- Healthcare

Projects, performed by department, cover such topics as gas turbines and heat exchange modelling, automation and control processes, software engineering for dependable embedded systems. Software engineering is a special topic of St.Petersburg office, where several groups are focusing on dependable systems, embedded networked systems (especially Open Source embedded platforms and Wireless Sensor Networks), as well as model predictive control algorithms. Corporate Technology in Russia employs more than 40 dedicated researchers. In order to fully leverage country scientific potential, CT has a broad cooperation with a leading academic and higher education institutions.

R&D activities in NESC sphere suggested for international cooperation with European partners
Wireless sensor networks, multicore technologies for industrial control applications, open source software platforms, model predictive control algorithms

Relevant publication of the workshop participant

See page 123

Wireless Sensor Networks: standards and driving forces
Maxim Osipov

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VEK-21, Ltd

Acronym: VEK-21
Type: Private Company
Size: < 10 employees

"VEK-21" Ltd. is a small innovative Russian company. It was founded in early 2009 by two postgraduate students of the Moscow State Institute of Electronics and Mathematics (MSIEM) - Mikhail Komarov and Sergey Efremov.
The company's main objective is to develop new solutions in the IT-field. Most of our current projects are based on the results of a long-term scientific research done by our personnel at MSIEM. The specialists of "VEK-21" Ltd have many years of combined experience in the following areas: computer systems and networks, wireless sensor networks, monitoring systems, virtual reality and motion capture systems.
Our company is interested in cooperation with both Russian and foreign companies.
Here is a summary of our achievements so far:
- 4 research grants from FASIE (The Foundation for Assistance to Small Innovative Enterprises).
- participation in the first all-Russian youth innovative convention.
- participation in Russian and international conferences and exhibitions, including CEBIT-2009.

R&D activities in NESC sphere suggested for international cooperation with European partners
The specialists of "VEK-21" Ltd have many years of combined experience in the following areas: computer systems and networks, wireless sensor networks, monitoring systems, virtual reality and motion capture systems. Our company is interested in cooperation with both Russian and foreign companies.

Relevant publication of the workshop participant

See page 127

Universal Wireless Sensor Networks Technology Platform and its Applications
L.S.Voskov, P.B.Panfilov, A.N. Vabischevich, M.M. Komarov, S.G.Efremov

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Proposal for cooperation

Title: System based on wireless sensor network

Project idea: The main idea of this project - is developing system (eg. monitoring system) which should consist of special software and hardware. We'd like to use our universal platform as a hardware part for the system. We're ready to connect different sensors to the platform or also we're able to use our platform as actuator for different systems. We can include our platform to the existent system, collect different data, analyze it and make some decisions. Everything depends on what kind of system our potential partner would like to create

FP7 ICT Work Program and Call Identification:
Objective ICT-2009.3.2: Design of Semiconductor Components and Electronic Based Miniaturised Systems,
Objective ICT-2009.3.5 Engineering of Networked Monitoring and Control systems

Potential project partners:
Fraunhofer IML, Germany, Dortmund, http://www.iml.fraunhofer.de
Fraunhofer Institute for applied Information Technology FIT, Germany, Sankt Augustin, http://www.fit.fraunhofer.de
Fraunhofer IIS, Germany, Nuernberg, http://www.iis.fraunhofer.de
PowerSoft, Cyprus, http://www.powersoft.com.cy/
UAB Forcom Group, Lithuania, Vilnius, www.forcom.lt
Biomedical Diagnostics Institute, Ireland, Dublin, http://www.bdi.ie
ComputArte, Italy, Rome, http://www.computarte.it

4. ARTICLES OF NESTER WORKSHOP PARTICIPANTS

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Hierarchical Control System for Complex Dynamical Plants

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Abstract. The paper is devoted to a concept of hierarchical control for complex dynamical plants and suggests architecture of control system consisting of robust, adaptive, and intelligent levels. Intelligent features of the proposed system are mostly concentrated at the third level incorporated into self-organizing algorithm and decision making approach realized by developers and process engineers. Some results are presented from present groundwork of research performed and future work is outlined. Case study has been chosen from the area of plasma magnetic and kinetic control in tokamak-reactor.

1 Introduction

Recent advances in control strategies, communications, hard and soft-computing technologies have favored an increasing trend towards the new generation of networked control systems for complex plants. The proposal described herein will address the development of scalable control methods and systems in accordance with the Information and Communication Technologies (ICT) Work Programme of the European Commission (EC), the objective ICT-2009 3.5a: Engineering of Networked Monitoring and Control systems with target outcome of Foundations of Complex Systems Engineering [1].

The engineering of networked monitoring and embedded systems is a challenge common to a wide scope of strategic application domains for complex processes. The project is focused on complex automation problems aiming at development of control theory and a framework for future technological and scientific breakthroughs in the conjunction with state-of-the-art of control theory, distributed and embedded computations, communications and intelligent systems. Proposal multidisciplinary fields include *control theory* (multi-sensor systems approach, linear and nonlinear stability, robust and adaptive control, and so forth), *computer science* (reconfigurable architectures, high-performance computations, signal processing, combinatorial optimization, and so forth), networking and monitoring *application-specific issues* (data fusion, fault tolerant and so forth), *network theory* (dynamic QoS management), and *artificial intelligence-based techniques* (fuzzy, neural and neuro-fuzzy systems).

Interdisciplinary and multidisciplinary essence of this proposal relies on all hierarchical levels of control, from local controllers linked to physical objects (processes) up to networked monitoring and complete managing of complex processes. On the one hand, a key issue is to make control systems easily implemented, self-configuring, and self-optimizing. Proposal goes beyond the current state-of-the-art improving the computational efficiency and the ways in which embedded systems interact with the physical world. On the other hand, the system has to guarantee fault-tolerance and efficiency of networking and monitoring.

To meet the goal stated by the EC a three level hierarchical control system was suggested in Bauman Moscow State Technical University to be applied to solve control problems of complex dynamic plants in science, engineering, and industry.

2 Philosophy of Hierarchical Control

The project is focused on design and development of scalar (Single-Input/Single-Output: SISO) and multivariable (Multi-Input/Multi-Output: MIMO) control systems based on scalable control algorithms for uncertain time-varying nonlinear complex dynamic plants. The major innovation of the proposal implies the elaboration of a new methodology for designing hierarchical adaptive self-organizing control systems to be applied to complex production processes, such as: plasma energy release, chemical and biological processes, casting in metallurgy, oil refinery, and so forth.

2.1 Features of Hierarchical and Heterarchical Control

Today's technologies are enabling complex processes to become more and more autonomous. Industry and academia have investigated a wide range of decentralized control architectures ranging from hierarchical decomposition to a completely decentralized (heterarchical) approach where individual controllers are assigned to subsystems and may work independently or may share data and information.

The main disadvantage of heterarchical approaches is that global optima cannot be guaranteed and predictions of the system's behaviour can only be made at the aggregate level. Hierarchical and heterarchical architectures lie at opposite ends of the distributed control architectures spectrum. The hierarchical approach is rigid and suffers from many of the shortcomings of the centralized approach, whereas it provides clear advantages in terms of overall system coordination alternatively. Despite the large amount of results related with hierarchical control methods, much work has still to be done to extend many theoretical results (stability, performance, robustness) nowadays available from advanced control implementations (H_∞, MPC) and non-traditional control strategies (e.g., neurofuzzy control systems) to the hierarchical structure [2]. In order to synthesize hierarchical control laws, the knowledge of suitable simulation functions is useful. However, an effective characterization of the simulation functions and of the associated interfaces for complex plants is not straightforward [3].

Hierarchical control can be used to integrate extra information (in addition to that concerning the usual control-loop variables such as output, error, etc.) into the control decision-making process. In many situations a hierarchical approach is an advantageous option for process optimization, instead of sophisticated design and implementation of high-performance low-level controllers.

Thanks to its own structural essence, the hierarchical control scheme ensures flexibility and compatibility with other controllers that have already been installed. It has other strong points as well, such as the relatively low cost of investments in improving automation scheme performance, the possibility of exploiting already-installed low-level regulation systems, and the relatively low cost of measurement systems which makes hierarchical control a wise choice from economic and practical viewpoints.

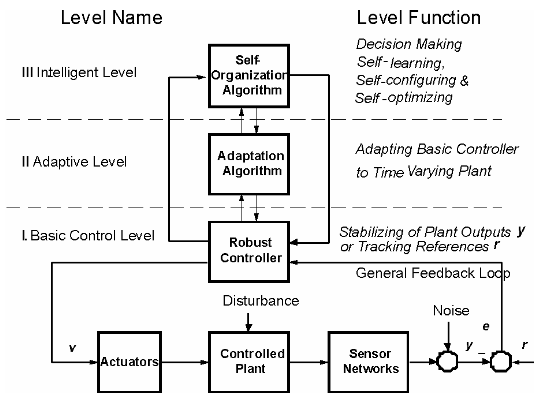


Fig. 1. General configuration of three levels hierarchical control system

2.2 Idea of Three Levels Hierarchical Control System

Whenever hierarchical levels are to be applied, goals and tasks must be broken down into levels of resolution. The architecture of the suggested hierarchical control system is composed of three levels (Fig. 1).

Basic Control Level (I) contains a controlled process under Disturbance, Actuators, Sensor Networks, and a multivariable Robust Controller capable of operation under process uncertainties. Here ***r*** is reference action, ***y*** is plant output containing Sensor Networks outputs with Noise and measurement inaccuracy, ***e*** is an error between reference ***r*** and plant output ***y*** which is related to the controller input, ***v*** is Actuators' input. This level is designed to monitor the process itself and its environment in order to undertake corresponding actions to reject internal and external disturbances and noise in output signals being measured. General Feedback Loop of Basic Control Level is to solve one of two control problems: *Stabilizing of Plant Output* ***y*** or *Tracking of Reference* ***r***. In the case of unstable process General Feedback Loop is to stabilize plant dynamics. Sensor Networks monitor processing conditions, and if plant input actions are required, changes are made by the Actuators. Robust

Controller provides General Feedback Loop capability to work in the presence of plant uncertainties and is to secure acceptable trade-off between robust stability and robust performance.

Adaptive Level (II) contains scalable Adaptation Algorithm which provides *Adapting Basic Controller to Time-Varying Plant* Parameters and Disturbance to achieve the goal of adaptation at this level. Adaptive Level helps Basic Control Level to accomplish closed-loop system trade-off at each discrete moment and to provide the best possible dynamical features of General Feedback Loop.

Intelligent Level (III) with *Self-Organizing, Self-Learning, Self-Configuring*, *Self-Optimizing, and Decision-Making* algorithms has more complex functions. This level is organized by rule base (knowledge base), working memory (facts), and inference engine (rule engine). The rule base contains declarative rules defined by user; the facts are instances of templates to be stored in working memory. The inference engine matches the facts against rules, fires rules, and executes associated actions. The actions are taken by the Robust Controller and carried out by Actuators at Basic Control Level. Adaptation to changing conditions or optimization of control processes is achieved at Self-Organizing Level by changing the structure of Robust Controller, switching separate subsystems on or off, qualitatively changing algorithms of Adaptive Level, changing connections between subsystems and their subordination schemes, and so on.

2.3 Levels Cooperation and Decision Making

The basic difference between Adaptive and Self-Organizing Levels means that Adaptive Level (II) provides tuning of the Basic Control Level (I) mostly through quantitative changes, whereas Self-Organizing Level (III) adjusts lower levels (II) and (I) through qualitative changes. In other words, Self-Organization Algorithm dynamically reconfigures system architectures. At this level self-learning models may be used to get on-line plant parameter and structure changes in order to predict optimal control at each discrete moment.

It is extremely complicated and unreliable to delegate decision making functions at level (III) to artificial intelligent agent. At this level the decision making procedures are assumed to be done by systems developers and process engineers in accordance with the best choice of control algorithms which are the most effective in the case studies and industry applications to complex plants under control (plasma in thermonuclear reactors, oil refinery plants and the like) taking into account expert system database and data knowledge.

3 Statements of Control Problems and Implementation

A number of new important complex control problems have to be studied, discussed and formulated to achieve control goals of acceptable trade-off between robust stability and performance of feedback systems. The problem statements concern the stabilization and tracking process output signals, optimal distribution of process parameters in space in the presence of non-modeled process dynamics, unobserved disturbances, nonlinearities, in particular saturations, wideband insufficiently known noise in output signals, non-minimum-phase dynamics, and time-varying parameters. To solve these control problems a set of approaches from linear and nonlinear control theory will be explored and developed to achieve scalable H_∞ robust, decoupling, model predictive, adaptive, hierarchy, cascade, soft-computing based control (e.g., neuro-fuzzy control systems), and facilitate decision-making in new appropriate combinations within continuous and discrete time of the three-level hierarchic control system (Fig. 1). Scalable control algorithms mean that the algorithms may be generalized to any numbers of controlled plant inputs, outputs, and space states.

The main scientific and technical contributions of the project imply the integration and synergy achieved as a result of the implementation of advanced control methods, relevant computational strategies and state-of-the-art technologies for embedded and networked systems. In the process of hierarchical structure control systems design the synthesis, analysis, and numerical modeling approaches are proposed to be performed in MATLAB/SIMULINK environment. The controllers to be designed are planned to be implemented in a test bed with primary objective to evaluate functionality of control systems in real time. The test bed should consist at least of two basic electronic blocks: dynamic process model under control and feedback hierarchical controller which interconnection should demonstrate advantages of scalable control algorithms to be elaborated and modern high-performance computations in real time.

4 Case Study of Plasma Energy Release

In order to advance the suggested control approaches plasma energy release case study is planned to be investigated on plasma in tokamaks. Nuclear fusion should be a new source of practically inexhaustible energy and tokamaks are the leaders in thermonuclear energy release area. The plasma control systems under investigation are supposed to be applied to ITER (International Thermonuclear Experimental Reactor).

It is an intense and challenging time for ITER to design the whole set of coupled plasma magnetic and kinetic control systems. Magnetic control systems have to provide accurate control of plasma magnetic configuration [4] and stabilize plasma against the main MHD modes [5]. Kinetic control systems are to control power fusion and power flow to the diverter [6, 7] as well as profiles of plasma kinetic parameters: plasma current, temperature, and density [8].

Reliable control of plasma shape and current in ITER is still a challenging problem because of necessity of controller change during transition from limiter to divertor phases, existence of separate loop to suppress plasma vertical speed of unstable vertical position, currents saturations in poloidal field (PF) coils, and so forth. Plasma tokamak configuration with a free boundary defined by currents in PF active coils and passive contours is described by vector Kirchhoff equation [9] and Grad-Shafranov nonlinear partial differential equation [9, 10]. These equations together with equation of magnetic field diffusion into plasma are realized numerically by DINA plasma-physics code [9].

Plasma magnetic control in ITER is planned to be realized by two-loops control system presented in Fig. 2: fast scalar loop stabilizes plasma vertical speed around zero and slower multivariable loop tracks (on ramp-up and ramp-down phases) and stabilizes (on quasi-stationary phase) plasma shape and current [11].

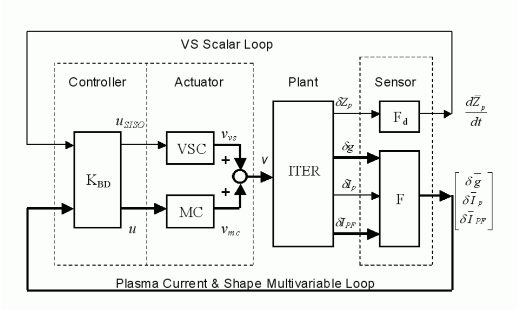
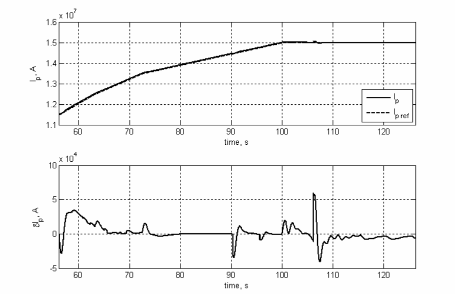


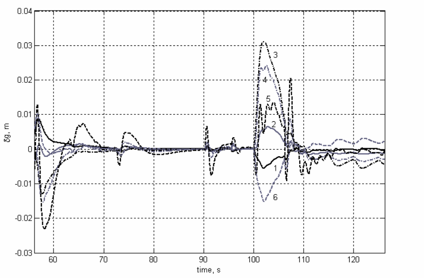
Fig. 2. Two-loops control system: K_{BD} is block-diagonal controller, MC is multivariable main converter, VSC is vertical stabilization converter, F_d is derivative filter, F is filter for plasma shape, current and control currents, g is a vector of gaps between separatrix and the first wall, I_p is plasma current

Plasma in ITER is a MIMO plant that has 11 inputs (voltages on 11 superconductive magnetic coils) and 19 outputs (6 gaps, plasma current, currents in 11 PF coils, plasma vertical speed). At the moment we have simulation results on DINA code of application of three control methodologies for plasma magnetic control specifically cascade decoupling with PI controllers, H_∞, and Model Predictive Control (MPC). Decoupling approach gave a chance to track plasma current (Fig. 3a) and gaps (Fig. 3b) on the plasma current ramp up phase [11]. In particular H_∞ and MPC control systems were applied at plasma current flat-top phase (Fig. 4a) where MPC showed better performance at minor disruptions but H_∞ system had larger robust stability margin [12].

The fragments of plasma magnetic control were applied for ITER reference scenario 2 with plasma current on flat-top of 15 MA. Multivariable robust controller design (Fig. 1) on level (I) *with adaptation* on level (II) is proposed to be done for the *whole plasma discharge* of plasma current ramp-up, ramp-down, and at quasi stationary stages. It is planned to be applied for ITER reference scenario 2 and for reversed share scenario 4 of plasma current of 9 MA.

The project control methodologies are planned to be advanced to solve *plasma kinetic control problem* as well. Plasma kinetic control means creation and maintenance of *optimal* plasma current, temperature, and density profiles by means of additional heating sources. Such regimes are necessary for stationary operation of tokamak-reactors. As the first step in this direction the kinetic plasma model was created on the base of diffusion equation which dynamically connects 5 inputs from power of heating sources for current drive and 5 outputs that are densities J_p of plasma current at 5 predetermined points of tokamak major radius [13]. For this kinetic model the identification problem was solved at zero frequency and then 5×5-multivariable controller was designed with the usage of decoupling principle and PI diagonal entries. Controller was simulated on the original kinetic model and showed capability of work in the range of plasma temperature on magnetic axis from 100 eV to 5 keV. Transient process from initial plasma current profile to designated positions at the given points as well as relaxation process after disconnection of the feedback are presented in Fig. 4b [13].



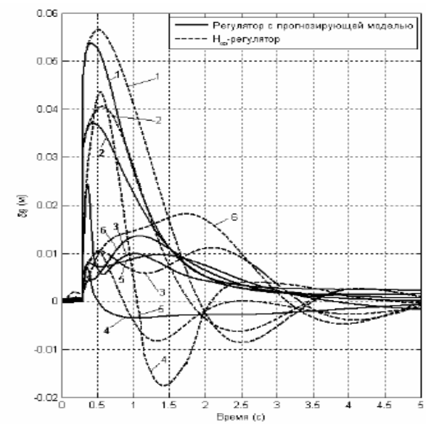


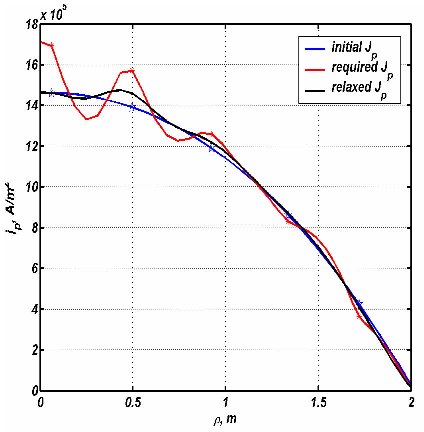
a **b**

Fig. 3. Tracking of plasma current and gaps: I_p is plasma current, δI_p is its tracking error (a); δg is a vector of gaps tracking errors (b)

Development of more full kinetic plasma models of plasma current, temperature, and density profiles and their identification taking into account dynamics of the plant are supposed to be done. Then design and modeling of plasma profiles control system in the temperature range at magnetic axis from 100 eV to 18 keV are assumed to be performed. Increasing of temperature range on plasma magnetic axis may arise of application of adaptation at the level (II) of hierarchical control system in Fig. 1.

The final issue of plasma control activity is assumed to be integration of plasma magnetic and kinetic control systems into joint system containing balanced subsystems with the usage of integrated plasma magnetic and kinetic models.





a **b**

Fig. 4. Six gaps stabilization by means of H_∞ and MPC controllers at plasma current flat-top phase when minor disruption occurs (a). Transient process from initial plasma current profile to predetermined profile and relaxation process result after feedback disconnection (b)

The ITER functionality is planned to be performed by means of CODAC software specifically Control, Data Access, and Communications (www.iter.org) via which one can install hierarchical control scheme proposed.

One of the main obstacles of plasma control systems design is to solve linearization and identification problems aiming at controller synthesis. In order to improve results on this way one can try to apply modern techniques with the help of neural networks and fuzzy logic. These approaches alone or combined (neurofuzzy) are able to model complex plants without knowledge of plant First Principle Equations using black-box or grey-box modeling approaches. In some cases these models are obtained from experimental input/output data or using simulation data from very complicated original plant models.

5 Intelligent Identification and Control Algorithms

Classic and non-traditional control strategies will be combined in order to incorporate self-* capabilities. Internal-model control (IMC) is a well-established approach to design controllers in which the process model is explicitly used in the control-system design procedure [14]. The use of the IMC paradigm theoretically guarantees control system robustness and stability in the presence of external disturbances. The actual roots of MPC are indeed in the IMC paradigm.

A block diagram of an internal model control based on Artificial Neural Networks (ANN) and Fuzzy Logic (FLC) is depicted in Fig. 5. All disturbances are considered to take place in the process output. In the figure G_M denotes a model of the process (direct model), G_M' is an approximate inverse of G_M, G_F is a low-pass filter, L denotes dead-time process plus network-induced delay, G_p denotes the process. The main assumptions are that an approximate reference model G_r is required and a maximum allowable delay (bounded delays) is known to deal with uncertainties and nonlinearities of the controlled process and delays in the corresponding network-based application.

Construction of the IMC system consists of two stages: (**i**) selection of a controller (usually the inverse model) to achieve perfect control and (**ii**) the introduction of a filter.

First an ANN is trained to learn the dynamics of the process and is therefore given known input- and output-data sets. So, one of the neural-network models developed is selected as a basis for IMC control. The inverse model is obtained on the basis of generalized training. Therefore, the network is trained off-line to minimize quadratic criteria $J(\theta) = \sum_{t=1}^{M} \left(v(t) - \hat{v}(t) \right)^2$.

Another ANN is trained to learn the inverse dynamics of the process and to work as a nonlinear controller. The back-propagation of error is applied for tuning $\theta = \left[K_F, K_{CF} \right]$ corresponding to the input scaling factors of the fuzzy block that can replace the inverse model (Fig. 5). The goal is the optimal setting of input scaling factors $\left[K_F, K_{CF} \right]$ to ensure that the overall system follows the reference signal $y'_r(t)$ closely. If inverse model actually describes the inverse dynamic of the plant, there will be a perfect cancellation and we should attempt to find $\theta = \left[K_F, K_{CF} \right]$ such that $v_{\mathrm{NN}}(t) \cong v_{\mathrm{FLC}}(t)$. Using the forward model one can estimate the Jacobians: $\partial y(t) / \left[\partial v(t-1) \right] \cong \partial \hat{y}(t) / \left[\partial v(t-1) \right]$.

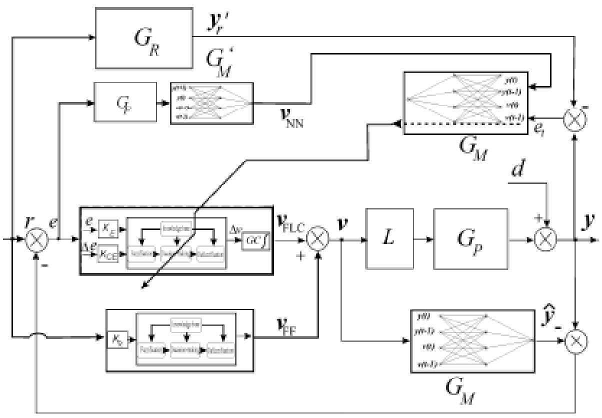


Fig. 5. A tailored scheme based on internal model control with self-learning, feedforward compensation and self-optimization based on ITAE criterion via error back-propagation

An important issue is the stopping condition to avoid overestimating $\theta = [K_F, K_{CF}]$. The best course is to use the integral of time multiplied by the absolute value of error (ITAE) criterion to optimize the transient response and to penalize lengthy transients $J_2 = \int_0^T t \cdot e(t)\,dt$. The ITAE criterion of J_2 is selected to obtain smaller overshoots and oscillations, which are quite harmful for the cutting tools used in machining.

It is important to remark that hybridization of FLC with ANN can also be applied in the IMC-based approach using other neuro-fuzzy inference systems [15].

6 Conclusions

The concept of three levels hierarchical control system was presented and discussed namely: philosophy of hierarchical control, statement of control problems, implementation, case study of plasma energy release, and intelligent identification and control algorithms.

The project will result in the creation of new process models, procedures of their identification and reduction, efficient, robust, predictable, and safe ICT control methodologies, scalable control algorithms, and high-performance controllers for the problem oriented hierarchical systems under consideration. Scientific, engineering, and industrial results will be accumulated in the data and knowledge bases with accurate classification, qualitative and quantitative assessment, and generalization.

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Early creation of cross toolkits for embedded systems

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Keywords: Cross-toolkit generation, ADL, hardware/software co-design, embedded systems development.

Abstract: Cross toolkits (assembler, linker, debugger, simulator, profiler) play a key role in the development cycle of embedded systems. Early creation of cross toolkits and possibility to quickly adapt them allows using them as early as at the hardware/software codesign stage, which becomes an important success factor for the entire project. Challenging issues for cross toolkits development is efficiency of simulation and CPU instruction set alterations at the design phase. Developing cross toolkits in C/C++ produces highly efficient tools but requires extensive rework to keep up with instruction set changes. Approaches based on automatic toolkit generation from some top level specifications in Architecture Description Languages (ADLs) are less sensitive to this problem but they produce inefficient tools, especially simulators. This paper introduces a new approach to cross toolkits development that combines the flexibility of ADL and efficiency of C/C++ based approaches. This approach was implemented in the MetaDSP framework, which was successfully applied in several industrial projects.

Introduction

Nowadays we witness emerging of various embedded systems with rather tough constraints (chip size, power consumption, performance) not only for aerospace and military applications but also for industry and even consumer electronics. The constant trend of cost and schedule reduction in microelectronics hardware design and development makes it reasonable to develop customized computing systems for particular applications and gives new momentum to the market of embedded systems. Such systems consist of a dedicated hardware platform developed for a particular application and a problem-specific software optimized for that hardware.

The process of simultaneous design and development of hardware and software components of an embedded system is usually referred to as *hardware/software codesign and codevelopment*. This broad term covers a number of subprocess or activities related to embedded system creation:

1. design phase, including functional design, when requirements are studied and transformed into functional architechture, and hardware/software partitioning, when functions are divided between hardware and software components;
2. development phase or software/hardware codevelopment when both hardware and software teams develop their components; both development activities may influence each other;
3. verification; it spans from unit and module tests to early integration testing in simulator/emulator.

Hardware/software codesign and codevelopment are crutial factors for success of embedded systems. They reduce time-to-market by better parallelization of the development wrokflows, and improve the quality by enabling early identification of design flaws and optimization the performance of the product.

Cross toolkits play an important role in hardware/software codesign and codevelopment. Primary components of such cross toolkits are assembler, linker, simulator, debugger, and profiler. Unlike chip production, development of cross toolkits does not require precise hardware design description; it is sufficient to have just a high-level definition of the target hardware platform: the memory/register architecture and the instruction set with timing specification. This allows developing cross tools as soon as the early design stages even if the detailed VHDL/Verilog specification is not ready yet. Cross tools could be used in the following scenarios:

- Hardware prototyping and design space exploration (e.g. (Hartoog et al., 1997) and (Yung-Chia, 2003)) – early development, execution and profiling of sample programs allows study and estimation of the overall design adequacy as well as efficiency of particular design ideas such as adding/removing instructions, functional blocks, registers or whole co-processors.
- Early software development including development, debugging and optimizing the software *before* the target hardware production.

- Hardware design validation. The developed cross-simulator could be used to run test programs against VHDL/Verilog-based simulators. This capability could not be overestimated for the quality assurance before the actual silicon production.

Paper Overview

In this paper, we present a new approach to cross toolkit development to be used in hardware/software co-development environments. The method enables software developers to create the cross tools as early as the system design phase, to follow rapidly hardware design changes, most notably instruction set modifications, thus reducing the overall time frame of the design phase.

The article is organized as follows. Section 2 discusses generic requirements to cross toolkit development that hardware/software codevelopment imposes. Section 3 presents the new ADL language for defining instruction set called *ISE*. Section 4 introduces MetaDSP framework for cross toolkit development that uses hybrid hardware description with both high-level ADL part and efficient C/C++ part. Section 5 briefly overviews several industrial applications of ISE and MetaDSP framework. Conclusion summarizes the lessons learned and gives some perspectives for future development.

Hardware/Software Codesign and Codevelopment Requirements to Cross Toolkit Development

Let's consider a typical co-development process depicted at the fig. 1. The development process involves at least two teams - one is working on the hardware part of the system while another one focuses on software development.

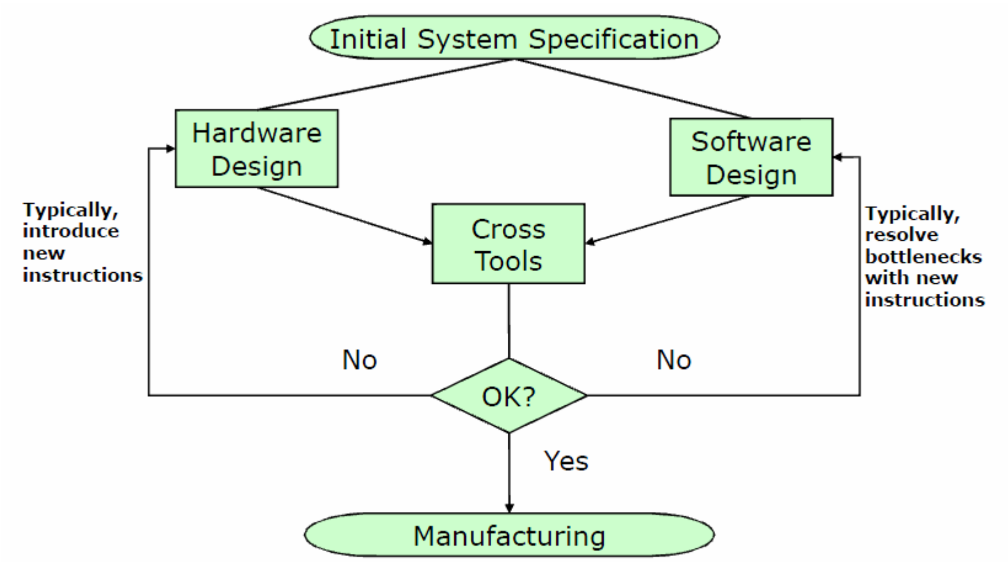

Figure 1. Co-development process.

Cross tools make it possible to run software on simulators or emulators of the target hardware early in the development process. Bottlenecks and performance problems identified during running the software might require modification of the design, most notably changes in instruction set or register file of the target embedded CPU.

Alterations in hardware design are characteristic features of co-development processes in the industry. In section 5 we provide basic statistics on several industrial project. The number of major changes in hardware specification vary from 25 to 39 with average 31 change per project.

In order to make the process seamless and continuous cross toolkit developers must rapidly react to such changes and produce new versions of the toolkit in short terms. Changes in instruction set require updates in every tool of the cross toolkit. Cross toolkit developers must be very careful not to introduce errors during the modification process.

Another critical issue for cross-toolkits application in the co-development process is performance of the tools. Special attention should be paid to the performance efficiency of the simulator. High-performance simulators are required to perform validation and profiling of the target
software on real-life data within reasonable time. For instance, processing a 10-seconds long speech sample on a DSP board takes about $7 \cdot 10^{11}$ CPU cycles. Running this sample on a simulator slower that 10 MCPS (10 millions of cycles per second) result in more than two hours long test execution which could hardly be considered feasible.

Simulator must be cycle-precise to guarantee correctness of profiling data. Usual practice is not to require simulation of the functional decomposition of the hardware. The externally observable behavior of the simulator must be equivalent to that of the actual hardware while the internal design need not follow the design of the target hardware (pipeline structure, ALU and FPU, internal buses etc.)

Related Work

Efficient cross toolkit development process requires automation to minimize time and effort necessary to update the toolkit to match new requirements. Such automation is built around a machine-readable definition of the target hardware platform. There are three groups of languages suitable for this task:

- Hardware Definition Languages (HDL, (Navabi, 2007)) used for detailed definition of the hardware;
- Architecture Description Languages (ADL, (Mishra and Dutt, 2005) and (Tomiyama et al., 1999)) used for high-level description of the hardware;
- and general purpose programming languages (such as C/C++).

HDL specifications define CPU operations with very high level of detail. All three major modern HDL – VHDL (IEEE Std 1076-2000, 2000), Verilog (IEEE Std 1364-2005, 2005), and SystemC (IEEE Std 1666-2005, 2005) – have execution environments that can serve as a simulator to run any assembly language programs for the target CPU: Synopsys VCS, Mentor Graphics ModelSim, Cadence NC-Sim and other. Still, low performance of HDL-based simulators is one of the major obstacles for HDL application in cross toolkit development. Another issue is the late moment of HDL description availability: it appears after completing the instruction set design and functional decomposition. Furthermore, HDL does not contain an explicit instruction set definition that makes automated assembler/disassemble development impossible. These issues prevent from using HDL to automate cross toolkit development.

Architecture Description Languages (such as nML (Fauth et al., 1995), ISDL(Hadjiyannis et al.,
1997), EXPRESSION(Halambi et al., 1999)) are under active development during the recent decade. There are tools created for rapid hardware prototyping at the high level including cross toolkit generation. Corresponding approaches are really good for early design phase since they help to explore key design decisions. Unfortunately, at the later design stages details in an ADL description become smaller, the size of the description grows and sooner or later it comes across the limitations of the language. As a result, is breaks the efficiency of the simulator generated from the ADL description and makes the profiler to give only rough performance estimates without clear picture of bottlenecks. Cross toolkits completely generated from an ADL description are not applicable for industrial-grade software development yet.

Manual coding with C or C++ language gives full control over all possible details and allows creation of cross toolkits of industrial quality and efficiency. Many companies offer services on cross toolkit development in C/C++ (e.g. TASKING, Raisonance, Signum Systems, ICE Technology, etc.). Still it requires significant efforts and (what is more important) time to develop the toolkit from scratch and maintain it aligned with the requirements. Long development cycle makes it almost impossible to use cross toolkits developed in C/C++ for hardware prototyping and design space exploration.

ISE Language

We developed ISE (*I*nstruction *S*et *E*xtension) language to specify hardware design elements that are subject to most frequent changes: memory architecture and CPI instruction set. ISE description is used to generate assembler and disassembler tools completely and to generate components of the linker, debugger and simulator tool.
The following considerations guided the language design:

- the structure of an ISE description should follow the typical structure of an instruction set reference manual (like (VIA Technologies, 2005) or (Texas Instruments, 2006)) that usually serve as the input for the ISE description development;
- support for irregular encoding of instructions typical for embedded DSP applications including support for large number of various formats, distributed encoding of operands in the word, etc.;
- operational definition of data types, logic and arithmetic instructions, other executable entities should be specified in a C-like programming language.

ISE module consists of 6 sections:

1. **.architecture** defines global CPU architecture properties such as pipeline stages, CPU resources (buses, ALUs, etc.), initial CPU state;
2. **.storage** defines memory structure including memory ranges, I/O ports, access time;
3. **.ttypes** and **.otypes** define data type to represent registers and instruction operands;
4. **.instructions** defines CPU instruction set (see more details below);
5. **.aspects** defines various aspects of binary encoding of CPU instructions or specifies additional resources or operational semantics of instructions;
6. **.conflicts** specifies constraints on sequential execution of instructions such as potential write after read register or bus conflict; assembler uses conflict constraints to automatically insert NOP instructions to prevent conflicts during software execution.

Instruction Definition

.instruction section is the primary section an ISE module. It defines the instruction set of the target CPU. For each instruction cross toolkit developers can specify:

- mnemonics and binary encoding;
- reference manual entry;
- instruction properties and resources used;
- instruction constraints and inter-instruction dependencies;
- definition of execution pipeline stage.

Mnemonics part of an instruction definition is a template string that specifies fixed part of mnemonics (e.g. `ADD`, `MOV`), optional suffixes (e.g. `ADDC` or `ADDS`) and operands. A singe instruction might have several definitions depending on the operand types. For example, `MOV` instruction could have different definitions for register-register operation, register-memory and memory-memory operations.
Binary encoding is a template that specifies how to encode/decode instructions depending on the instruction name, suffixes and operands.
Reference manual entry is a human-readable specification of the instruction.
Properties and resources specify external aspects of the instruction execution such as registers that it reads and writes, buses that the instruction accesses, flags set etc. This information is used to detect and resolve conflicts by the assembler tool. Besides this the instruction definition might specify explicit dependencies on preceding or succeeding instructions in the constraints and dependencies section.
ISE language contains an extension of C programming language called ISE-C. This extension is used to specify execution of the operation on each pipeline stage. ISE-C has extra types for integer and fixed point arithmetic of various bit length, new built-in bit operators (e.g. shift with rotation), built-in primitives for bit handling. ISE-C has some grammar extension for handling operands and optional suffixes in mnemonics. Furthermore ISE-C expression can use a large number of functions implemented in ISE core library.
An example of instruction specification is presented at Figure 2.

```
/*
 * This is a C-style block comment.
 */
// This is a C++-style one-line comment.
// <ALU001> - the identifier of the definition.
// ADD[S:A][C:B] - instruction mnemonics with optional parts.
// Actually defines 4 instructions: ADD, ADDS, ADDC, ADDSC.
// GRs, GRt - identifiers of a general-purpose register. Rules
// for binary encoding of GRs and GRt are defined in .otypes section.
<ALU001> ADD[S:A][C:B] {GRs}, {GRt}
 // Binary encoding rule.
 // For example, "ADDC R0, R1" is encoded as 0111-0001-1000-1001
 0111-0A0B-1SSS-1TTT
 // The reference manual string.
 "ADD[S][C] GRs, GRt"
 // instruction properties:
 // reads the registers GRs and GRt,
 // writes the register GRs.
 properties [ wgrn:GRs, rgrn:GRs, rgrn:GRt ]
 // Operation of the EXE pipeline stage specifies using ISE-C language.
 action {
 alu_temp = GRs + GRt;
 // If the suffix `C' is set in mnemonics use `getFlag' function
 // from the core library.
 if (#B) alu_temp += getFlag(ACO);
 // If the suffix `S' is set in mnemonics use `SAT16' function
 // from the core library.
 if (#A) alu_temp = SAT16(alu_temp);
 GRs = alu_temp;
 }
```

Figure 2. An example of instruction specification.

Please note that unlike classic ADL languages ISE specification does not provide the complete CPU model. The purpose of ISE is to simplify definition of the elements that are subject to the most frequent changes. All the rest of the model is specified using C/C++ code. This separation allows for flexible and maintainable hardware definition along with high performance and cycle-precise simulation.

Application to the Codevelopment Process

The proposed hybrid ADL/C++ hardware definition is supported by the *MetaDSP* framework for cross-toolkit development. The framework is intended for use by software developers. Typical use case is as following:

1. hardware developers provide the software team with hardware definition in the form of ISE specification;
2. software developers generate cross tools from the specification;
3. software team develops the software in Embedded- C(ISO/IEC TR 18037:2008, 2004) and build using the generated cross-assembler and cross-compiler;
4. the machine code is executed and profiled in simulator.

To support this use case the framework includes:

- ISE translator that generates components of cross tools from the ISE specification;
- pre-defined components for ISE development (e.g. ISE-C core functions library);
- an IDE for hardware definition development (in ISE and C++), target software development (in Embedded C and assembly languages), controlled execution within simulator; the Embedded C compiler supports a number of optimizations specific for DSP applications(Rubanov et al., 2006).

The figure 3 presents the structure of the MetaDSP framework.

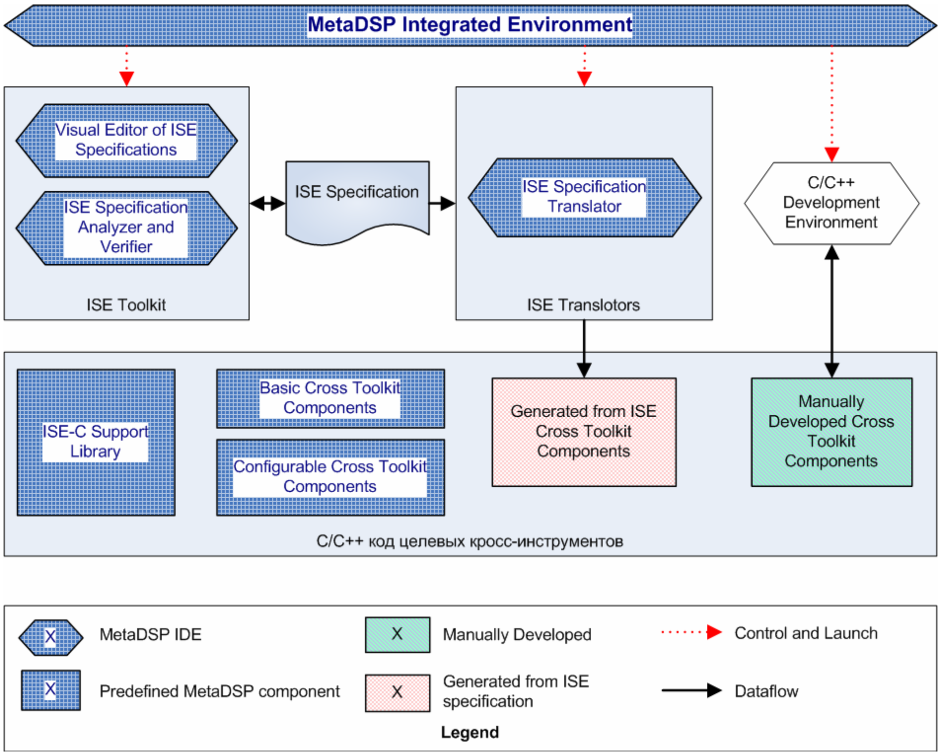

Figure 3. MetaDSP framework structure.

MetaDSP toolkit uses ISE specification to generate cross tools and components. For example, the MetaDSP tools generate assembler and disassembler tools completely from the ISE specification. For linker MetaDSP generates information about instruction binary encodings, instruction operands and relocatable instructions. Debugger and profiler use memory structures and operand types from the ISE specification.

The cycle-precise simulator is an important part of the toolkit. Figure 4 presents its architecture. MetaDSP tools generate several components from the ISE specification: memory implementation (from **.storage** section), resources (from **.architecture** section), instruction implementations and decoding tables (from **.instruction** section), as well as conflicts detector and instruction metadata.

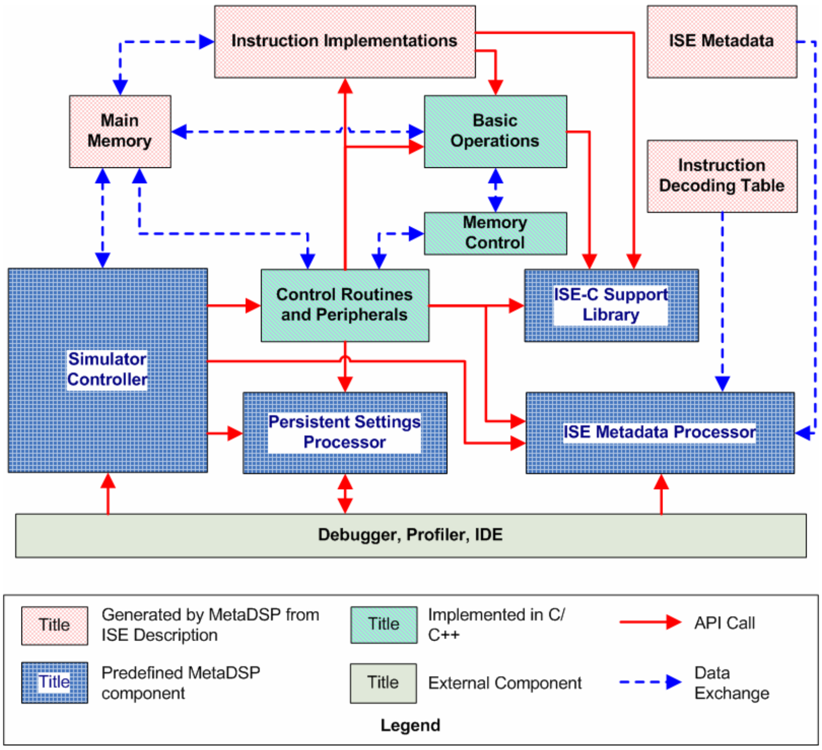

Figure 4. MetaDSP simulator architecture.

Within the presented approach certain components are specified in C++:

- control logic, including pipeline control (if any), address generation, instruction decoder;
- memory control;
- model of the peripheral devices including I/O ports.

For most of the manual components MetaDSP tools generate stubs or some basic implementation in C++. Developers may use the generated code to implement peculiarities of the target CPU, such as jumps prediction, instruction reordering, etc.

Using C/C++ to implement CPU control logic and memory model facilitates high performance of the simulator. Another benefit of using C/C++ compared to true ADL languages is an early development of the cross toolkit: it might start before completing the function decomposition of the target CPU; thus the simulator could be used to experiment with design variations.

The framework includes OSCAR Studio, the IDE for target software development within the MetaDSP framework. The IDE closely follows the look-and-feel style of Microsoft Visual Studio and provides the following capabilities to developers of embedded systems:

1. Project Navigator. It displays the tree of the source files and data files.
2. Source Code Editor. The editor supports syntax highlight and instruction autocompletion (from the ISE specification). The editor window is integrated with the debugger - it marks break points, frame count points and trace points.
3. Stack Memory window that displays the contents of the stack.
4. Call Stack window that displays the enclosing frames (both assembly subroutines and C functions).
5. Register window that displays the contents of the CPU registers.
6. Memory dump window that displays contents of various memory regions.
7. Watch window that displays the current value of arbitrary C expressions.
8. Code Memory that window to track instructions being executed in the debugger. It supports both binary and disassembly forms as well as displaying the current pipeline stage (fetch, decode, execute, etc.).

9. OS debugger that enables steb-by-step debugging at C and assembler level with various breakpoints and tracing the state of the execution environment (OS): list of the current tasks, semaphores, mutexes, etc.
10. Profiler collecting various profiling data. The profiler is integrated with the editor as well – the editor can show profiling information associated with code elements.

Industrial Applications

The approach presented in this paper and MetaDSP framework were applied to five industrial projects. Please note that the each «major release of the cross toolkit» mentioned in the project list below is caused by a major change in CPU design such as modification of the instruction set or memory model alteration.

- 16-bit RISC DSP CPU with fixed point arithmetic. Produced 25 major releases of the cross-toolkit.
- 16-bit RISC DSP CPU with support for Adaptive Multi-Rate (AMR) sound compression algorithm. Produced 25 major releases of the cross-toolkit.
- 32-bit RISC DSP CPU with support for Fourier transform and other DSP extensions. Produced 39 major releases of the cross-toolkit.
- 16/32-bit RISC CPU clone of ARM9 architecture.
- 16/32-bit VLIW DSP CPU with support for Fourier transform, DMA, etc. Produced 33 major releases of the cross-toolkit.

The following list summarizes lessons learned from the practical applications of the approach. We compared time and effort needed in a pure C++ development cycle of cross toolkits with the ISE-enabled process:

- size of assembler, disassembler and simulator sources (excluding generated code), in lines of code: reduced by 12 times;
- cross-toolkit development team (excluding C compiler development): reducing from 10 to 3 engineers;
- number of errors detected in the presentation of hardware specifications in cross tools: reduction by the factor of more than 10;
- average duration of the toolkit update: reduced from several days to hours (even minutes in many cases).

Performance Study

This section presents a performance study of a production implementation of the AMR sound compression algorithm. The study was performed on Intel Core 2 Duo 2.4 GHz.

The size of the implementation was 119 C source files and 142 C header files, and 25 files in the assembly language; total size of sources was 20.2 thousand LOC without comments and empty lines. The duration of the audio sample (10 seconds voice speech) lasted 670 million of cycles on the target hardware.

Table 1 presents elapsed time measurements of the generated cross tools for the AMR case study. Table 2 presents measurements of the generated simulator in MCPS (millions of cycles per second).

Operation	**Duration, sec.**
Translation (.c → .asm)	22
Assembly (.asm → .obj)	14
Link (.obj → .exe)	1
Build, total	37
Execution on the audio sample (fast mode)	53
Execution on the audio sample(debug mode with profiling)	93

Table 1. AMR sample – cross toolkit performance.

Execution mode	**MCPS**
Fast mode	12.6
Debug mode with profiling	7.2
Peak performance on a synthetic sample	25.0

Table 2. AMR sample – simulator performance.

Conclusion

The paper presents an approach to automation of cross toolkit development for special-purpose embedded systems such as DSP and microcontrollers. The approach aims at creation the cross tools, namely assembler/disassembler, linker, simulator, debugger, and profiler, at early stages of system design. Early creation of the cross tools gives opportunity to prototype and estimate efficiency of design variations, co-development of the hardware and software components of the target embedded system, and verification and QA of the hardware specifications before silicon production.

The presented approach relies on a two-level description of the target hardware: description of the most flexible part – the instruction set and memory model – using the new ADL language called *ISE* and description of complex fine grained functional aspects of CPU operations using a general purpose programming language (C/C++). Having ADL descriptions along with a framework to generate components of the target cross toolkits and common libraries brings high level of responsiveness to frequent changes in the initial design that are a common issue for modern industrial projects. Using C/C++ gives cycle-accurate simulation and overall efficiency of the cross toolkits that meets the needs of industrial developers. The approach is supported by a family of tools comprising MetaDSP framework.

The approach is applicable to various embedded systems with RISC core architectures. It supports simple pipelines with fixed number of stages, multiple memory banks, instructions with fixed and variable cycle count. These facilities cover most of modern special purpose CPUs (esp. DSP) and embedded systems. Still some features of modern general purpose high performance processors lay beyond the capabilities of the presented approach: superscalar architectures, microcode, instruction multi-issue, out-of-order execution. Besides this, the basic memory model implemented in MetaDSP does not support caches, speculative access, etc.

Despite the limitations of the approach mentioned above it was successfully applied in a number of industrial projects including 16 and 32-bit RISC DSPs and 16/32 ARM CPUs. Number of major design changes (with corresponding releases of cross toolkits) ranged in those projects from 25 to 40. The industrial applications of the presented approach proved the concept of using the hybrid ADL/C++ description for automated development of cross toolkits in a volatile design process.

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Prospects of “one-level” architecture of control systems on the basis of Ethernet network

DCS "Tornado-N" with “one-level” architecture on the basis of Ethernet

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Keywords: DCS, Controllers, Networks, Ethernet.

Abstract: Modern DCS of technological processes have “multi-level” architecture. The “low” level of DCS is represented by controllers. They provide three main functions: data acquisition, processing and control of object. Input-output devices are connected directly to controller for information interchange with object and processing unit (CPU). The upper level connects controllers together and provides their interaction with "the top" level of a system. In systems with such architecture, controller which needs to obtain variables connected to an other controller, it requires to have a special complex service for interconnection with the other controller: for performance of base “low” level function of input-output, upper level is involved. Many suppliers of control systems do not have a solution for it, i.e. the data exchange function of controller in vast majority of systems is absent. Level of today's network technologies allows to construct homogeneous “one-level” control system on the basis of a high-efficiency local network, for example Fast Ethernet. In such systems network is used not only for interaction of workstations, servers, but for direct interaction with input-output devices, connected directly to Fast Ethernet network. Thus the concept of classical controllers disappears and control algorithms may be carried out in any point of the system.

1 INTRODUCTION

The idea of common bus interface now exists for more than 30 years. This principle is being used to construct separate subsystems (e.g. computers, controllers) and integration of such subsystems. There exists a majority of bus interfaces for these purposes.

Bus (e.g. PCI) merges all the primary devices in computers and servers, bus interface in controllers merges all processor and I/O modules. Thus, different subsystems use different inner bus interfaces. Modern distributed control systems (DCS) of technological processes have “multi-level” architecture. The “low” level of controllers providing information interchange and commands with object through the devices of input-output, connected directly to the controller (Figure 1).

The next upper level connects controllers together and provides their interaction with "the top" level of a control system. In systems with such architecture, controller which needs to obtain variables connected to an other controller requires to have the special complex service for interconnection with the other controller, i.e. for performance of base “low” level function of input-output, upper level will be involved.

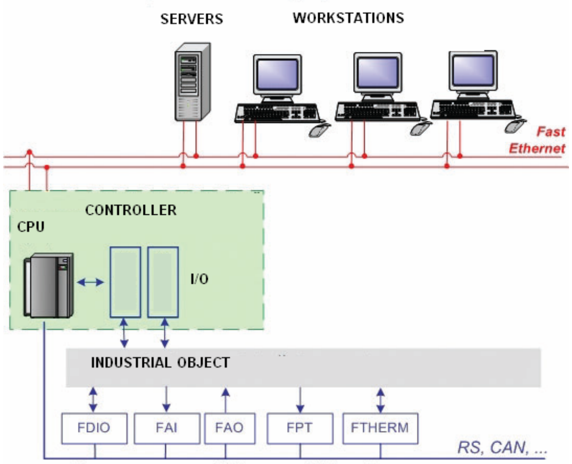

Figure 1: Traditional heterogeneous architecture.

This problem not so is simple, as may seem and many suppliers of control systems do not have a solution for it, i.e. the data exchange function of the controller’s in vast majority of systems is absent. The level of today's network technologies allows to construct homogeneous “one-level” control system on the basis of a high-efficiency local bus interface (Fig. 2). In such systems the network is used not only for interaction of workstations, servers, but for direct interaction with input-output devices, connected directly to network. It is quite possible to suggest the possibility of building the whole system based on one common bus interface (a homogeneous system). Nowadays Ethernet technology gives the developers of Industrial Control Systems all the sufficient facilities.

2 FAST ETHERNET BUS

Analyzing the history of computer systems progress one can note such tendency that with development of new technologies the system constructor gets an opportunity to deal with more and more higher-level interfaces of informational exchange. Nowadays Ethernet is a Bus Interface of high-level for building DCS. If I/O modules are connected directly to the common-system bus interface, we have different architecture of DCS with a list of new advantages; controllers are assumed as something different from familiar sight.

Thus the concept of classical controllers disappears. Control algorithms can be carried out in any point of the system, but for reasons of reliability it is more preferable and better to allocate special computing devices of "an automation server". It is possible to consider such architecture almost "ideal", possessing nearby considerable advantages. It is possible to expect that the future development of control systems will go this way.

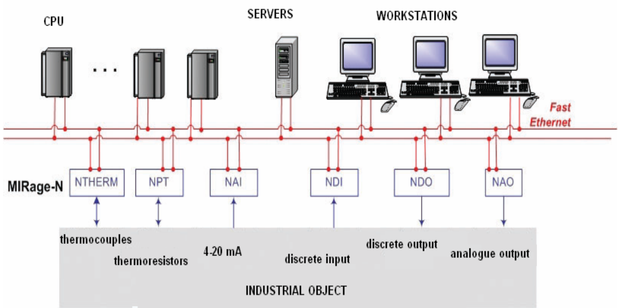

Figure 2: Homogeneous architecture.

The main goal of “Modular Systems Tornado” company’s (www.tornado.nsk.ru, Nosovibirsk, Russia) developers was to create the automation facilities for maximum broad spectrum of process tasking, to have an opportunity to use these facilities on really large major industrial objects. MIRage-N I/O modules with duplex Ethernet bus may be successfully implemented not only in systems of general-automation use but the module line is sufficient for objects with enhanced reliability, fail-safety and high-availability requirements. Distributed I/O modules of this product line can be implemented both as parts of DCS and for local means of visualization and maintenance.

Unlike the other products of distributed I/O, MIRage-N line provides the data of industrial workflow directly to the common Fast Ethernet industrial bus aggregating all elements of the automation system: CPU modules, servers and workstations.

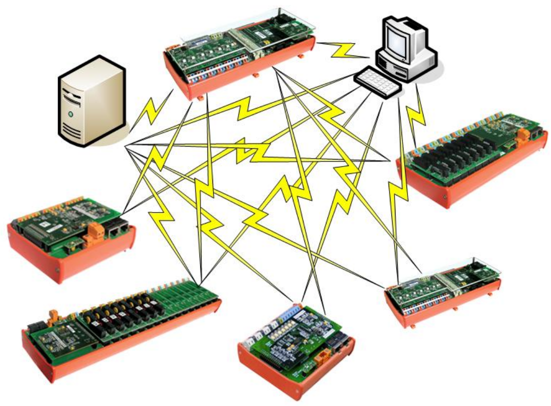

Figure 3: MIRage-N: equal right DCS member.

Architecture with absence of controllers (in usual assumption) gives a new degree of freedom to developer. There is no need in affixment of I/O modules to the specified definite CPU (like in all common systems). This factor substantially simplifies the process of DCS cabinet’s construction: MIRage-N modules transfer data to any active CPU of the system attaining the state of distribution of data collecting and data processing.

2.1 MIRage-N advantages

Thereby systems with distributed I/O based on MIRage-N modules have such advantages:

- It’s standard and innovative, specified by use of progressive Ethernet technologies and organization of data transfer services by copper cables, optical cables and radio communication;
- Fail-safety provided by duplex Ethernet bus. Communication channel restoration is an expensive long-run and complicated procedure. Duplication of the industrial bus gives an opportunity to detect and restore the failure troubles. Such system is operable and runs even with failure of one communication subsystem. Also according to requirements it is possible to duplicate the functional parts and assemblies of the system;

- Reduction of charges: as an industrial bus interface, Fast Ethernet (10/100 Mbit/sec) gives a wide variety of computing sources from industrial CPU to PC-compatible devices that dramatically reduces the upper-level cost of industrial control system. Distributed structure of the system allows to make changes “on-site” enhancing operational and metrological characteristics of the system and substantially reducing expenditures for cable materials;
- High Availability: the system architecture allows to make hot-swap of any system element, replacement of defective modules without an impact on the rest of the system with minimum time;
- hot-swap of any system element, replacement of defective modules without an impact on the rest of the system with minimum time;
- Convenience in exploitation. The module construction allows the mounter to make the replacement of defective elements without demounting of field cables. Signals from sensors are plugged directly in MIRage-N modules in WAGO spring clips that do not require periodic maintenance;
- Scalability, extensibility. The functioning system may be populated with additional modules. The scaling procedure does not require any modification of functioning part of the system. Industrial interface bus of large and major industrial objects may contain several segments that use different communication mediums, e.g. copper wire, optical cable and radio connection;
- Developed software for integration of MIRage-N modules with ISaGRAF programming environment. Developed applications include .dll libraries implementing Modbus interfaces; OPC DA server supplying compatibility with SCADA systems for Windows OS supplying duplex Ethernet bus interface; components for usage of modules in LabView environment;
- Fixed time cycle of data acquisition for all devices equal to time of answering interval for one device (1 msec). The possibility of same time device scan rids from necessity of passive reply wait.

Open standards and technologies used in bus interface modules MIRage-N give the possibility to develop and maintain any systems of automation with different configuration of Ethernet, any processing devices, any programming environments and SCADA-systems, servers, e.t.c. The configuring of MIRage-N modules and visualization of data is maintained with “Configurator” software.
Unified module body of MIRage-N allows the installation of the module on DIN-rail (35 mm), it provides electrical insulation, galvanic isolation, fail-safe connection of the sensor cables. Field cable cross section square is 0,08 to 2,5 mm2.

2.3 Module construction

Every MIRage-N module is a two-part construction – motherboard and plug-in boards - mezzanines. Mezzanines contain all the active elements. Figure 4 features MIRage-N parts:

1. Motherboard with no active elements;
2. Field Terminal blocks;
3. Mezzanine connectors;
4. Protective device;
5. Power supply connection;
6. Fast Ethernet connection inputs.

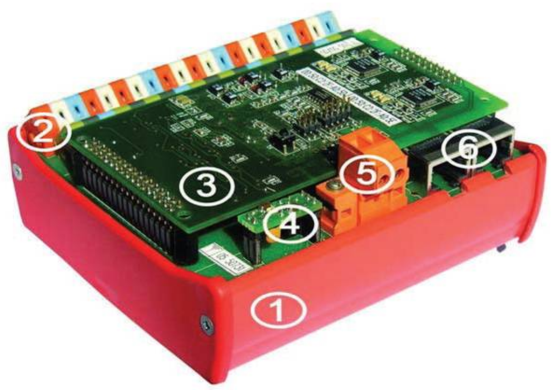

Figure 4: MIRage-N module construction (with cover removed).

2.3 MIRage-N line

The MIRage-N line includes all types I/O modules to fulfil the requirements of Industrial Control Systems:

- MIRage-NAI – 16 differential channels or 32 single channels, analogue signal input -20 + 20- mA, -10 +10 V, 16-bit delta-sigma ADC, 3-pole digital filter, individual DC-DC converter to power supply of sensor.
- MIRage-NDIO – 24 discrete channels. 12 input channels, 12 output channels. 24 V, 220 V.

- MIRage-NDI – 24 input channels. 24 V or 220 V, 4mA input current.
- MIRage-NDO – 24 output channels. 24 V or 220 V AC/DC: 3 A – AC, 0,5 A – DC.
- MIRage-NAO – 4 analogue output channels, 8 programmable discrete channels.
- NIRage-NTHERM – 8 analogue channels, thermocouples.
- MIRage-NPT – 8 analogue channels, thermoresistors.

The company "Modular Systems Tornado" has finished system engineering of DCS "Tornado-N" with “one-level” architecture on the basis of Ethernet. Today DCS “Tornado-N” is used to build industrial control systems of large power units for power stations.

3 CONCLUSIONS

In architecture where all system elements are connected directly to integrated Ethernet bus interface the developer gets one of the most promising solutions applicable in DCS development. DCS “Tornado-N” architecture with common Ethernet bus based on MIRage-N distributed I/O line gives substantial economic benefits; in comparison with other world well-known industrial automation companies DCS “Tornado-N” decreases expenses up to 30 % in major automation systems of heat and power engineering plants with hundreds and thousands of signals and furthermore gives developer new levels of freedom in system construction allowing to use different connection schemes and benefit from open standards and technologies underlying in described approach philosophy.

Described above architecture approach is currently being implemented in automation systems of power stations, thermal power plants and other major industrial objects in Russia and CIS and demonstrated it’s positive qualities.
It is very likely that soon this approach will become the most widespread architecture in modern DCS.

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Linguo-Combinatorial Simulation in Complex Systems for Creation of Embedded Systems and Control Systems

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Abstract. Any complex system interacts with its changing environment and its viability depends on its adaptability. The number of arbitrary coefficients in the structure of equivalent equations of complex system changes in the process of learning. In systems with more than six variables, the number of arbitrary coefficients increases first, and then, passing through the maximum, begins to decrease. This phenomenon makes it possible to explain the processes of system growth, complication and death in biological, economical and physical-engineering systems. We use the linguo-combinatorial method of investigation of complex systems, in taking key words for building equivalent equations. This phenomenon is able to increase the adaptability of different systems and permit to build the embedded systems and control systems.

Keywords: Adaptability, Combinatorial simulation, Uncertainty, Appearance, Essence, General systems theory, Social-economics, Embedded Systems, Control Systems.
PACS:

1. INTRODUCTION

The natural language is the main intellectual product of mankind. The structure of the natural intellect is reflected in natural language that is accessible for investigation. Some scientific experiments can be expensive and dangerous. The simulation techniques permit to decrease the cost for investigating these systems. The simulation must accurately reflect the characteristics of the real world. Combinatorial simulation allows studying the full set of system variants including uncertainty. Any system contains some types of uncertainty, which are determined by their existence in real world. Humans interact with both physical objects and their descriptions in terms of natural language, mathematics or tables. Descriptions often only partially represent the essence of real processes. The inaccuracy of description introduces uncertainty. More often the uncertainty of systems is, however, inherent to the real world. This study is aimed toward such types of uncertainty in mental processes. Physical laws, the balance of energy and matter, and information limit the systems behavior. Within these limits, systems interact and adapt to other systems and environment, and undergo destructive actions.

2. LINGUO-COMBINATORIAL SIMULATION

Frequently we use the natural language to describe systems. We propose to transfer this natural language description to mathematical equations.

For example, we have a sentence

$$\text{WORD1} + \text{WORD2} + \text{WORD3} \qquad (1)$$

where we assign words and only imply meaning of words, the meaning (sense) is ordinary implied but not designated.

We propose to assign meaning in the following form

$$(\text{WORD1}).(\text{SENSE1}) + (\text{WORD2}).(\text{SENSE2}) + (\text{WORD3}).(\text{SENSE3}) = 0 \qquad (2)$$

This equation (2) can be represented in the following form

$$A1.E1 + A2.E2 + A3.E3 = 0 \qquad (3)$$

where Ai, i = 1, 2, 3, will denote words from English Appearance and Ei will denote senses from English Essence. The equations (2) and (3) are the model of the sentence (1). When we have a mathematical equation in the form F(x1, x2, x3) = 0, we can turn such a form by means of differentiation where the partial derivatives are the appearances and the derivatives with respect to time are the essences. This model is an algebraic ring and we can resolve this equation with respect to the appearances Ai or the essences Ei [4,5,6]:

$$\begin{aligned} A1 &= U1.E2 + U2.E3 \\ A2 &= -U1.E1 + U3.E3 \\ A3 &= -U2.E1 - U3.E2 \end{aligned} \tag{4}$$

or

$$\begin{aligned} E1 &= U1.A2 + U2.A3 \\ E2 &= -U1.A1 + U3.A3 \\ E3 &= -U2.A1 - U3.A2 \end{aligned} \tag{5}$$

where U1, U2, U3 are arbitrary coefficients, can be used for solution of different tasks on the initial manifold (2) or (3). In general if we have n variables in our system and m manifolds, restrictions, then the number of arbitrary coefficients S will be defined as the number of combinations from n to m+1 [4], as shown in Table 1,

$$S = C_n^{m+1},\ n > m \tag{6}$$

TABLE 1. The number of arbitrary coefficients depending on the number of variables n and the number of restriction m.

n /m	1	2	3	4	5	6	7	8
2	1							
3	3	1						
4	6	4	1					
5	10	10	5	1				
6	15	20	15	6	1			
7	21	35	35	21	7	1		
8	28	56	70	56	28	8	1	
9	36	84	126	126	84	36	9	1

The formula (6) is the basic law of cybernetics, informatics and synergetics for complex systems. The number of arbitrary coefficients is the measure of uncertainty. Usually, when solving mathematical systems, the number of variables is equal to the number of equations. In practice we frequently do not know how many constraints there are on our variables. Combinatorial simulation makes it possible to simulate and study the systems with uncertainty on the base of incomplete information. The problem of simulation of condition, guaranteeing the existence of maximum adaptability is investigated.

It is supposed that the behavior of a system with n variables is given with an accuracy of m intersecting manifolds, n > m. If the system is considered as a multidimensional generator (Fig.1) where at least a part of the variables interact with environment variables, and if the objective of the system is to decrease the functional of discoordination between them (Δ 1… Δ k), the system control unit has two instruments of impact, a and b, upon the system. First, this is the tuning – the changing of uncertain coefficients in the structure of the differential equations of the system, taking account that the greater number of these coefficients implies more accurate system response to changing environment. Second, this is the learning – the imposing new restrictions on the system behavior. The number of arbitrary coefficients, in the structure of equivalent equations, changes in the process of learning, of consecutive imposing new and new restrictions on the system behavior. In the systems with more than six variables the number of arbitrary coefficients increases first, and then, passing through the maximum begins to decrease. This phenomenon makes it possible to explain the processes of system growth, complication and death. The existence of maximum adaptability phenomenon is observed in and proved by numerous biological, economical and physical-engineering systems.

Fig. 1 shows the interaction between system and environment. It is important that we describe a system with a full sum of combinations and have all the variants of decisions. The linguo-combinatorial simulation is a useful heuristic approach for investigation of complex, poorly formalized systems.

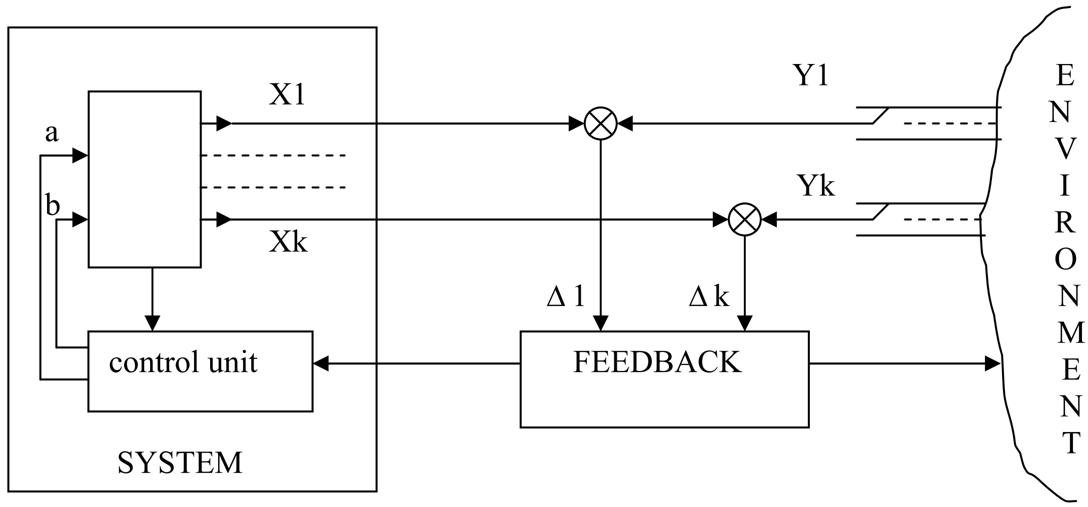

FIGURE 1. Model of "System - Environment"

Natural language is the main intellectual product of mankind; the structure of natural language reflects the structure of natural intellect of mankind and its separate representatives on the level of consciousness and unconscious. Linguo-combinatorial simulation is the calculation, which permits to extract the senses from texts. Wittgenstein wanted to have the calculation of senses [2,3]. In our calculation we have the three groups of variables: the first group – the words of natural language Ai, the second group – the essences Ei, which can be the internal language of brain [1]; we can have the different natural languages, but we have only one internal language of brain; this hypothesis opens a new way for experimental investigation; the third group of variables – the arbitrary coefficients, uncertainty in our model, which we can use for adaptation in translation processes and etc

3. SYSTEM WITH THE ARGUMENT CORRECTION

For example we can investigate the adaptation possibilities of system on a one-dimensional manifold F(x, y) = 0,

$$(x)^2 + (y)^2 = R^2 \quad (7)$$

After differentiation, we will have

$$(x)dx/dt + (y)dy/dt = 0 \quad (8)$$

and the structure with arbitrary coefficients will be

$$dx/dt = U1.y \quad (9a)$$

$$dy/dt = - U1.x \quad (9b)$$

The arbitrary coefficient U1 can be used for correction of multidimensional generator 1, as shown in Fig.2, where we have two servomechanisms, f1 and f2 – noises, Δx and Δy – errors of servomechanisms. Block 2 calculates the correction signal

$$\Delta = (\gamma)^2 - (\Delta x)^2 - (\Delta y)^2 \quad (10)$$

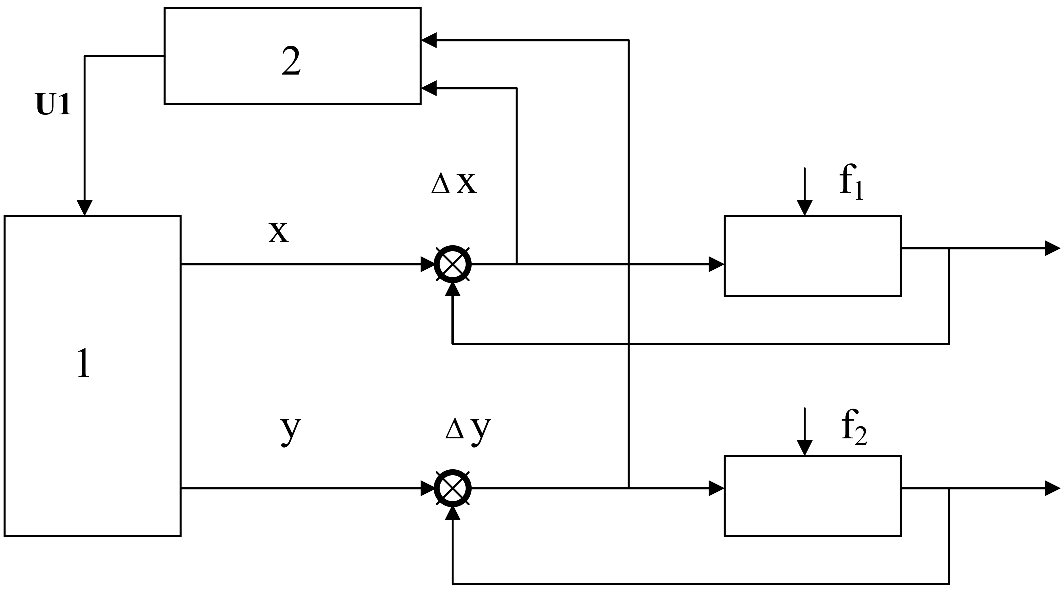

FIGURE 2. The system with an argument correction minimizes the servomechanisms errors.

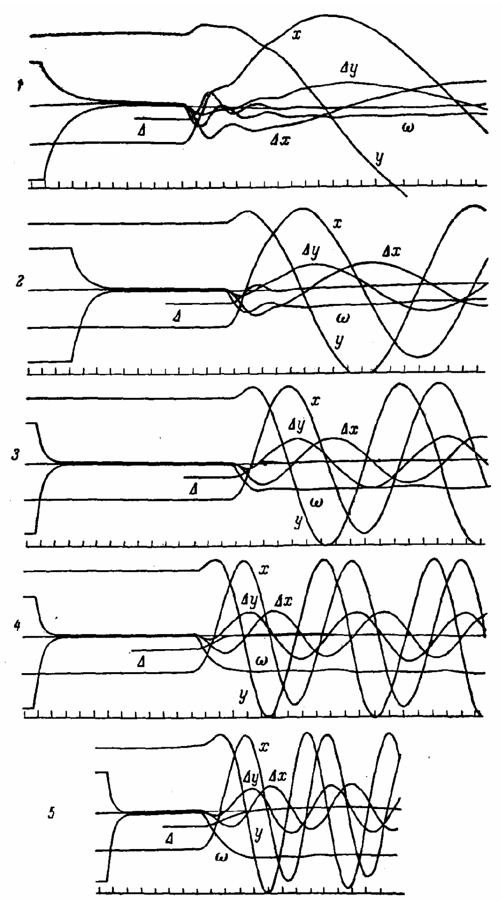

FIGURE 3. The oscillograms 1 – 5 are the result of argument correction system simulation with common servomechanisms, which have the different speeds of acting on different oscillograms in proportion 1:2:3:4:5, and where ω is the equivalent of U1.

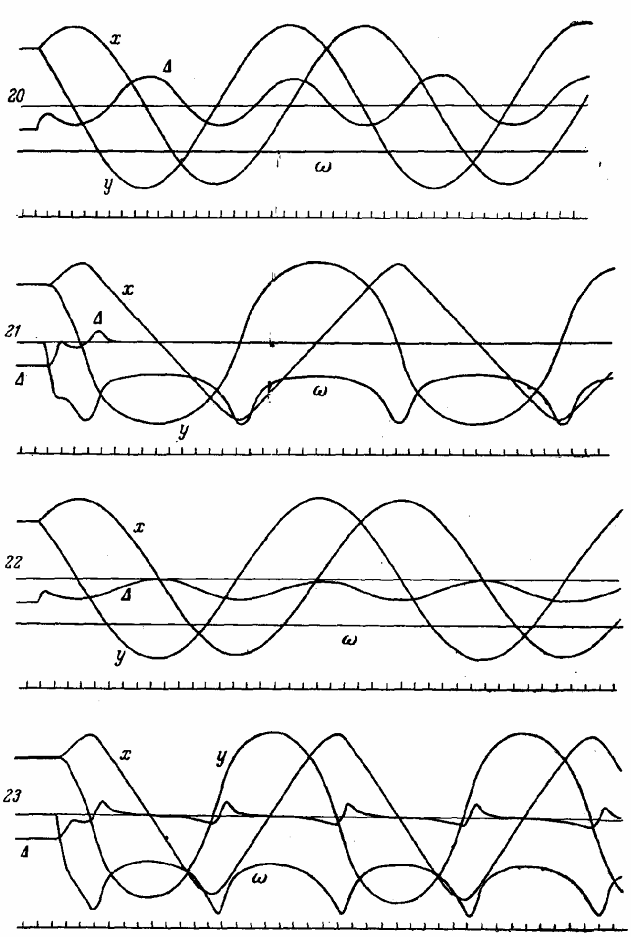

FIGURE 4. The oscillograms 21-23 are the result of argument correction system simulation with uncommon servomechanisms. The oscillograms 20-22 are the result of simulation without argument correction.

4. THE ULTRASTABLE SYSTEMS

The next aspect of the adaptation possibility is the synthesis of ultrastability systems. For decreasing the errors of our generator, we introduce the new variable x3

$$(x1)^2 + (x2)^2 - R^2 = x3 \qquad (11)$$

After differentiation we will have equations (3) and (5), where A1 = 2.x1, A2 = 2.x2, A3 = −1, and

$$\begin{aligned} dx1/dt &= U1.2.x2 - U2 \\ dx2/dt &= - U1.2.x1 - U3 \\ dx3/dt &= - U2.2.x1 - U3.2.x2 \end{aligned} \qquad (12)$$

If we assign U2 = x3.x1.a, U3 = x3.x2.a, where a – amplification factor, we will have

$$\begin{aligned} dx1/dt &= U1.x2 - x3.a.x1 \\ dx2/dt &= - U1.x1 - x3.a.x2 \\ dx3/dt &= -x3.a\,[(x1)^2 + (x2)^2] \end{aligned} \qquad (13)$$

where the variable x3 strives stable to zero.

If we have a sphere for decreasing the errors of our generator, we introduce the new variable x4

$$(x1)^2 + (x2)^2 + (x3)^2 - R^2 = x4 \qquad (14)$$

and the system of equivalent equations will be

$$dx1/dt = U1.2x2 + U2.2x3 - U3$$
$$dx2/dt = -U1.2x1 + U4.2x3 - U5$$
$$dx3/dt = -U2.2x1 - U4.2x2 - U6 \quad (15)$$
$$dx4/dt = - U3.2x1 - U5.2x2 - U6.2x3$$

If we assign U3 = x4.x1.a, U5 = x4.x2.a, U6 = x4.x3.a, we will have

$$dx1/dt = U1.2x2 + U2.2x3 - x4.x1.a$$
$$dx2/dt = -U1.2x1 + U4.2x3 - x4.x2.a$$
$$dx3/dt = - U2.2x1 - U4.2x2 - x4.x3.a \quad (16)$$
$$dx4/dt = -x4.a.2[(x1)^2 + (x2)^2 + (x3)^2]$$

where x4 will strive to zero in spite of different disturbances.

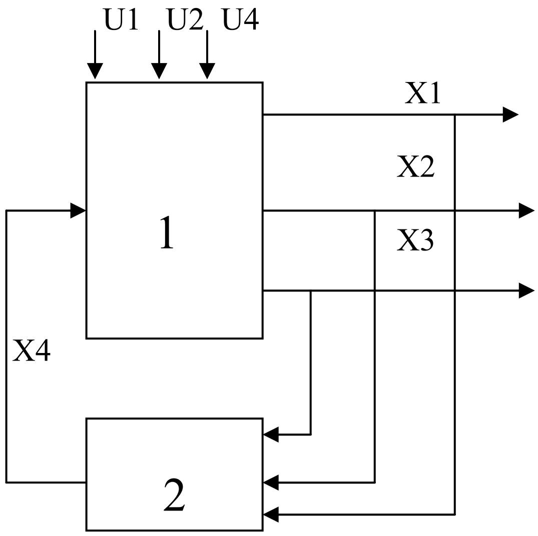

FIGURE 5. The ultrastable generator, where block 1 calculates first three equations (16), block 2 calculates equation (14), and the arbitrary coefficients U1, U2, U4 can be used for decision of different tasks on the sphere surface.

So, we have built an ultrastable generator with great possibilities of adaptation in spite of different disturbances, for example, the numerical errors in algorithms.

5. STRUCTURE OF GENERAL MODEL OF CITY

If we have the key words – Population, Passionarity, Territory, Production, Ecology and Safety, Finance and External Relation for simulation of city [11], then the equivalent equation of our model will be

$$E1 = U1.A2 + U2.A3 + U3.A4 + U4.A5 + U5.A6 + U6.A7$$
$$E2 = - U1.A1 + U7.A3 + U8.A4 + U9.A5 + U10.A6 + U11.A7$$
$$E3 = - U2.A1 - U7.A2 + U12.A4 + U13.A5 + U14.A6 + U15.A7$$
$$E4 = - U3.A1 - U8.A2 - U12.A3 + U16.A5 + U17.A6 + U18.A7 \quad (17)$$
$$E5 = - U4.A1 - U9.A2 - U13.A3 - U16.A4 + U19.A6 + U20.A7$$
$$E6 = - U5.A1 - U10.A2 - U14.A3 - U17.A4 - U19.A5 + U21.A7$$
$$E7 = - U6.A1 - U11.A2 - U15.A3 - U18.A4 - U20.A5 - U21.A6$$

where A1 is a characteristics of population (health, education, employment and etc), E1, a variation of this characteristics, A2, a characteristics of "passionarity", intentions of social groups of population, E2, a variation of this characteristics, A3, a characteristics of territory, E3, a variation of this characteristics, A4, a characteristics of production (industrial, agricultural, science, service etc), E4, a variation of this characteristics, A5, a characteristics of ecology and safety, E5, a variation of this characteristics, A6, a characteristics of finance, banking, individual finance etc, E6, a variation of this characteristics, A7, a characteristics of external relation, input and output flows of material, energy, information, finance, population E7, a variation of this characteristics, U1, U2, . . . U21, arbitrary coefficients, which compose the block of control in our city structure(Fig.6).

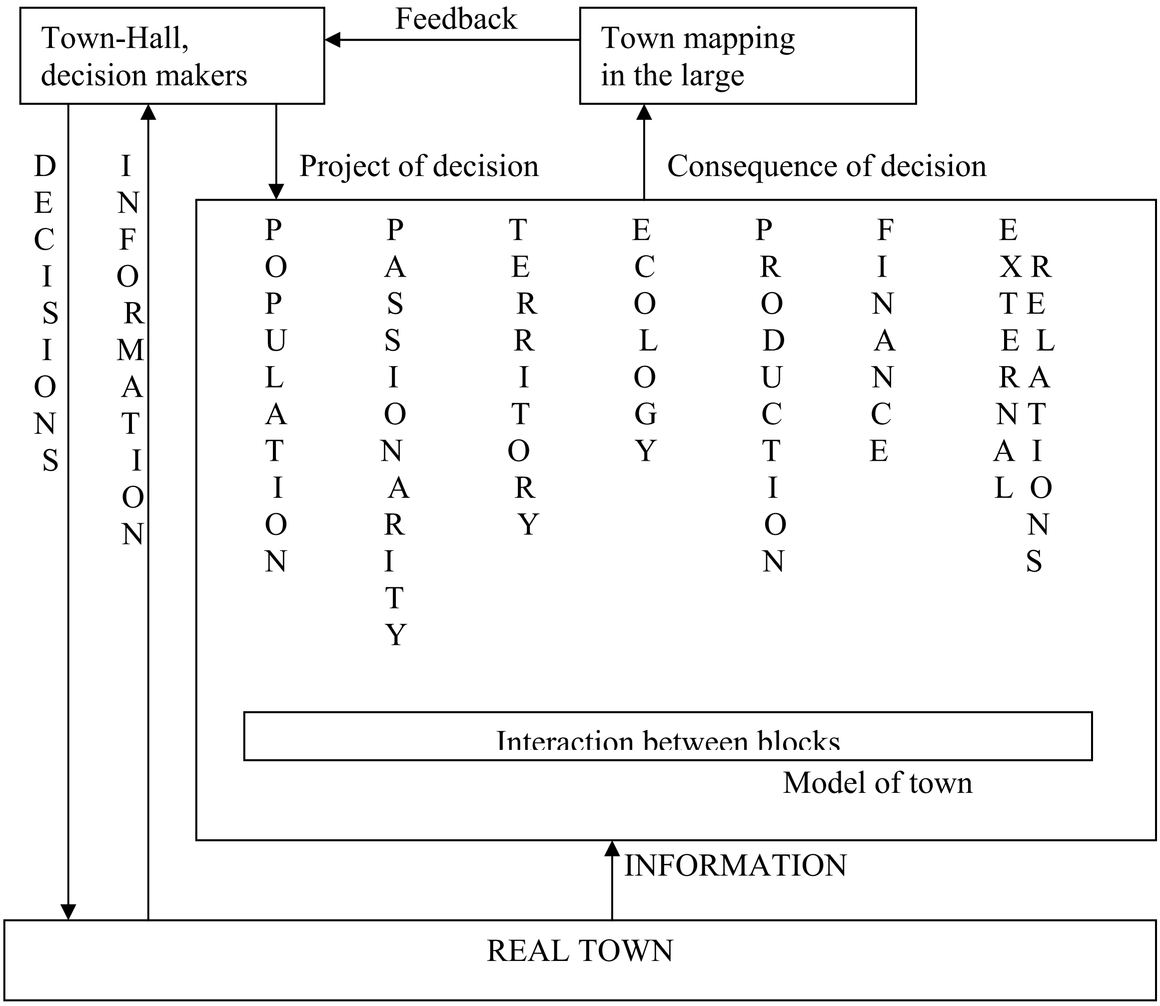

FIGURE 6. Simulation of a town for decisions making support.

6. MAXIMUM ADAPTABILITY PHENOMENON

The equivalent equations of any system contain arbitrary coefficients, which can be used for controlling it. The control may be internal or external. The behavior of any system with an environment contact will be determined by means of formula (6), which is the main law of cybernetics.

Each organism has a maximum adaptability zone. Table 2 shows the mortality depending on the age as a result of the census in Russia in different times. The minimum of mortality is observed within 10-14 ages in different historical periods. The minimum of mortality is identified with the maximum adaptability. Having passed through the maximum adaptability zone, the organism has got the possibility of reproduction.

TABLE 2. The mortality depending on the age as a result of the census in Russia in different times

Years/ages	1896-1897	1958-1959	1969-1970	1978-1980	1982-1983	1984-1985
0 – 4	133,0	11,9	6,9	8,1	7,9	7,7
5 – 9	12,9	1,1	0,7	0,7	0,6	0,6
10 – 14	5,4	0,8	0,6	0,5	0,5	0,5
15 – 19	5,8	1,3	1,0	1,0	1,0	0,9
20 – 24	7,6	1,8	1,6	1,7	1,6	1,5
25 – 29	8,2	2,2	2,2	2,3	2,2	2,0
30 – 34	8,7	2,6	2,8	2,9	2,9	2,8
35 – 39	10,3	3,1	3,7	4,3	3,8	3,6
40 – 44	11,8	4,0	4,7	5,4	5,6	5,7
45 – 49	15,7	5,4	6,0	7,8	7,4	7,3
50 – 54	18,5	7,9	8,7	10,3	10,9	11,3

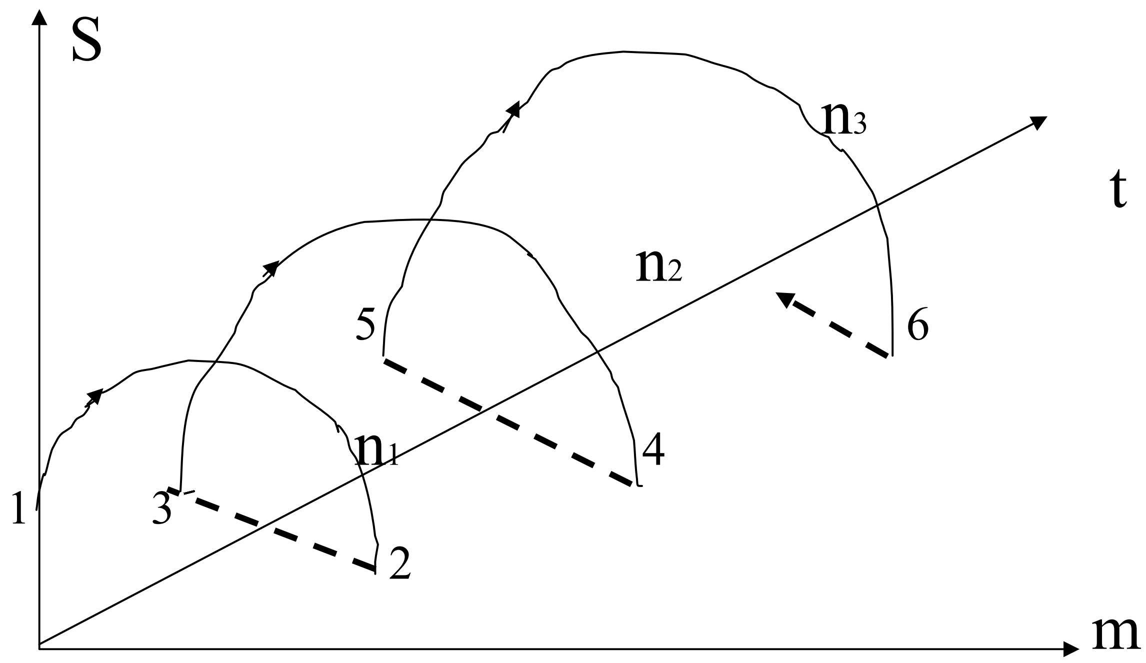

FIGURE 7. Transformation of developing system, n1 < n2 < n3, trajectory of system: 1-2-3-4-5-6-…

Fig.7 shows the evolution of system, the cycle of development begins in point 1, passes the maximum of the arbitrary coefficients number, and finishes in point 2, where the system must have the transformation, forgetting old restrictions, after new cycle begin in point 3 and etc. Maximum adaptability phenomenon makes it possible to explain different cycles in biological and socio-economical systems, for example, Kondratiev cycles. Each enterprise must be within maximum adaptability zone if we would like to retain this enterprise in changes flow. The sustainable development of systems can be only within maximum adaptability zone. The sustainable thermonuclear reaction is possible only within this zone.

For retaining the system within maximum adaptability zone, we have the different instruments – increasing the variables number, imposing new restrictions or removing the old ones etc. For example, we can joint different systems in an integral system to increase or decrease the adaptability of systems. So, from the two following systems

$$S1 = C_{n1}^{m1+1} \quad \text{and} \quad S2 = C_{n2}^{m2+1} \qquad (18)$$

we can joint them in imposing new restrictions, mcol, in view of obtaining the new collective system

$$\text{Scol} = C_{n1+n2}^{m1+m2+mcol}$$
(19)

where the adaptability of this new system can be either Scol > S1 + S2 or Scol < S1+ S2 depending upon concrete parameters. We can only see the collective, total effect.

7. CONCLUSION

The combinatorial simulation is a universal method for simulation and modeling. With it, it is possible to create a new model in different areas – in physics, chemistry, biology, psychology, etc. The linguistic basement of the simulation determines the universality of this method: the natural language is the universal sign system and the linguo-combinatorial simulation is thus the simulation method, perhaps, of everything. We have tried to show different levels of models. For reliability, each system must be then within maximum adaptability zone. It is necessary to carry out the verification of these models, but their structure is interesting for understanding complex systems. We investigated the system with argument correction and ultrastability system, which are the embedded systems in numerical control systems for machine tools and robot - manipulators. It is good illustration of linguo-combinatorial approach using for synthesis of different control systems.

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The automated system of monitoring and registration for technical and economic performance calculations of industrial enterprise

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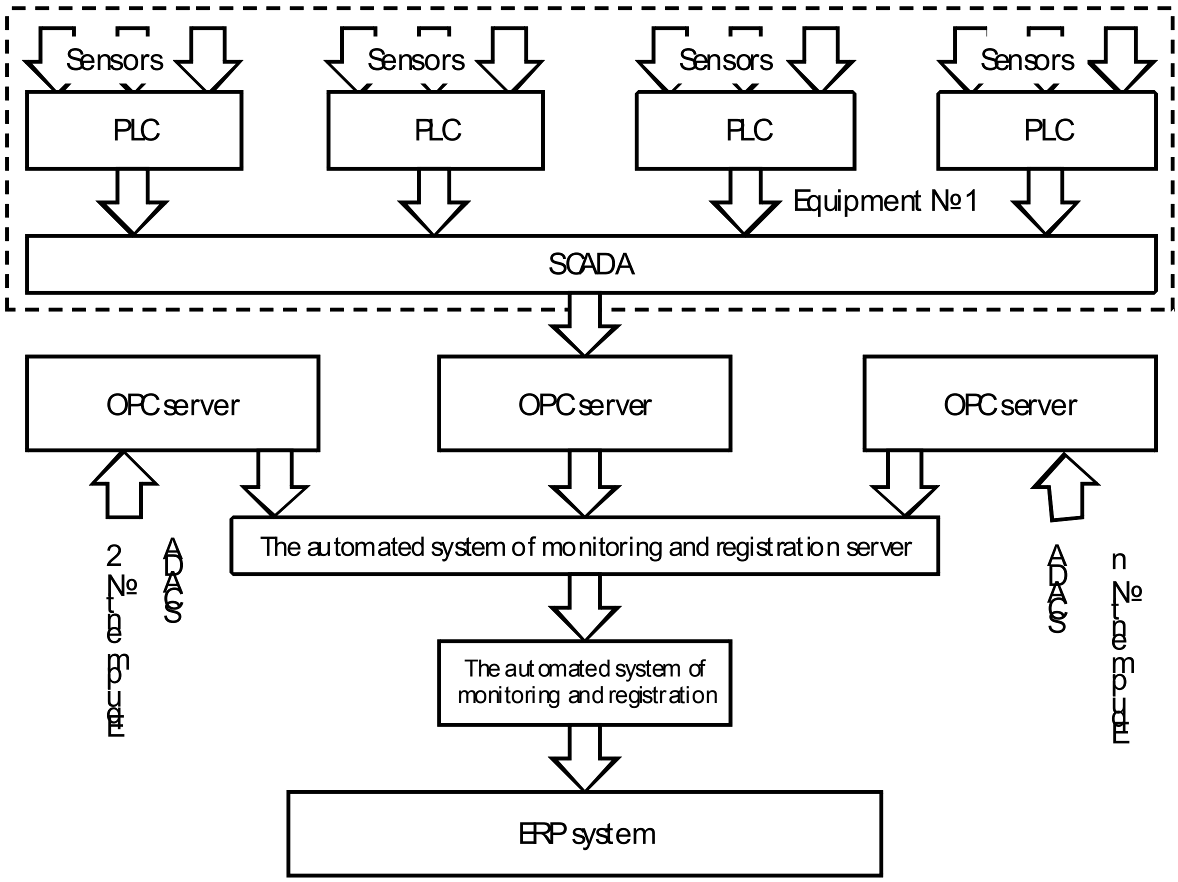
The automated system of monitoring and registration is used for recording and collecting current indicators of industrial enterprise, their storing, grouping and calculation for random period, for making reports to analyze the efficiency of industrial enterprise. It must correspond modern ergonomic demands, program platform and production process.

The automated system of monitoring and registration may be used at any type industrial enterprise (with previous adaptation of current algorithms), desirably with the system of automated collection and data handling from sensors. He must make detail calculations for given part of plant, taking into account indexes (including the state of common industrial enterprise equipment) in exact data volume, additionally entered in any convenient way, for example, periodically manually in the form of estimated constants and amendments. The program complex serves for calculation of non-operative technical and economic indicators. The picture below shows the way of interaction between SCADA system of industrial enterprise and automated system of monitoring and registration.



The automated system of monitoring and registration must support different databases for data collection. For this purpose, it is necessary to build in database drivers and to give a choice of the suitable driver to the user.

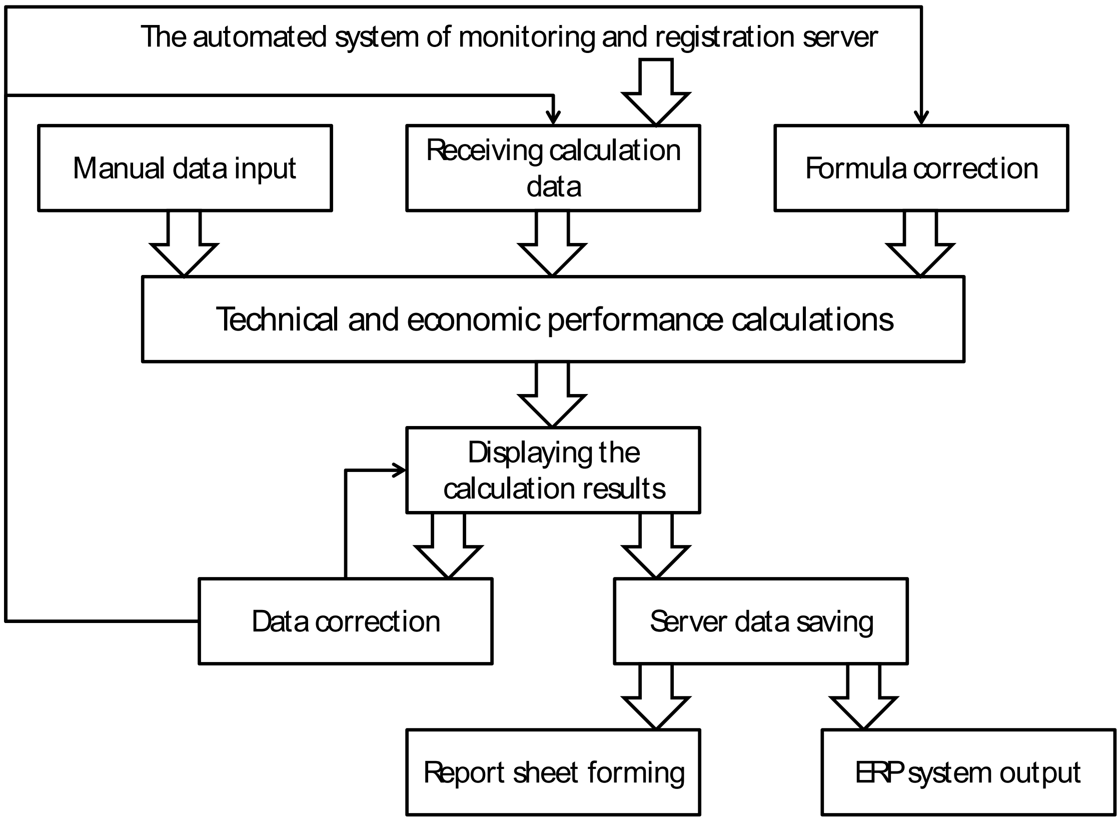
The information in the automated system of monitoring and registration should be collected from several sources:

- SCADA system – the main source of information;
- Manual values input without automated measurements.

It should be provided the reliability sign with two conditions (true/false) for entrance information and 'true' sign as default for unsigned information. The reliability sign, calculated by the rules, written in technical task, is assigned to all intermediate and final indicators while data handling.

The condition information, other periodically changed information (fuel structure values, conditions of common industrial enterprise equipment values, etc.), is entered and corrected manually.

Common structure of program complex shows below.



The module of operative and non-operative calculations, connected together through own database (installed in any convenient computer, for example, on an enterprise level server) should be provided in the program complex. The separation of functions between modules should be distributed to provide convenience and ergonomics for users.

From expediency and convenience reasons the operative calculations module (as a rule, but not obligatory) should be installed on PC, that is a part of SCADA, and provide the possibility of automatic schedule work. Being a part of SCADA the automated system of monitoring and registration server will be provided with round-the-clock work.

The non-operative calculations module can be installed and used on the workplace, located in any convenient place, for example in engineer's workroom.

The operative technical and economic performance calculations are defined at calculation stations of SCADA system. They can't be edited, contain only the data necessary for equipment operating. In most cases, operative technical and economic performance calculations define a plant performance while non-operative technical and economic performance calculations serve for an estimation of whole industrial enterprise performance and top management report forming.

In case of absence or incorrect measurements of sensors, that are necessary for calculation of all technical and economical characteristics, manual data input, their correction and saving of the edited data in the program complex should be provided.

Hourly technical and economic characteristics are important. It is necessary to display them in a user-friendly way before saving and archiving in a new database. If there are errors in calculation, engineer can visually see them on schedules and recalculate them before saving.

It is necessary to create several groups of users with various access rights in program complex:

- Administrators – users, who have full access to information and editors;
- Experience users – users, who have full access to information and formula editor;
- Engineers – users, who have full access to information;
- Guests – read-only users.

People (heads, analysts etc.), having access to calculation results (for example enterprise calculation database or SCADA calculation database), don't participate in maintains task and are not considered as users. They are classified as "information consumers" and concern to "Guests" group.

The interface and the system rights access to specific functions of the task must take into account the various authorities and activities of different user groups and, if necessary, hide unnecessary information.

While changing the equipment or connecting the new equipment, technical and economic performance calculations formulas will change. In this case an open interpreter must be integrated in the program. This openness will allow adding any interpreter language function, which can be used in the calculation. Also it will allow correcting formula by introducing the coefficients or their full change. The advantage of this method is in the possibility of writing formula by users customizing the program complex without involving professional programmers. Such an approach will reduce the automated system of monitoring and registration supporting costs.

The difference in the adjustment of values and manual input should also be indicated. Tuning is a change of values at a fixed value or formula for calculating them. Thus, after adjusting the calculation can be run in automatic mode. Manual input allows changing output parameters of already finished calculation by changing the input or output arguments. In this approach it is necessary to control the calculation each time and change the incorrect values of variables.

Automatic reporting will reduce time and labor cost of technical and economic performance calculations. Program complex can create templates for each report sheet. The reporting is created in the form of Microsoft Excel tables. Often it is necessary to create additional documents for the analysis of equipment work at the industrial enterprise. . User can also set parameters, create a template of report, form and divide it into convenient categories. The program must have a debugger for primary and daily adjustments of the program work. Primary tuning of program complex means exact industrial enterprise tuning, validation tuning means comparing manual calculation with automatic calculation with searching errors at each stage. Daily adjustment is searching variables, which meanings leads to incorrect results.

For a temporary substitution of the individual input parameters (fault sensor, non-typical operation mode of equipment, etc.) program complex should possess replacement function of any input values, such as a constant replacement, other parameters replacement, an expression with the given values replacement. Turning on/off option of parameters substitution should be organized and clearly convenient for the user. User must be possible to view replacement list. Enabling / disabling substitution must be written in own program log files.

The program must maintain a backup source of data, made up accounts and the received data. The latter will allow calculation of monthly technical and economic indicators based on a daily technical and economic indicators and annual on a monthly very fast. Also at any time it will be possible to show the results for any date and compare them with current data. Sorting support will make the process simpler.

In case of normal sensors mode and communication links, i.e. reliable data in SCADA system, program complex support timer calculation mode. Ability to manage type of calculation will help to set interval tasks. This feature can provide the opportunity to make full technical and economic performance calculations, for example, every hour, and the calculation of some important parameters - every half hour.

It is necessary to provide an automated shipment reporting on a local network or via the Internet in the parent organization, other departments, or ERP-system. So, program complex should contain network drivers.

Module type of program complex allows writing new add-ons without changing it structure.

In general, the automated system of monitoring and registration will automate the calculation of technical and economic performance calculations. Embedded examples of calculation (templates) will use the experience of other users and available forms of accountability that will lead to a reduction of the cost of product maintenance.

The finish goal is creating of program complex, oriented on technical and economic performance calculations, without connecting to exact industrial enterprise equipment. All calculated formulas, the list of input data, controlling the sequence of calculations, etc. must be configurable via the dialog forms, information tables, etc. The program must be embedded interpreter, providing an opportunity to write algorithmic formulas on simplified engineering language in the table sequence of calculations without help of programming specialist.

Optimization of Digital Wireless Transceiver Embedded System Built on Xilinx FPGA

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Abstract. FPGA is becoming the most popular technology for developing new wireless systems. It makes design flow easier to realize even in a small company or academic institution with limited resources (human and/or budget). But when system is ready to enter production stage some drawbacks may stop its further progress. A short description of the wireless transceiver project for mobile vehicles is presented. Drawbacks are highlighted. The most critical of them, that reduces market attractiveness, is cost. To reduce cost a decision has been made to replace expensive Virtex4 by cheaper Spartan3 FPGA. This required making some changes in architecture. But the most part of previously created software and firmware were reused in new design.

1 Introduction

Today we can see a rapid growing market demand of high-rate wireless communication lines for mobile vehicles: cars, trains, ships, even more for unmanned vehicles. This communication line could be used to create ad-hoc type networks. Typical requirements for wireless transceivers of this communication line are following:

- Data rate up to 10 Mbits per second for uplink (to base station or control site);
- Data rate up to 100 kbits per second for downlink (control commands to mobile vehicle);
- Traffic types: high resolution color video, voice, control commands and telemetry;
- Vehicle speed from 0 up to 1000 km/h.

Existing and successfully selling technologies such as WiFi and WiMAX were tried to solve the problem but they do not fit requirement and are unusable. Fast movement of communicating objects causes OFDM signal structure totally degraded. Mobile WiMAX is not stable for today also. These technologies are too complex and have excessive functionality for asynchronous managed or ad-hoc networks. Furthermore implementations of WiFi and WiMAX modules presented at the market do not allow measuring power and other characteristics overload baseband and network layer logic required for cross layer optimization.

Worth mentioning that flexible and energy efficient ad-hoc networks needed cross layer interaction, another words, tight communication between baseband processing and software implementing network management should be enabled.

The challenge we have stated to ourselves is to create wireless digital communication line for mobile vehicles with parameters and characteristics described above.

2 Existing System

There is a short description of currently existing wireless transceiver that was designed at our labs. The transceiver uses super heterodyne architecture that implemented in two parts: analogue front-end and digital baseband processing coupled with control unit based on embedded system with embedded Linux OS running on PowerPC 405 CPU (Fig.1).

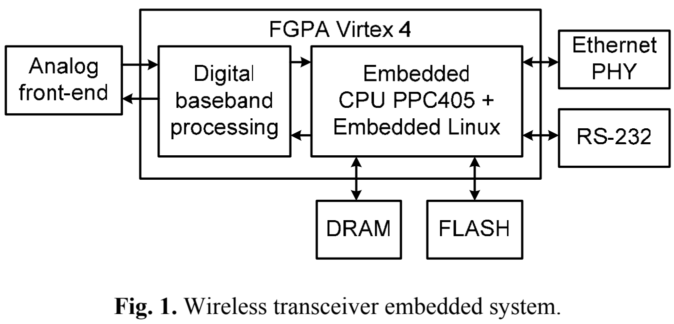

Fig. 1. Wireless transceiver embedded system.

Analog front-end made as digital-IF heterodyne architecture [1] and is presented on Fig.2. This architecture has some advantages and disadvantages:

Pros:
- only single channel ADC and DAC are used,
- quadrature modulation/demodulation is in digital domain,
- absence of quadrature imbalance due to demodulation made in digital domain.

Contras:
- high sample rates and dynamic range of AD/DA converters is required to digitize IF,
- extra band pass filtering stage (BPF2) for image rejection,
- reduced ability of miniaturization due to a big amount of external components.

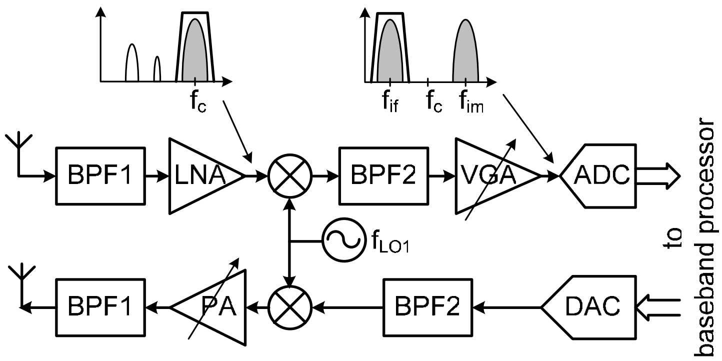

Fig. 2. Wireless transceiver analog front-end. f_c – carrier frequency; f_{if} – intermediate frequency; f_{im} – image center frequency; f_{LO1} – local oscillator frequency;

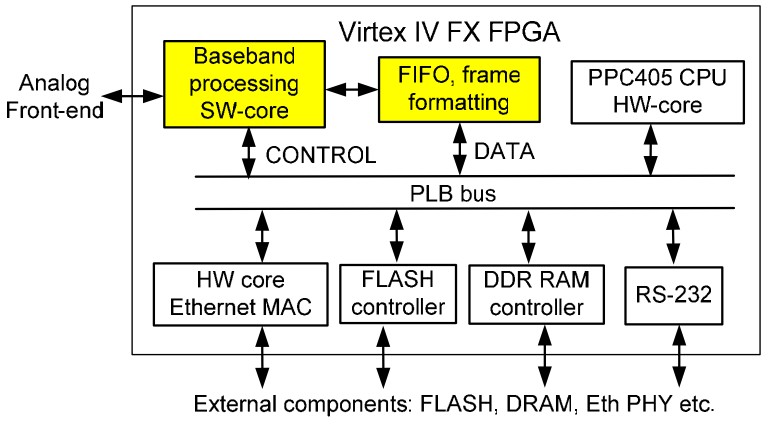

Fig. 3. Existing embedded system architecture for wireless transceiver based on Xilinx Virtex IV FPGA

Main drawback of described transceiver is its cost. Main part of the transceiver is a Virtex 4 FPGA. This FPGA is very comfortable for engineer and is as flexible as it allows changing design and debugging in a very simple way. However, the price of Virtex 4 is few thousand dollars and it really disappoints potential customer.

3 Modified Transceiver Architecture

Another one disadvantage of existing scheme is high sample rates of converters and additional bandpass filter stage for image rejection. The SAW filters are used in this architecture. They are expensive too and can not be used in reconfigurable SDR. Thus the decision was made to optimize transceiver by switching from digital-IF heterodyne architecture to digital baseband processing at zero-frequency (Fig.4).

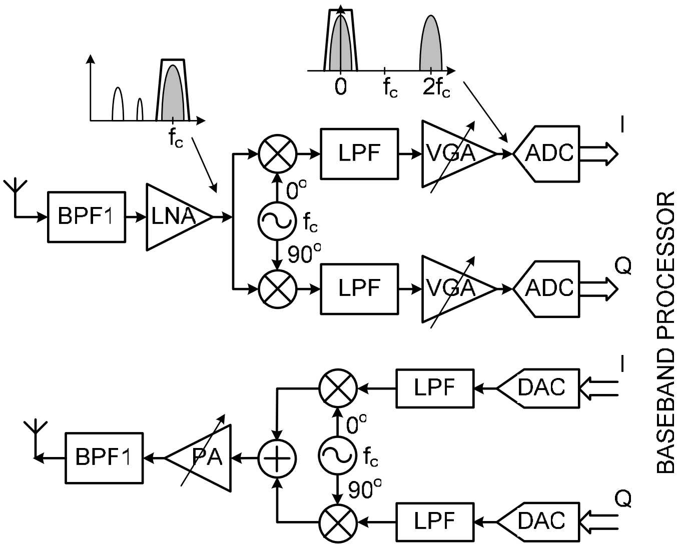

Fig. 4. Modified analog front-end architecture.

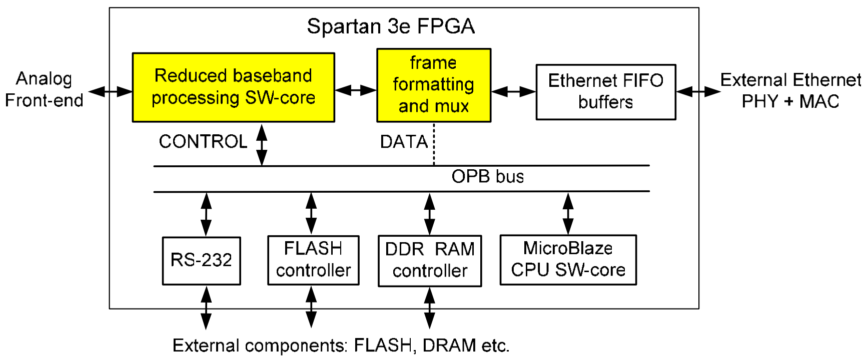

Fig. 5. Modified embedded system architecture for wireless transceiver.

As it can be seen after replacement of Virtex4 FPGA with Spartan3 embedded processor and peripheral bus are also changed from Power PC 405 hard-IP and PLB-bus to MicroBlaze soft-IP and OPB-bus. Fortunately there is Linux kernel and drivers for both architectures [2]. But we need to find proper Linux distribution for embedded Xilinx MicroBlaze CPU. A number of Linux embedded distributions are presented in Table 1.

Table 1. Embedded Linux Distributions supporting Xilinx FPGA embedded CPUs

Name	URL	Supported CPUs	License	Real-time
ELDK	www.denx.de	PPC only	free	soft
Petalinux	www.petalogix.com	MB only	free	?
BlueCat	www.lynuxworks.com	both	commercial	soft/hard
MontaVista	www.montavistalinux.com	both	commercial	soft/hard
WindRiver	www.windriver.com	both	commercial	soft/hard

As we decided too reduce cost we refused commercial Linux distributions such as BlueCat, MontaVista and WindRiver. PetaLinux is the best choice for us. Unfortunately it does not have any real-time support. Possible solution is to use another SW platform, Quantum Leaps [3], for example. But major code revision will be required even more totally new code should be created.

Currently a novel ad-hoc network architecture is under development. One of the challenges we faced is to reduce real-time requirements of this network protocol. To determine what degree of real-time is required the ad-hoc network imitation should be evaluated. This network can be created with cheap Spartan FPGA based development kits like “Spartan 3A Starter Kit” [4] with embedded PetaLinux on board.

4 Conclusions

Two different wireless transceiver architectures are described. The first one has critical drawbacks that blocked successful entering to the market. The main core of the transceiver is an embedded system built on FPGA. The solution is to replace more powerful but expensive Virtex4 by Spartan3 FPGA. Such replacement requires to make some architecture improvements that were found and now are being implemented. Also a novel methods and algorithms of ad-hoc networks managing can be verified on this platform. We expect that this architecture with novel ad-hoc networking will help us to start commercial producing and distribution.

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3. Quantum Leaps Innovating Embedded Systems, http://www.state-machine.com
4. Spartan-3A Starter Kit, http://www.xilinx.com/products/devkits/HW-SPAR3A-SK-UNI-G.htm

New Paradigm of Context based Programming-Learning of Intelligent Agent

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Abstract. In this paper we propose new paradigm combining concepts "programming", "learning" and "context" for usage in development of control system of mobile robots and other intelligent agents in smart environment. And we suggest architecture of robot's control system based on context and learning with natural language dialog. The core of this architecture is associative memory for cross-modal learning. Main features and requirements for associative memory and dialog subsystem are formulated.

1 Introduction

One of challenges in development of intelligent robots and other intelligent agents is human-robot interface. Two kinds of such known interfaces are oriented on programming and learning respectively. Programming is used usually for industrial robots and other technological equipment. Learning is more oriented for service and toy robotics.

There are many different programming languages for different kinds of intelligent equipment, for industrial robots-manipulators, mobile robots, technological equipment [1], [2]. The re-programming of robotic systems is still a difficult, costly, and time consuming operation. In order to increase flexibility, a common approach is to consider the work-cell programming at a high level of abstraction, which enables a description of the sequence of actions at a task-level. A task-level programming environment provides mechanisms to automatically convert high-level task specification into low level code. Task-level programming languages may be procedure oriented [3] and declarative oriented [4], [5], [6], [7], [8] and now we have a tendency to focus on second kind of languages. But in current time basically all programming languages for manufacturing are deterministic and not oriented on usage of learning and fuzzy concepts like in service or military robotics. But it is possible to expect in future reduction of this gap between manufacturing and service robotics.

On the other hand in service and especially domestic robotics most users are naive about computer language and thus cannot personalize robots using standard programming methods. So at last time robot-human interface tends to usage of natural language [9], [10] and, in particular, spoken language [11], [12]. The mobile robot for example must understand such phrases as "Bring me cup a of tea", "Close the door", "Switch on the light", "Where is my favorite book? Give it to me", "When must I take my medication?".

Using natural language dialog with mobile robot we have to link words and phrases with process and results of perception of robot by neural networks. In [13] to solve this problem the extension of robot programming language by introducing of corresponding operators was proposed. But it seams that such approach is not enough perspective.

In this paper we suggest novel bio- and psychology-inspired approach combining programming and learning with perception of robot based on usage of neural networks and context as result of recognition and concepts obtained by learning during dialog in natural language. In this approach we do not distinguish learning and programming and combine: a declarative (description of context) and procedural knowledge (routines for processing of context implementing elementary behavior) on the one hand, learning in neural networks and ordering of behavior by dialog in natural language on the other hand.

2 Proposed paradigm and architecture of intelligent agent

Our paradigm is based on relationships with other known paradigms and is shown in Fig.1.

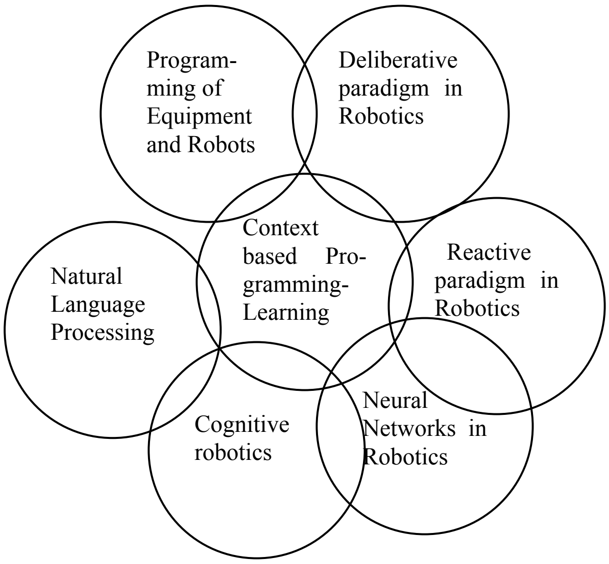

Fig1. Relationships between paradigm "Context based Programming-Learning" and other paradigms.

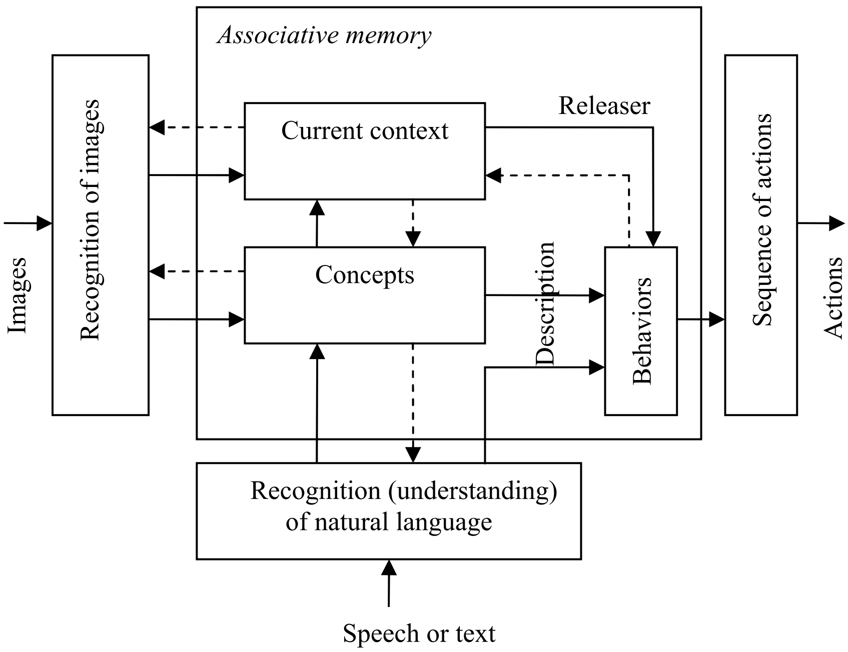

Fig.2. Intelligent agent functional structure oriented on context based programming-learning.

Concepts are associations between images (visual and others) and phrases (words) of natural language. In simple case we will name as concept just name of them (phrases). These phrases are using for determination of context in which robot is perceiving environment (in particular, natural language during dialog) and planning actions. We will name them as *context variables*.

Context is a tree of concepts (context variables) and is recognizing by sensor information and determining by dialog with user. Feedbacks between concepts/context and recognition of images/phrases mean that recognition is controlled by already recognized things.

Dialog with user aims to describe elementary behaviors and conditions for its starting. To start any behavior the system recognizes corresponding concept-releaser as in reactive paradigm of control system of robot.

Behavior is not influence on just actions but also on context. Moreover, behavior may be not connecting directly with actions in environment. In this case we have only thinking under context variables. And even when behavior is oriented on execution of actions it is possible to block this connection and in this case we have any simulation in mind sequence of actions (e.g., it may be mean as planning).

The associative memory must satisfy to follow requirements:

1) to allow usage of both analog and binary inputs/outputs,
2) to provide incremental learning,
3) to provide storing of chain of concepts (as behavior or scenarios).

The elementary behavior is similar to subroutine and contains sequence of actions adaptable to context variables which may be viewed as parameters of subroutine. Of cause, we need to use some primitives directly connecting with elementary actions and describing parameters of these actions or basic context variables. Connections between these primitives and words of natural language must be a prior knowledge of robot obtaining at development of robot or during a preliminary teaching by specialist. It may be simple language similar to CBLR, proposed by author for context based programming of industrial robots in [9], [14]. Feature of this language is absence of different motion primitives. There we have just one motion primitive. All other primitives aims to represent of context variables needed for execution of this motion primitive. To distinguish these primitives and usually using motion or geometric primitives we will call its below as *output primitives*.

3. Cross-Modal Incremental Learning and Associative Memory

Associative memory satisfied to above requirements may be based on hybrid approach and similar to Long-Short Term Memory (LSTM) [15] or table based memory proposed by author in [16].

Concept in Fig. 2 is more common thing as *context*. Concepts are introducing by dialog subsystem for determination of objects, events, properties and abstraction. But *context* consists of several concepts separated by three rules: 1) preliminary defined concepts (names) are using as names of “parameters” to utilize in elementary behavior (see 4); 2) some concepts are using as values of these “parameters”; 3) some concepts (releasers) are using as names of any events causing any behavior.

Dialog subsystem must provide robustness to faults in sentences. For it implementation may be used approach proposed by author in [17] and based on semantic networks combining with neural networks algorithms. This approach is oriented on fuzzy recognition of semantics. Dialog subsystem must provide attend the visual recognition subsystem to link word (phrase) with recognizing image. In this case the recognition subsystem create new cluster with center as current feature vector. And couple of this feature vector and word (phrase) is storing in associative memory for concepts. It may be as result of processing of follow sentence “This is table”. In contrast to that case when system processes sentence “Table is place for dinner” the new cluster is not created and associative memory is used for storing of association between words (phrases).

Thus associative memory must be able to store associations between both couple of symbolic information and couple of word (phrase) and feature vector. Besides concept storing in associative memory must have some tags: basic concept (preliminary defined) or no, name or value, current context or no. And every concept in associative memory must be able to link in chain with other ones. The order of concepts in chain may be defined by dialog subsystem.

4. Output primitives for mobile robot

Set of output primitives may be selected by different way. One approach to that is determination of enough complex behaviors, such as “Find determined object”, “Go to determined place” and so on. These actions may be named as *motion primitives*. Determined *object* and *place* must be obtained from context as value of corresponding context variable. And these variables may be viewed as another kind of output primitives: *context primitives*. In this case such actions must include inside any strong intelligence and ones limit capabilities to learn mobile robot. Another approach may be based on very simple *motion primitives* such as “act”, which may be just one. If we want to make capability to say anything by robot not only during dialog inside dialog subsystem we need introduce also at least one motion primitive “say”. All another *output primitives* are *context primitives* and ones define features of execution of primitive “act”. In other words ones are parameters of subroutine “act”. Examples of robot’s context variables are shown in Table 1

Table 1. Examples of context primitives.

Name of context primitive	Possible value	How this parameter influence on execution of motion primitive
Object	Name of object	May be used in action “say”
Internal state	Good, Bad, Normal	May cause motion to or from *Object*
Direction	Left, Right, Forward, Back	May cause corresponding turn depending on *Internal state*
Person	Name of person	May be used in action “say”
Obstacle distance	Far, Middle, Close	May be used in “act”
Obstacle type	Static, Dynamic	May be used in “act”
Speed	Low, Normal, High	May be used in “act”

5. Conclusions

In this paper we have suggested new paradigm combining programming and learning of mobile robot based on usage of context and dialog in natural language. Architecture of programming/learning of mobile robot was proposed. Some features of associative memory and dialog subsystem were formulated. Now this architecture is developing for simulated mobile robot and then to be implemented in real robot. This approach may be used for programming/learning of smart object in ambient intelligence [18].

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Minimum Tracking with SPSA and Applications to Image Registration

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Abstract. An application of simultaneous perturbation stochastic approximation (SPSA) algorithm with two measurements per iteration to the problem of object tracking on video is discussed. The upper bound of mean square estimation error is determined in case of once differentiable functional and almost arbitrary noises. Weak restrictions on uncertainty allow to use random sampling instead of full pixelwise difference calculation. The experiments show significant increase in performance of object tracking comparing to the classical Lucas-Kanade algorithm. The results can be generalized to improve more recent kernel-based tracking methods.

1 Introduction

Object tracking on video is an important problem for security surveillance systems. One of possible approaches to this problem is to look for a disparity vector h between object's locations in consequent frames I_n and I_{n+1} of the video stream. Disparity vector h can include object size and other properties as well. Well known algorithm of B. Lucas and T. Kanade [1] uses the functional of pixel-wise differences in consequent frames $F_{n+1}(x)= \sum_{p \in O_n} 1/w(p) ((I_{n+1}(x+p)-I_n(x_n+p))^2$, where O_n is a set of object's pixels p in the n-th frame, $\sum_{p \in O_n} w(p)=1$, x_n is a center of previous object's location, p represents the relative position of a pixel with respect to the object's center. The functional needs to be minimized to find real disparity $x_{n+1}^* = \operatorname{argmin} F_{n+1}(x)$. If the object's locations on consequent frames have significant intersection, then the algorithm of minimum tracking based on convex optimization can be applied to this problem. Stochastic optimization allows to use not all the pixels of the object's image O_n, but some random sample $R_n \subset O_n$ to compute the functional each iteration, because the convergence of the algorithm can be proved in this case. This property allows to decrease the amount of pixel-wise difference measurements per algorithm iteration. The experiments' results in the end of the paper show significant increase in the performance of the method. The same approach of randomization of the pixel sample combined with stochastic optimization can be used in more recent kernel-based object tracking algorithms, described in [2].

More specifically, in this article the convergence of the SPSA (simultaneous perturbation stochastic optimization) algorithm of stochastic optimization class will be proved in case of minimum tracking. The functional measurement $y_n=F(x_n,w_n)$ depends on two arguments, one of which is the actual point of measurement (in case described above, $x_n=h_n$) and the second one is the uncertainty presented by random variable w, $\int P(dw)=1$. The minimization is understood in average risk setting, such that $f_n(x) = E_w F(x,w,n) \to \min$.

In case of object tracking on video, we consider $F(x,w,n+1) = \sum_{p \in R_n} (I_{n+1}(x+p)-I_n(x_n+p))^2$, $f(x,n)= \sum_{p \in O_n} 1/w(p) F(x,w,n)$. The average risk setting is perfectly suitable here, since we would like to evaluate a pixel-wise difference on a randomly chosen subset of pixels. We demonstrate this approach in the example provided below, where the pixel-wise difference is computed only 2 times per iteration.

Problem of functional optimization arises in many practical cases. While in some cases extreme points could be found analytically, many engineering applications deal with unknown functional, which can only be measured in selected points with possible noise. In some cases functional itself could vary over time and its extreme points could drift. In this case problem setting could be different, depending on goals of optimization and possible measurements. In general, there are two different variants of a function behavior over time - it has a limit function, to which it tends when time goes to infinity, or there is no such function [3]. In this paper we consider the second variant.

Non-stationary optimization problems can be described in discrete or continuous time. In our paper we consider only discrete time model. Let *f(x, n)* be a functional we are optimizing at the moment of time n $(n \in \mathbf{N})$. In book [4] Newton method and gradient method are applied to problems like that, but they are applicable only in case of two times differentiable functional and $l < \nabla^2 f_k(x) < L$. Both methods require possibility of direct measurement of gradient in arbitrary point.

In real world measurement always contains noise. Sometimes the algorithms that perfectly solve the problem on paper do not provide good estimates in practical cases. Robustness is important in engineering applications. For problems with noise the Robbins-Monro and Kiefer-Wolfowitz stochastic approximation algorithms were developed in 1950s. The history of development of such algorithms is described in [5-8]. Common approach used in these algorithms can be formalized in a following way:

$$\hat{\theta}_{n+1} = \hat{\theta}_n - \alpha_n \hat{g}_n(\hat{\theta}_n), \qquad (1)$$

where is the sequence of extreme points estimates generated by algorithm, g_n - pseudo-gradient (replacing the gradient from Newton method). Pseudo-gradient has to approximate the true gradient. The important properties of algorithms described in this form are simplicity and recurrence. Because of these properties they are often applied in different areas.

Kiefer-Wolfowitz algorithm with randomized differences is also known as SPSA (Simultaneous perturbation stochastic approximation). Algorithms of this type with one or two measurements on each iteration appeared in papers of different researchers in the end of the 1980s [9-12]. Later in the text we will refer to this class of algorithms as SPSA for simplicity. These algorithms are known for their applicability to problems with almost arbitrary noise [8]. The measurement noise should be bounded and only slightly correlated with perturbation on each iteration. Moreover, the number of measurements made on each iteration is only one or two and is independent from the number of dimensions of the state space *d*. This property sufficiently increases the rate of convergence of the algorithm in multidimensional case ($d>>1$), comparing to algorithms, that use direct estimation of gradient, that requires $2d$ measurements of function in case if direct measurement of function gradient is impossible. Detailed review of development of such methods is provided in [7,12].

Stochastic approximation algorithms were initially proven in case of the stationary functional. The gradient algorithm for the case of minimum tracking is provided in [4], however the stochastic setting is not discussed there. Further development of these ideas could be found in paper [3], where conditions of drift pace were relaxed. The book [5] uses the ordinary differential equations (ODE) approach to describe stochastic approximation. It addresses the issue of applications of stochastic approximation to tracking and time-varying systems in a following way: it is proven there that when the step size goes to zero in the same time as the number of the algorithm's iterates over a finite time interval tends to infinity, then the minimum estimates tend to true minimum values. This is not the case here, since we consider the number of iterates per unit of time to be fixed. In this paper we consider application of simultaneous perturbation stochastic approximation algorithm to the problem of tracking of the functional minimum. SPSA algorithm does not rely on direct gradient measurement and is more robust to non-random noise than gradient-based methods mentioned earlier. The most closely case was studied in [6], but we do not use the ODE approach and we establish more wide conditions for the estimates stabilization. In the following section we will give the problem statement that is more general than in [3,4], in the third section we provide the algorithm and prove its estimates mean squared stabilization. In the last section we illustrate the algorithm, applying it to minimum tracking in a particular system.

2 Problem Statement

Consider the problem of minimum tracking for average risk functional:

$$f(x,n) = E_w\{F(x,w,n)\} \to \min_x, \qquad (2)$$

where $x \in \mathbf{R}^d$, $w \in \mathbf{R}^p$, $n \in \mathbf{N}$, $E_w\{\ \}$ - mean value conditioned on the minimal σ-algebra in which *w* is measurable.

The goal is to estimate θ_n - minimum point of functional *f(x,n)*, changing over time:

$$\theta_n = \operatorname{argmin}_x f(x,n). \qquad (3)$$

Let us assume that on the iteration we can do a following measurement:

$$y_n = F(x_n, w_n, n) + v_n, \qquad (4)$$

where x_n – is an arbitrary measurement point chosen by algorithm, w_n - random values, that are non-controlled uncertainty and v_n --- observation noise. Time in our model is discrete and implemented in number of iteration n.

To define the quality of estimates we will use the following definition [7]:

Definition. A random matrix (or vector) sequence $\{A_k, k > 0\}$ defined on the basic probability space $\{\Omega, \mathbf{F}, \mathbf{P}\}$ is called L_P-stable (p>0) if

$$\sup_{k>0} E|A_k|^p < \infty.$$

3 Algorithm

In this section a modification of SPSA algorithm provided by Chen et al [16] is described to illustrate the main idea of SPSA. It takes one perturbed and one non-perturbed measurement on each step.

Let perturbation sequence $\{\Delta_n\}$ be an independent sequence of Bernoulli random vectors, with component values +/- $1/d^{0,5}$ with probability 1/2. Let vector $\hat{\theta}_0 \in \mathbb{R}^d$ be the initial estimate. the algorithm tries to track a sequence of minimum points $\{\theta_n\}$ providing a sequence $\{\hat{\theta}_n\}$. Then the SPSA algorithm can be written as:

$$\begin{cases} x_{2n} = \hat{\theta}_{2n-2} + \beta\Delta_n, \; x_{2n-1} = \hat{\theta}_{2n-2}, \\ y_n = F(x_n, w_n, n) + v_n, \\ \hat{\theta}_{2n} = \hat{\theta}_{2n-2} - \frac{\alpha}{\beta}\Delta_n(y_{2n} - y_{2n-1}), \\ \hat{\theta}_{2n-1} = \hat{\theta}_{2n-2}. \end{cases} \quad (5)$$

Here α is a real constant defining the step size of the algorithm, which should be found according to the drift speed. The fact is derived from the theorems proved in [15,19] and presented in the conference proceedings volume as well. Another real parameter β defines accuracy of the derivative estimate.

The theorems from [15,19] show conditions needed for the theoretical convergence of the algorithm. However, often it is the case that the conditions are not satisfied or it is impossible to check them, but the algorithm is still converging to the true parameter value.

4 Application to Object Tracking

The application of the algorithm to the problem of object tracking on video is demonstrated by the following example. We took an image presented at the Fig. 1 as a second image, I_{n+1}. The object is a rectangle with a picture of butterfly, of size 208x120=24960 pixels. The image I_n contains the object in the lower-right corner. Vector h is 2-dimensional.

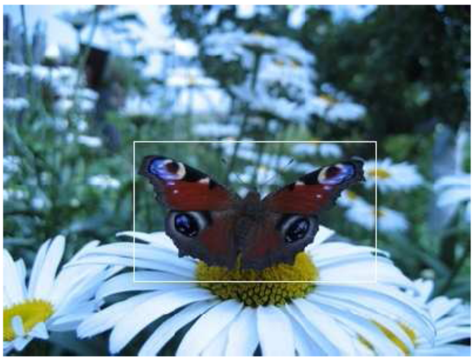

Fig. 1. Object tracking example.

The results are presented at the Table 1. We see significant increase in performance gained from the application of more advanced optimization technique.

Table 1. The results of the experiment: amount of pixel-wise difference calculation for Lucas-Kanade and SPSA-based algorithms

Characteristic	Lucas-Kanade	SPSA-based
Number of measurements per iteration	24960	2
Number of iterations	3	1201
Number of measurements	74880	2402

5 Conclusions

In our work we apply the SPSA-type algorithm to the problem of object tracking on video. The novelty of the approach comes from the use of stochastic optimization instead of standard pseudo-gradient technique to find a location of an object. SPSA does not require possibility of direct gradient measurement, needs only 2 function measurement on each iteration and once differentiable function. Drift is only assumed to be limited, which includes random and directed drift. It was proven that the estimation error of this algorithm is limited with constant value. The modeling was performed on a multidimensional case.

The results show the potential performance gains of using the SPSA-type algorithms for tracking of objects on video. Probably, more sophisticated algorithms based on optimization such as kernel-based methods of tracking [2] can also be improved by the same technique. Authors want to try such application in future.

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Information and telecommunication intellectual monitoring technology and system for complex technical objects under dynamic conditions in real time

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Abstract. The aim of the investigation is to develop methods, models and algorithms of synthesis and intellectualization of monitoring technology and system oriented to concurrent on-line user software assurance for all sorts of measuring information specifying states of complex technical objects under dynamic conditions in real time. This aim should be achieved by here suggested artificial intelligent information technology. The basis of this artificial intelligent information technology is flow computing models exploitable by state hipping (constraint programming) in real time and in territorially distributed computing network. At the same time each network node represents artificial intelligent agent. Furthermore, the problem of efficient information transmission between the complex technical objects and monitoring systems by means of contemporary wireless technologies is considered.*

1 Introduction

Many complex technical objects (CTO) are remotely controlled [1, 2, 3]. Operators (dispatchers) receive information about current CTO states in a form of telemetry. Complication of modern technical objects is resulted in expansion of their parameters to be measured and controlled. Today the number of such parameters can achieve several hundreds or thousands for various classes of technical systems [4, 5]. Usually CTO state monitoring is not automatized completely. Thus, operators receive semantic information about some elements of CTO rather than information characterizing integral CTO state. To estimate CTO state the operators should be able to analyze various context conditions of interaction between CTO elements and subsystems. There are no universal methods and technologies for solution of the above-mentioned problems [6, 7]. Existing program systems for gathering, processing, and analysis of CTO telemetry usually depend on characteristics of particular control objects and is not adaptable to undesired alteration of objects' structure. The methods and tools for construction of monitoring algorithms and systems are very specific and can be used in narrow domains. The problems of CTO monitoring were investigated rather thoroughly in USA and in Russia (former USSR), first of all for aerospace and electric power systems [7]. The most important results were received in this domain. However, semantic interpretation of integral CTO state remains the prerogative of operators.

Other feature of modern monitoring system for CTO (MS CTO) is the changeability of their parameters and structures as caused by objective and subjective reasons at different stages of the MS CTO life cycle. In other words we always come across the MS CTO structure dynamics in practice. Reconfiguration is a widely used variant of the MS CTO structure control. Reconfiguration is a process of the MS CTO structure alteration with a view to increase, to keep, or to restore the level of MS CTO operability, or with a view to compensate the loss of MS CTO efficiency as caused by the degradation of its functions. But, unfortunately, now MS CTO reconfiguration is not tied in with monitoring and control processes [2, 8 9].

So the following main problems complicate formalization of state-monitoring process and systems under dynamic conditions now: firstly, the rules of CTO interaction cannot be discovered and described in a simple way, secondly, there are no universal methods of interaction representation for a broad class of objects and finally, there are no universal methods and models of MS CTO optimal reconfiguration under dynamic condition [8,10]. We consider that description of monitoring procedures and system should be based on system methodology and modern conception of intelligent information technology in order to fit various classes of CTO. This description

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must be clear to different specialists implementing general rules of monitoring to particular objects. Our investigation contributes to a solution of the fundamental problem lying in synthesis and intellectualization of monitoring and control processes for complex technical objects under dynamic conditions via multiple-model complexes and multi-criteria approaches.

So the first aim of our investigation is to develop methods, models and algorithms oriented to concurrent on-line user software assurance for all sorts of measuring information (information fusion) specifying states of complex technological process (situation assessment) at all phases of complex technological process life cycle and control function in real time. The second aim of our investigation is a development of models, methods and algorithms for real-time monitoring system reconfiguration under the presence of structure degradation.

Additionally, we develop simulation and analytical models as well as conduct test-bed experiments for the analysis of the efficient monitoring information transmission between the MS and CTO. We believe that contemporary wireless communication technologies should be used for this purpose, especially for the cases when CTO are located distantly and in the regions difficult of access from the MS CTO. Due to the requirement of monitoring in real-time, communication technology should be chosen and configured appropriately in order to provide desired time-probabilistic characteristics of the transmission. This problem becomes challenging in wireless environment, where characteristics of the communication channel may significantly vary in time. Therefore, the third aim of our investigations is to conduct performance analysis and optimization of contemporary wireless protocols and standards.

2 Investigation overview and related work

Analysis of a market dealing with modern software complexes oriented to monitoring automation for the states of complex technological processes shows that the existing software complexes have narrow application scopes strictly specified by controlled objects; they also have limited capacities for adaptation to environmental disturbances. This is why there exist many monitoring applicable software complexes having contiguous functionality and differing in organizational methods of computational processes, and in used operational environment. As an example, three directions in practical implementation of analyzed software complexes could be mentioned [4, 6, 11]:

1. Widely applied real time dynamic expert systems like G2 (software firm Gensym, USA), RT Works (software firm Talarian, USA), COMDALE/C (Comdale Techn., Canada), COGSYS (SC, USA), ILOG Rules (ILOG, France) are worth mentioning.

2. The results received through application of a so-called theory of unfinished computing based on constraint programming methods and the theory of multi-agent artificial intelligent systems. The following software packages demonstrate some advantages of this approach: integrated software product SPRUT (OCTORUS) and intelligent mathematical problems solver UniCalc.

3. The third direction incorporates so-called data fusion and control systems like SCADA-systems (Supervisor Control and Data Acquisition – data fusion and control system, operator's interface, etc.). Well known products: Genesis, IsaGRAF, TraceMode could be good examples of this development line.

A thorough study of theoretical results showed that there exists a great number of publications in the area of measuring information processing and analysis methods, on the other hand, research in the areas of design automation for monitoring software complexes, development of techniques allowing to arrange for parallel processing and analysis of measuring information in computing environment with changing structure are poorly reflected in literature [12, 13, 14]. The impact of types and structures of the processed information on the composition and structure of the considered software complexes is also not well investigated. The above-mentioned circumstances become important if to account for the fact that a certain successful experience in practical realization of software complexes for monitoring of states of complex technological process is based upon the better solutions of structural and functional as well as organizational problems dealing with the synthesis of software complexes. However, experimentally received positive results in software complexes for monitoring creation and implementation are of the heuristic nature and are based on intuition and experience of developers; their elaboration also requires time-consuming, labor-intensive experiments at the synthesis stage. Moreover, the existing methodology and software do not meet certain requirements for embedded special software of geographically distributed real-time complex technological systems with variable structures [14].

Development of flow-oriented knowledge-representation models, methods, and algorithms for monitoring and control of objects and for reconfiguration of monitoring system plays the important role in decision of the main problems of synthesis and intellectualization of monitoring technology and system for complex technical objects under dynamic conditions in real time. This task includes the following subtasks:

- development of methodological basics for accumulation and use of ill-formalized knowledge about states of complex technical objects under "rigid" constraints (for example, real-time operation mode and recurrence of computational processes) applied to both process of knowledge accumulation and process of state estimation; development of methodological basics for structure reconfiguration of objects and of monitoring system (first line of investigation);
- development of model-and-algorithmic basics for analysis and synthesis of reconfigurable monitoring system (second line of investigation);
- development of new information technology for creation and maintenance of monitoring software and software prototype; approbation of the technology in typical application domains (third line of investigation).

As a relatively separate subtask we emphasis the problem of performance evaluation of wireless communication protocols by means of analytical models, simulations and test-bed experiments. We consider the following contemporary wireless technologies IEEE 802.11 Wi-Fi, IEEE 802.16 WiMAX, IEEE 802.15.14 ZigBee etc. Our objective is to identify, design, test and evaluate wireless network technologies and architectures, which are able to interconnect CTO in an energy-efficient, secure, robust, and powerful way to MS CTO under dynamic conditions to guarantee real-time stable monitoring process. Mechanisms based on the conceptions of cognitive network for stable and energy-efficient operation of wireless mesh and sensor networks are required.

Cross-layer design conception is becoming increasingly important in wireless networks. They abuse the traditional layered approach by direct communication between nonadjacent layers or distribution of internal information among layers [21]. Cognitive radio is a paradigm in which either a network or a wireless node changes its transmission or reception parameters to communicate powerfully avoiding interference [22]. The cognitive radio concept is extended also to higher protocol layers, what results in the introduction cognitive networks [23]. A cognitive network can recognize current network conditions and adapt accordingly. The network can learn from these adaptations and use them to make decisions in the future.

Therefore, the forth line of investigations is the development of new protocols and architectures based on the above paradigms as well as performance evaluation of internationally standardized protocols.

3 The results of investigation

Within the first line of investigations the following scientific and practical results have been obtained by now.

It was established that the change from an automated processing of measuring information to a computer-aided analysis of received materials involves semantic aspects of data representation in place of syntactic ones. Thus, the information about control objects should rather be regarded as a set of interrelated parameters jointly characterizing objects' technical state than a simple collection of measurements. This provided for a conclusion that the metric-space concepts, typically used in simple monitoring problems, are weak and not suitable for our purposes, hence more general constructions should be used.

It was proved that the parameters of objects' technical states can be described via a system of open sets forming a base of topology. It was assumed that the set of parameters has a topological structure. Thus a system of neighborhoods (meeting the axioms of topological spaces) was established for each element. The notion of a technical state was worked out. By the technical state we meant an abstract collection of data including whole information both about object's current attributes and the state of computations within the monitoring process. This view lets optimize computations in order to receive monitoring results in real time. The following basic statements were proved: the whole set of technical-state parameters constructed trough the proposed model of knowledge representation is a lattice or a lattice ordered set; if the set of technical states have the greatest element and the least element (defining the initial data and the results correspondingly), then a complete lattice (an algebra over the set) can be formed via a construction of additive and multiplicative lattices; necessary and sufficient conditions for topology base existence were obtained for the set of technical parameters. The last result is very important, as the constructed topology is used for whole description of possible technical states and for planning of states analysis (for construction of computational scheme).

Moreover w*ithin the first line of investigations* we have been obtained the following the results [18, 19, 20]:

Formal description of all possible kinds of controlled states (assessed situation) accounting for their adequacy to actual actions and processes on controlled object caused by application of different mathematical apparatus for various functional objects. Multi-model formalization intends for describe actions and processes on the controlled object;

New integrated methods of program synthesis for automatic analysis (AA) of measuring information (MI) about CTO states were worked out. These methods, as distinct from known ones, give an opportunity of, firstly, interactive intellectual processing of data and knowledge about CTO states for different physical properties (for example, functional parameters, range parameters, signal and code parameters, and integrated parameters) and for different forms of states description without reference to their physical features and, secondly, automatic generation of alternative program schemes for MI analysis according to the objectives of CTO control under the presence of changing environment;

New algorithms of automatic synthesis of AA MI programs were proposed for poly-model description of monitoring processes via attribute grammars, discrete dynamic systems, and modified Petri nets. Applying of polytypic models resulted in adequate adaptation of the algorithms to different classes of CTO. Another distinguishing feature of the algorithms lied in application of underdetermined calculation and constraint-driven programming and provided that CTO states could be estimated rather adequately even if some parameters were omitted and the measuring information was incorrect and inaccurate;

A general procedure of automatic (computer-aided) synthesis of CTO monitoring programs was developed. This procedure includes the following steps.

The 1st step. Description of conditions and constraints for the problem of AA MI programs synthesis via a special network model connecting input data with goals. An operator (he need not be a programmer) uses a special problem-oriented language to execute this step.

The 2nd step. Automatic existence analysis for a solution of AA MI problem that is defined via a formal attribute grammar.

The 3rd step. If the solution exists then the alternative schemes for AA MI programs are generated and implemented in a special operational environment (problem solver of the CTO monitoring system).

The main advantage and substance of the proposed procedure is simple modeling of MI sources (models generation) that can be performed by a non-programming operator in the shortest time and the real-time implementation of the intellectual methods and algorithms of MI processing and analysis for arbitrary structure of the measuring information.

The proposed methods of monitoring automation and modeling let switch from heuristic description of the telemetry analysis to a sequence of well-grounded stages of monitoring program construction and adaptation, from unique skills to unified technologies of software design. These methods are based on a conclusion that a functional description of monitoring process is much less complicated than detailed examination of software realizations. Consecutive specification of software functions is the ground of technologies to be used for creation of monitoring systems. The suggested technology of continuous design process includes such well-known phases as new proposal phase based on special operational environment [18, 19, 20].

Within the second line of investigations the following scientific and practical results have been obtained by now [10].

System analysis of the ways and means to formalize and solve the problem of the control over structure dynamics of monitoring system (MS) servicing CTO under changing environment was fulfilled. It was shown that the problems of structure-functional synthesis of monitoring systems and intellectual information technologies as applied to complex technical objects and the problems of CTO structure reconfiguration are a special case of structure-dynamics control problem. Other variants of structure-dynamics control processes in MS are: changing of MS objectives and means of operation; reallocation of functions, tasks, and control algorithms between MS levels; control of MS reserves; transposition of MS elements and subsystems.

The basic concepts and definitions for MS structure-dynamics control were introduced. It was proposed to base formulating and solving of the structure-dynamic control problems on the methodologies of the generalized system analysis, the modern optimal control theory for the complex systems with reconfigurable structures and artificial intelligence. The stated methodologies find their concrete reflection in the appropriate principles. The main principles were marked out: the principle of goal programmed control, the principle of external complement, the principle of necessary variety, the principles of poly-model and multi-criteria approaches, the principle of new problems.

During our investigations the main phases and steps of a program-construction procedure for optimal structure-dynamics control in MS were proposed. At the first phase forming (generation) of allowable multi-structural macro-states is being performed. In other words a structure-functional synthesis of a new MS make-up should be fulfilled in accordance with an actual or forecasted situation. Here the first-phase problems come to MS structure-functional synthesis.

At the second phase a single multi-structural macro-state is being selected, and adaptive plans (programs) of MS transition to the selected macro-state are constructed. These plans should specify transition programs, as well as programs of stable MS operation in intermediate multi-structural macro-states. The second phase of program construction is aimed at a solution of multi-level multi-stage optimization problems.

One of the main opportunities of the proposed method of MS SDC program construction is that besides the vector of program control we receive a preferable multi-structural macro-state of MS at final time. This is the state of MS reliable operation in the current (forecasted) situation. The combined methods and algorithms of optimal program construction for structure-dynamics control in centralized and non-centralized modes of MS operation were developed too.

The main combined method was based on joint use of the successive approximations method and the "branch and bounds" method. A theorem characterizing properties of the relaxed problem of MS SDC optimal program construction was proved for a theoretical approval of the proposed method. An example was used to illustrate the main aspects of realization of the proposed combined method.

Algorithms of parametric and structural adaptation for MS SDC models were proposed. The algorithms were based on the methods of fuzzy clusterization, on the methods of hierarchy analysis, and on the methods of a joint use of analytical and simulation models

The SDC application software for structure-dynamics control in complex technical systems was developed too.

Within the third line of investigations the following scientific and practical results have been obtained by now: the pilot versions of computer-aided monitoring system (CMS) for CTO states supervision (in space systems and atomics) work in network of IBM/PC-compatible computers; it uses special operational environment [18, 19, 20], real-time database management system, multi-window interface, and programming language C/C++.

The prototypes of CMS belong under the class MMI/CACSD/SCADA/MAIS (man-machine interface/ computer-aided control system design/supervisory control and data acquisition/ multi-agent intellectual system).

Within the forth line of investigations the following scientific and practical results have been obtained by now: sufficient number of different analytical and simulation models for contemporary wireless networks, methods to compute time-probabilistic characteristics and to optimize the performance of these networks (e.g. [24], [25]).

4 Conclusion

Suggested intelligent information technology will allow reducing costs of complex technological process underlying the elaboration of a system for monitoring and control of states of complex technological process, and will facilitate significantly its further modification. At that systems for real time monitoring of states of complex technological process acquire principally new qualities. Particularly they allow monitoring in real time the states of complex technological process characterized by great number of measured parameters under structure reconfiguration of the controlled objects. The proposed information technology rises the automation level of complex technological processes control, increases possibilities of control of objects under degradation of their structures, improves reliability and efficiency of control processes, increases possibilities of early detection of various technical faults as well as timely prediction of catastrophes allowing to make right decision and to undertake appropriate prevention measures. The proposed approach to the problem of MS structure reconfiguration control in the terms of general context of MS structural dynamics control enables the following: common goals of MS functioning can be directly linked with those implemented (realized) in MS control process; a reasonable decision and selection (choice) of an adequate consequence of problems to be solved and operations to be fulfilled related to structural dynamics can be made (in other words, MS control method can be synthesized and developed); a compromise(trade-off) distribution of a restricted resources appropriated for a structural dynamics control can be found without additional expenses.

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Problems of abstract representation of embedded systems at high-level stages design

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Abstract. Conditions and nature of embedded systems design demand today serious revision of techniques and technologies of their creation. To a considerable degree artificial dividing the computer system into hardware (HW) and software (SW) components and, moreover, allocation of the SW industry in a separate sphere only aggravates the situation. One of the ways of this problem decision can be usage of architectural abstractions system directed on the creation of an integrated design space of the computational process organization in which for the computer system a representation of traditional HW and SW implementations becomes unified, there are obviously functional and nonfunctional aspects of designing and the tool component is integrated.

1. Introduction

Impetuous growing requirements for embedded systems (ES) forces developers to improve actively design methods and tools. The ES share with a complex internal organization actively grows that becomes apparent in the multiprocessor heterogeneous architecture, the distributed character of calculations, a wide range of computational resources potentially accessible to the developer. The significant part of the most complex ES has the distributed organization and refers to a category of network embedded control systems (NECS).

It is necessary to consider as the key feature of the ES creation the necessity of the complex approach to the designing, covering practically all levels of the computer system (CS) organization. The developer really faces with the necessity to analyze the large number of various potentially-possible variants of the architectural organization both a target system created, and a project infrastructure as a whole (it is a matter, first of all, of design technologies and tools). An experience of development of microprocessor systems convinces of the necessity of joint (parallel) designing HW and SW parts of the system that in practice within the limits of traditional technologies is realized extremely seldom.

From a space of the limited set of canonical structures and circuit decisions designers can today already move in a space of practically free architectural design.

Change of the situation on a background of growing needs in ES and requirements to them demands overcoming crisis of designing, which becomes apparent in insufficient speed of creation and bad quality of a product. The disturbing state in the field of ES design is marked by all leading experts of this sector of informatics and computer engineering [6, 13, 12].

Top priority importance in overcoming the crisis has the further development of methods and means of high-level (architectural) ES design. Still there are opened questions of creation effective CAD of complex (through all stages) design of ES.

2. Problems of embedded systems design

Custom microprocessor systems design. The hands-on experience of ES design bases on the fine-tuned technological methods and tools and consists in a choice of one of canonical computational platforms on the basis of which due to a program superstructure the applied task is solved. Other variant is also applied: computer platform is being chosen and along with upwards completion updating downwards modification is carried out. Such way is used less often because of high labour-intensiveness.

The first problem, which ES developers face with, consists in the following:

– existing programming languages assume the description of a task for idealized virtual (language) machine;
– the compiler maps this language machine on the real machine, bringing the certain restrictions and leaving out many important technical features of the executive machine realization;
– there is no uniform system of the language machine description, the compiler and the executive machine.

The second problem - the large number of tasks, especially in the field of control systems of physical objects, which badly keep within the scheme of implementation on the basis of canonical computer platform with a program realized superstructure. Such tasks demand specialized computer platform, for example, with a high degree of parallelism and specialization of operational blocks, and in this case efficiency of the traditional scheme of designing can appear to be inadmissibly low.

The third problem is connected with constantly growing volume of necessary ES designing. Particularly the disunity of descriptions noted above, prevents from a reuse of the developed components (hardware blocks, programs, realizations of algorithms).

State and perspectives of high-level ES design. The basic directions of researches for overcoming the listed problems lay in the field of perspective techniques of high-level (system) ES design (HLD). For these directions the following design levels are determined by specialists:

- *mission (or operational, or specification) level* - development of the system behavior script in the form of «the executed system specification/model»; modeling of an external system environment.
- *architecture (or macroarchitecture, or performance) level* - formation of system architecture, irrespectively to a way of realization: the analysis of architecture for conformity with functional and nonfunctional requirements/restrictions.
- microarchitecture (or functional) level or (especially with reference to development digital VLSI and SoC) - electronic system level (ESL) - a choice of a way of realization of architectural model components is carried out, algorithms, interfaces are being developed, specifications and the environment of verification are prepared for the implementation stage of the system.

General problems of accessible methodologies, tools and environments of designing (frameworks), inducing to the certain choice of directions and development of research works in the field of system designing for ES are fixed below:

- particular (especially nonfunctional) aspects of designing are considered separately within specialized entire system models: power consumption, reliability, information protection, etc. It is necessary to develop such structure and the form of architectural components description, which obviously will offer aspect estimations (weights) that are reflected in the concept of the architectural aggregate (AA), which is explained further in this article.
- explicit priority of the functional aspect at an architectural level is held true. The nonfunctional aspects either play a role of auxiliary (secondary) criteria of the project, or many of them are not taken into consideration at all. But in general case for ES functionality not always appears the most higher-priority requirement. These issues should be taken into consideration in the tool development process of the system architectural description.
- a set of variants of the microarchitecture realization is limited by HW/SW of the runtime phase. Search of project decisions at a variation of Design/Run Time ratio, consideration of various levels of architecture virtualization, integration of a tool component in most cases within the limits of the system designing is not carried out.

The decision of the specified problems is probable through integral perception of target system space project, and project infrastructure. This assumes integrated space creation of ES design in terms of computational abstractions (computational mechanisms, functional converters, virtual machines, architectural aggregates), and, accordingly, a new model of the design process. The necessary conditions of the creation of such space are:

- unification of hardware/software treatments;
- ES representation within the limits of possibly a lot of design steps (from the beginning) without dividing on HW/SW realization;
- using «aspect technologies», which allows to track explicitly transformations of key ES components in the design process (functionality, tool, reliability aspect, and others), and to consider during designing factors, which explicitly are not present in specification requirement, but seriously influence on results (tool aspect, the possibilities of the team, accessible technologies, taking into account a groundwork and team interests, and others).

3. Integrated design space of embedded systems

Computational process organization. The concept of computational process in ES occupies the central position. We consider, that *process of the computer system design* as the object solving a specific target of the user, it is reasonable to consider as *the organization of a computational process in space and time in the restrictions specified by the technical requirements*.

Tools of the realization of computational process are:
- design concepts (platform-oriented, model-oriented, actor-oriented, and others);
- computational models (models of computation - MoC);
- virtual machines;
- platforms (computational, tool, protocols of interaction, and so on);
- mechanisms (as technical decisions from various areas-aspects in an abstract representation);
- element base (as a set of mechanisms realizations).

The carrier of a run-time component of computational process is ES architecture - ES representation with a minimum refinement level, showing all its unique technical decisions in relation to the computational process organization. Depending on the one to whom given ES architectural representation is addressed, the set of "known" elements can essentially differs.

Embedded systems programmability. Modern ES is accepted to name SW-dominated systems, which are created on the basis of «highly programmable platforms» [1, 13] that is caused by inseparable connection of a computational platform and an applied level.

The most part of modern element base is programmed or configured. In whole it expands the developer potentialities, simultaneously significantly increasing risk of an error and a labor intensiveness of low-level design. The range of system organization levels, which the developer is forced to cover for the qualitative hardware control, is extremely wide. Attempts to minimize the low-level design volume in the ES field didn't have any success, as imposing on the developer in this case the limited number of configuration patterns significantly worsens design quality.

Models of Computations. There are various MoC definitions, which can be divided into two directions. One of them [5, 7] is based on the desire to be limited by use of simple (by «a principle of action») models of one (abstract) level (model of data-flows, FSM models, models of synchronous processes, and others). Another direction assumes a formalization of computer devices representation as virtual machines irrespective of their complexity and a belonging to the computational hierarchy level.

In a context of integrated design space MoC is interpreted as *mathematical model showing to the user computational possibilities and rules of the computer device use*.

Virtual machines. *The virtual machine is understood as the computer device, for which rules of behavior are certain* (for example, command system, conditions of command and data input, reception of the result, a rule of process synchronization), *allowing unambiguously to describe algorithm of the task decision*. The virtual machine description shows only external properties of the computer device and the rule of its use, not concerning of its organization. A principle of extraction of virtual machines is powerful technological instrument, allowing to structure the design process, to provide portability and a reuse of groundwork, to get scale project decisions.

Computational platforms, mechanisms, element base. A *computational platform* formalism takes the important place in computer engineering. In the context of the integrated design space the *platform can be considered as unity of "external" and "internal" representation [any] of a functional-completed and a functional-significant object in ES structure.*

The computational mechanism as an abstraction solving a particular task plays a role of the «building block» in the computational process organization. The range of functional complexity of computational mechanisms is limited only by developer imagination that creates serious problems for formalization of their representation and operations on them [8, 10].

The element base is considered as a set of mechanisms realizations. It is necessary to expand this concept by inclusion in it a set of objects (physical, informational, technological, and others), which belong to all aspects of the design space.

Design/Run Time Space is effective means of ES analysis. In many respects a template type of nowadays ES designing uses in the majority of cases empirical decisions. Chains of computational process realization include such elements, as compilers, interpreters, virtual machines, hardware programmed processors, special functional hardware blocks, and many other things. The developer, often not consciously, distributes elements of the computational process inside of tool (design-time) and performing (run-time) phases of the project. The analysis and the realized choice of decisions in both phases of ES existence allow to increase significantly quality of designing.

4. Aspect technology bases of embedded systems design

Today Aspect-Oriented Software Development was formed as an independent direction in programming [14]. Abstractions of aspect representations have actively started to be used in ES design [2], however, this direction is in a formation stage.

The authors demonstrate below the use of the aspect ideology in a combination with the system of architectural abstractions in ES design.

On the top level of aspect technology the developer deals *with project architecture* and *product architecture* (ES designed), which contain all components respectively of design process and product created. We shall name such components as *aspects of designing* (or simply aspects).

Let's define *ES architecture* as a *set of ES conceptual aspects of some refinement level, completely representing designed system for the given level of consideration*. In the list of conceptual ES aspects, besides traditional structural and functional elements reliable, constructive-technological, power assumption, conditions of maintenance, tools, reuse, organizational-economical, documental, and others elements are included.

Certain elements of architectural representation we shall name *aggregates*. Thus, *the architectural aggregate* (AA) represents a base element of the system design process.

AA, describing not all aspects, is named an *abstract.* Complete AA (describing all project aspects), which cannot be realized now by a concrete team in an element base accessible to it, we name *virtual*. It mast be said, that AA virtuality can be determined not only by objective limitation of the element base, but also by subjective restrictions, such as requirements specification, predilections, and interests of the team. Accordingly, complete AA for which there are all necessary conditions of realization, we shall consider realizable.

The system model expressed in AA terms, we shall name *architectural model* or *A-model* of the system. A-model can be abstract, virtual and realizable.

Abstract A-model contains at least one abstract AA. The model essentially unrealizable and demands further completion. But such models have their way of application, namely, such models should be considered as *platforms*. Abstract A-models, passed in the category of the standard platforms is possible to consider standard interfaces, protocols, computational cores, operational systems, and many others. Some abstract A-models are convenient as a reusable platform within the team bounds which can fix the certain successful decision, designate a direction of development, to provide continuity, having determined abstract A-model of the system and developing it in variety of concrete applications.

Virtual A-model. In such model abstract AA's are not present, but there is at least one virtual AA. Such model cannot be realized because of the virtual AA's, but it is already completely determined and, in principle, can be realized if to expand accessible element base. For successful realization of the model it is necessary to get rid of virtual AA's. It is achieved in two ways: by changing the model or changing external factors. In the first case developers change model (carry out design process) until virtual AA's don't remain in its structure. In the second case the model remains constant, and external factors vary (requirements specification accurate definition along the lines of restrictions changes; team education; transition to other computational cores; use of new technologies for team).

Realizable A-model consists only of realizable AA. Such model can be realized by the team in an element base and a technology accessible to it.

During designing of target system at the initial stages there is a concrete definition and verification of A-model. The result of that becomes "golden" model. *The "golden" model is the verified and fixed architectural model of the system, which is not limiting ways of the implementation.* An important task of the "golden" model becomes a creation of initial specifications for developers who are engaged in final realization of components and units of the system. Being A-model the "golden" model specifies the whole set of aspects of ES being realized.

An architectural platform acts as the reuse tool of the conceptual decisions within the bounds of aspect ideology. *The* architectural platform should be considered as association of following elements of design:

- aspect space of design process (the list of design aspects);
- model (models) of computation (MoC, behavioral aspect);
- external factors setting admissible different aspects ratio (design criterions);
- list of the fixed patterns of reuse;
- element base.

Architectural platform reconfigurability is defined as an ability to change MoC "embodied" at realization. The superstructure on the architectural platform, created with the purpose to change MoC, is named *as an operational environment*.

Tool aspect of ES designing on importance ranks with functionality [11] that assumes its taking into consideration not only "outside" on a course of the project, but also its inclusion at an early stage in the initial specification of the project/system.

5. Conclusion

Formalization and automatization of design processes always demands enormous efforts. Field of custom ES design - an example, where such efforts are necessary to make. A serious obstacle on the way of design technologies implementation on the basis of computational architecture abstractions is the problem of specialists education in the field of computer engineering and informatics possessing HLD-ideology is represented.

It is necessary to recognize, that a large number of ES developers teams nowadays insufficiently high estimate a role and labor-intensiveness of high-level design stages. They do not have adequate technical language for communication at this level, mutual understanding and a correctness of differentiation of developers' responsibility zones suffers, and there is no due integration.

The understanding of responsibility zones by HLD-specialists in a context of offered integrated ES design space determines of the design efficiency. The scope of ES architectural abstraction should extend by means of system engineering from the bottom border of computer system organization up to the top border of the project, which the requirements specification containing computational functionality of the project in aggregate with nonfunctional components is. As the bottom border the computational mechanisms distinctly showing the organization of computational process in analyzed structure (today it is RTL level) acts.

The system of architectural abstraction allows creating effective communication language in the field of ES design, qualitatively to advance technologies and tools, dramatically to improve the engineering documentation. For this purpose the coordinated efforts of operating developers of computer engineering and specialists of universities are necessary.

In St. Petersburg State University ITMO [15] within the framework of direction ES/NECS works on development aspect technology of design are carried out. Objective-event models of computations OEMoC, DOMoC [9, 11] have been offered and developed, researches in the field of virtual machines with a dynamic set of instructions [4] are carried out, models of actualization of ES computational process [3] are developed and investigated.

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Real-time embedded system generative framework

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Abstract. The present paper is devoted to generation technology and framework used in real-time embedded systems design. The technology is based on the generative domain model, the design pattern language and the metaprogramming. The generative domain model allows to create and modify the configuration knowledge base for real-time embedded systems. The framework allows real-time embedded systems developers to improve the software development, while increasing reliability and simplifying maintenance and support.

1 Introduction

At present 90 per cent of all microprocessors do not work directly in "traditional" computer systems such as desktops and mainframes. They operate as embedded systems that are considered to be specialized control and information processing systems. Experts estimate the world market for embedded systems at 138 billion Euros, and its rise is estimated at 9% per year. Modern real-time embedded systems (RTES) are complex hardware and software systems. They must be highly efficient. Many RTES have important safety-critical and high-reliability requirements. Functional requirements to them increase every year. Continuous development of these systems leads to necessity of efficient hardware and software control and program code portability while using new hardware platforms without efficiency loss.

2 Methodology

Automated software development deals with two problems:
1. Change from the single systems development to the systems family development;
2. Implementation components assemblage automation with generators.

Generating programming is a development technology paradigm based on modeling a software system family that allows developers to get specialized and optimized intermediate or final product from the specific technical requirements using basic components and the configurations knowledge base.
Family components are generated on the basis of general domain generating model. This model consists of three components:
1. instruments defining family parts;
2. implementation components building family parts;
3. knowledge base of configurations assembling a specialized product.

Generating programming consists of two cycles. The first cycle is used to develop a general domain generating model while the second one is intended to produce a specific system using this model.
The software architecture should include a components description and the interaction between them, patterns used to build them and the limitations for the given patterns.
System family architecture using the pattern language can be described as:
- Generic architecture (architecture with a constant topology). This architecture can be described as a block with a number of slots you can use to connect the extending or modifying components you need. Interfaces of these components must be clearly defined;
- High-flexible architecture. Structural changes can be made in this architecture, and you can obtain any generic architecture.

Object-oriented analysis and design methods are widely applied in industry. Unfortunately, they are not intended for software reuse. Particularly, they are not suitable for the framework and component development.
The problem solution is to integrate the subject areas engineering and the object-oriented technology, i.e. develop and implement the development tools for special design pattern languages. As the modern industrial programming languages such as C++ do not support this level of abstraction, the only acceptable solution is to use the technology of metaprogramming.
Metaprogram is a program code that generates a new code that performs the developer's tasks.

The metaprogramming patterns are the most practical approach for the generators implementation in the libraries of C++ to obtain a clear interface and high performance. Patterns simplify the reuse of successful software and architectural solutions. Since patterns allow you to describe interactions of classes and objects very clearly, they can improve the quality of documentation and maintenance of existing systems. A pattern names, abstracts and identifies the key aspects of the general solution allowing you to use it for creation reusable design.

3 Conclusions

On the basis of the present methodology the framework for real-time embedded systems design will be developed. The framework will allow RTES developers to improve the software development, while increasing reliability and simplifying maintenance and support.

Intellectual systems of monitoring, protection and control in electric power networks of different voltage levels

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1. System of diagnostics and monitoring of distributive electric power networks with difficult topology on the basis of the intellectual plc-modem

The open air lines of electric power networks having the big length are the most unreliable elements of a power supply system. The most part of damages of open air lines is made by short circuits and a wire breakage. Natural and artificial conditions can be the reason of their occurrence. Especially strongly this problem concerns electric power networks of high voltage 6-35 кВ because of their branched out treelike structure.

The analysis of the modern russian and foreign technical literature has shown that neither in Russia, nor abroad the problem of operative diagnostics of distributed electric systems is not solved strongly now.

1.1. Method of diagnostics of electric power networks on the base of locator

The method on the base of locator (locator method) for definition of places of damages in distributive networks of an electrical supply is new and progressive. The method of pulse reflectometering, named also a method of the reflected impulses or locator method, is based on transmission of pulse signals in two- and multiwire system (lines and cables) communications.

The devices realizing the specified method, are called as pulse reflectometers.

The essence of a method of pulse reflectometering consists in performance of following operations:

1.Cable Sounding (a two-wire line) with voltage impulses.

2.Receiving of the impulses reflected from a place of wire damage and from heterogenety of wave resistance.

3.Filtering of reflections from a place of damages from noise (casual and reflections from heteroginities of wire).

4.Definition of distance to damage place by a time delay of the reflected impulse relatively the probing impulse.

Required distance to a damage place is:

$$l = \frac{t_л}{2} v,$$

where v – transmission speed of impulse in a line,

$t_л$ – time of double run of this impulse to a damage place.

At sounding of a line with a big number of branches received reflectogram becomes complicated and the locatoor method becomes almost inapplicable for damage place definition, as:

1. There is a set of reflections and next reflections from branches and from the line ends that strongly deforms received reflectograms.

2. It is impossible to define on what branch there is the damaged site since reflectogram gives only distance to damage.

For elimination of the first lack of locator method, the accumulation method of reflectograms and their comparison with standard reflectogram for given network, received in a mode of normal functioning of a network is used. The first point where is difference from standard reflectogram is a required damage of a network.

For elimination of the second lack of locator method it has been offered the system that allows to organize on electric power lines an intellectual information network. Such system will allow to eliminate all minuses of locator method and will simplify recognition of reflectograms. On fig. 1 there are electric power lines with damage at one place and locator at the end of line.

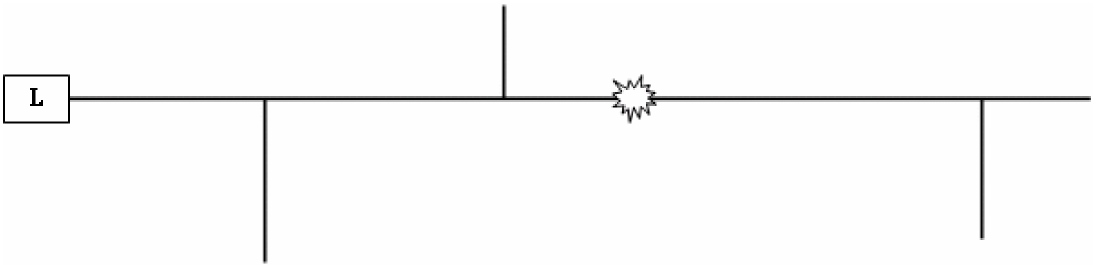

Fig. 1. An example of the damaged line with branches

After pulse sounding of such line we will get reflectogram that does not give us information of where exactly the breakage place happened because of presence of branches. The problem of search of breakage place considerably will be easier, if the locator investigates only a corresponding direct line, as is shown in fig. 2.

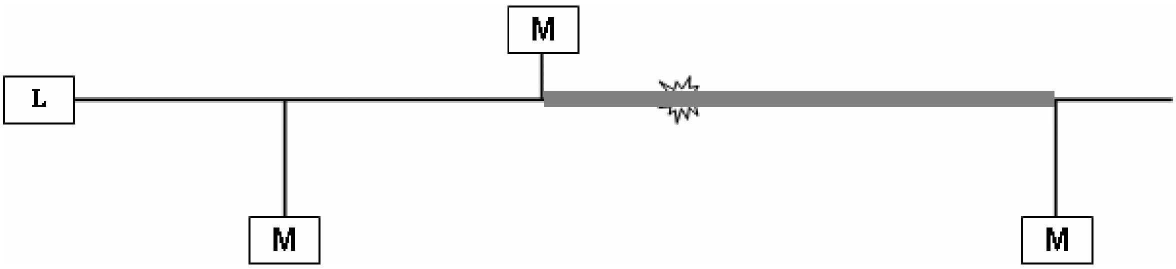

Fig.2 Localization of the damaged site

The given system works as follows. The master L-modem periodically sends a signal of polling to whole system which consists of consecutive polls to all slave M-modems connected to a network, containing in a database. The database is made manually or at a stage of a configuration of a network. If the answer from any M-modem during set time is not present, then the master plc-modem saves the address of the given slave plc-modem in a special file. After end of polling the L-plc-modem goes to a mode of the analysis of a file in which addresses of not answered M-plc-modems are saved. As a result after end of processing of a file, the module of monitoring of the L-modem sends to the module of a location a command to start locator sounding. After that, received reflectograms are analyzed and the distance to a damaged place is defined. The obtained data together with addresses of not answered plc-modems are transferred to the operator terminal.

The master L-plc-modem consists of two modules: the module of monitoring and the location module. The monitoring block represents the M-plc-modem. On fig. 3 the structural scheme of monitoring module is presented.

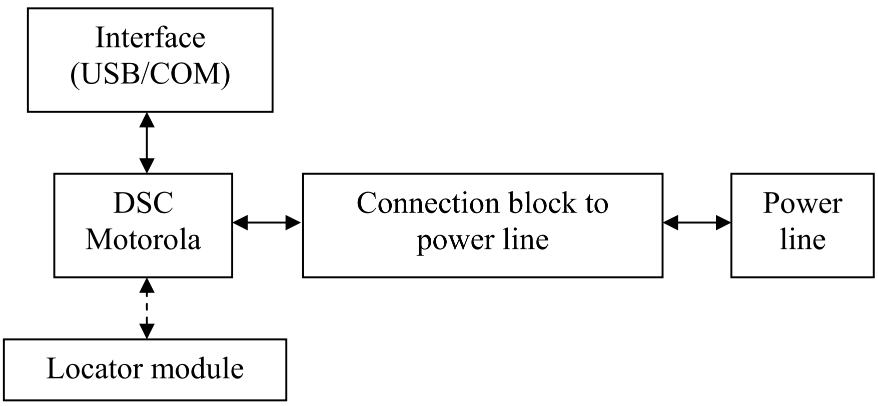

Fig. 3. Block-scheme of monitoring module

The monitoring module is constructed on DSC-controller Motorola (signaling processor). It realizes protocols of data transmission of channel and network levels. The work of monitoring module consists of monitoring, diagnostics and managements of device as a whole system. The given module is equipped with interfaces for communication with the computer (terminal). DSC-controller is isolated from power line with optocoupler. Device connection to a power line is realized through HF-filter which passes high frequency useful signal and remove a 50-Hz component.

The structural scheme of the locator module is presented in fig. 4.

From the DSC-controller to EPLD (programmable logic device) the impulse to start a procedure of a location comes. EPLD forms probing impulse of necessary duration which then goes to the impulse amplifier which also performs a function of the agreement with a line. Because of attenuation reflected from a damaged place impulse has small amplitude, therefore it at first passes through the input amplifier and then comes to ADC. EPLD processes the data received from ADC, and calculates distance to a damaged place. The received result goes to DSC-controller. Also the graphic indicator can be connected to a locator to watch the reflectograms. The locator can perform function of accumulation of signals to define a probing impulse from noises.

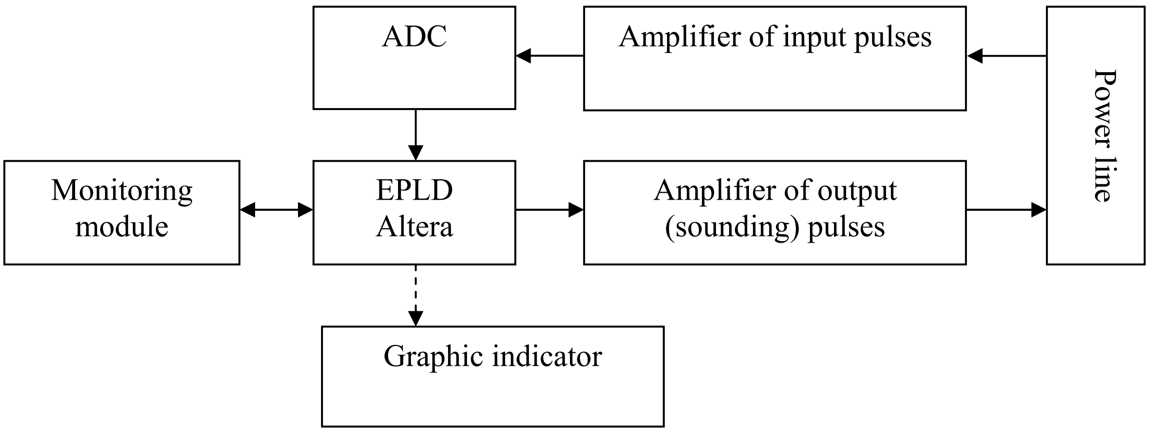

Fig. 4. Scheme of locator module

The choice of DSC-controller as the shaper of impulses and data handler is caused by wide flexibility and presence of internal fast two-port memory which is used as buffer of ADC. Also EPLD from Altera allows to use a ready kernel of processor Nios which considerably simplifies to perform an extraction of a useful signal and its further processing.

1.2. Characteristics of intellectual plc-modem:

- Range of locator sounding – up to 20 – 30 km.
- Possibility of on-chip reprogramming.
- A power supply from an industrial network, presence of an independent supply
- Accuracy of definition of distance to damage - is not worse 2 %
- Realization of constant monitoring of the branched electric system

2. System of protection of the low-voltage electric system 0,4кV from current leakages

The purpose of the given work is development and creation of system of data gathering and management of devices through the electric power networks of 0,4kV. Basic purpose of the system – protection of the electric power system from current leakages and control of the electric power network.

Function of protection of the electric network is based on a principle of longitudinal current differential protection of electric line (see fig. 5). If the electric power line has no damages values of a current at the end of a line are equal to values at the beginning: Il1 = Il2. In the case of damages in the line, the current part will flow away on external conductors, thus Il1> Il2. If the difference between Il1 and Il2 is greater than a certain value Imax (Il1-Il2)> Imax then the loading at the end of power line will be switched off.

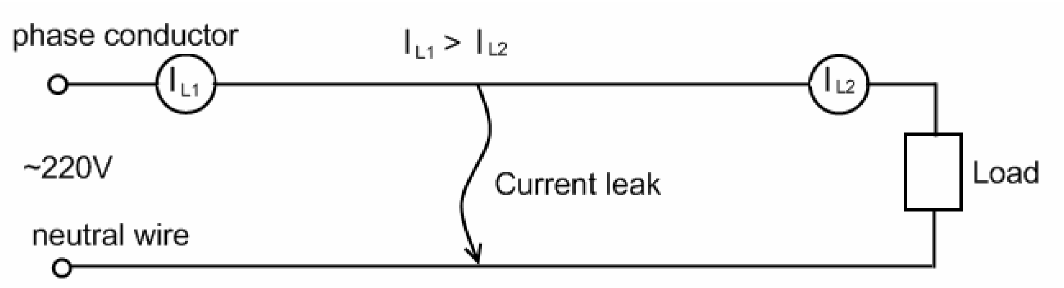

Fig. 5. Longitudinal differential current protection

Alternating current networks of 0,4kV are base of an electrical supply of all buildings. A main reason for wire ignition is current leakage between a phase and null wires. For example, the minimum current leakage for ignition has made:

- for wire APPVS (russian terminology) – 54mA (11,8Watt) at action time 39,3sec;
- for wire APV - 114мA (25Вт) at time of action from 14,7sec to 48,5sec.

For monitoring and protection of electric power networks it has been developed whole system consisting of end devices distributed through the power network (fig.6).
It is provided two basic types of devices «Central device» and «Local device» for our protective and control system. «Local devices» are fixed at the beginning and at the end of a power line, and make current measurements in these points, and also switch a line. "Central device" drives all "local devices". Each 10 seconds the information of current values comes to «Central device» from each power network knot. The information is analyzed about presence of current leakage. If leakage is found out, the damaged line is disconnected from a network. Configuration process of «central device» is performed from computer through USB interface. Communication between all devices is performed through wires of electric power lines 0,4kV by PLC protocol.

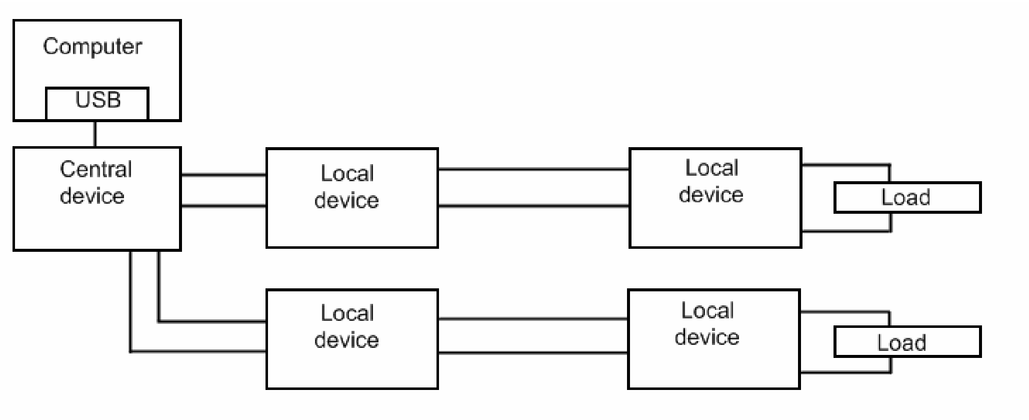

Fig. 6. Protective and control system of electric power network

On fig. 7 the block-schemes of the "Central" and "Local" devices are shown. They are made of the same element base, except for USB interface that implemented into “central” device. A device basis is the processor which is carrying out functions of device interaction between its components and external devices. The measurement module carries out current measurements on loading after the commutator. The loading can be a separate device and a network segment. The commutator is for switching on/off of loading to/from the power network. Module of PLC - modem is connected to a network through the amplifier with low output resistance for the agreement with a network impedance.

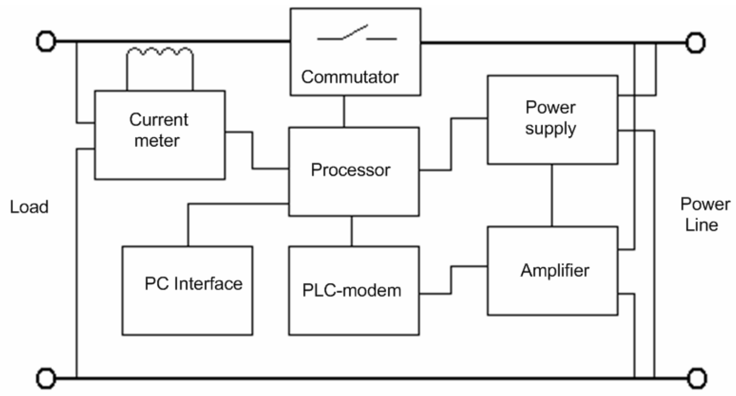

Fig. 7. The block-scheme of the "Central" and "Local" devices

Modulator of PLC – modem (see fig. 8) works as follows. At the end of timer period there is a change-over of frequency of the generator according to the modulated parameters – logic zero or logic one. Thus we get the frequency-manipulated signal. It has been chosen for logic zero - frequency of 90 kHz, for logic one – 101кГц, amplitude of a signal – 1V. Output parameters of signals correspond to GOST P 51317.3.8-99.

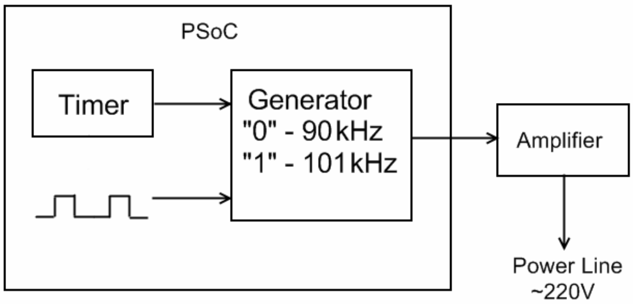

Fig. 8. Modulator of PLC – modem.

For demodulation the method of frequency separation of signal is used. The frequency-manipulated signal goes to inputs of strip filters with the central frequencies 90 kHz and 101 kHz. On an exit of each filter the rectifier is provided. From exits of both rectifiers the signal goes to comparator inputs. From a comparator exit it comes out a demodulated signal

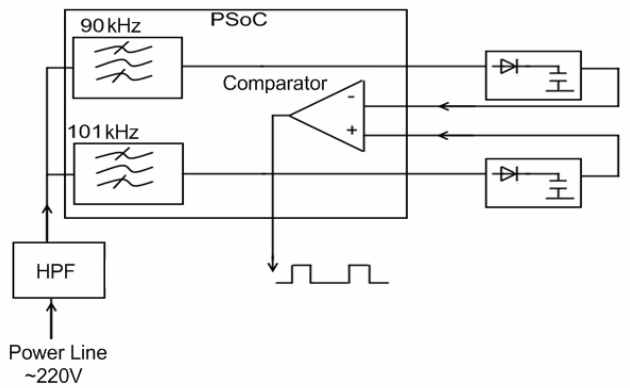

Fig. 9. Demodulator of PLC – modem.

The format of a transfer frame used in system is shown on fig. 10. The first bit is a start-bit, 8 address bits containing the address of the device, 8 information bits containing commands or values of the measured current, bit of parity of address byte, bits of parity of information byte and stop bit.

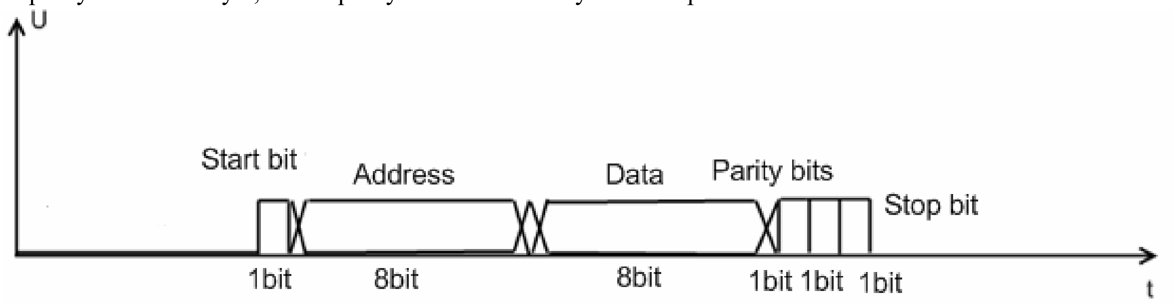

Fig. 10. A frame format

For current measurement it is used the current detector on the basis of the current transformer, the amplifier and ADC. The scheme of current measurement is shown on fig. 11.

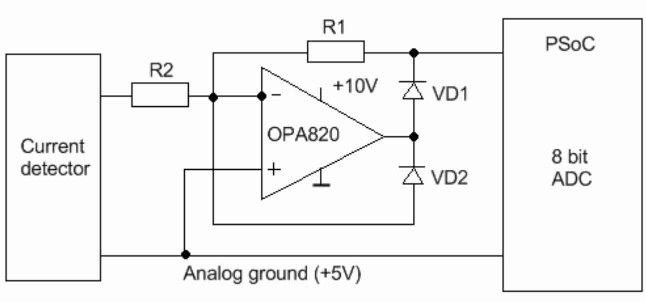

Fig. 11. The scheme of current measurements

Devices consist of microcontroller PSOC having on a single crystal digital and analogue blocks. Such architecture allows to realize on a single crystal both analogue devices to connect to detectors and the PLC-modem. Thus, we get the single-crystal decision necessary to minimize the size and cost of devices.

Tests of this system were executed with scheme shown on fig. 12. Between the scheme of tests and a power line of 220V the isolation filter was put.

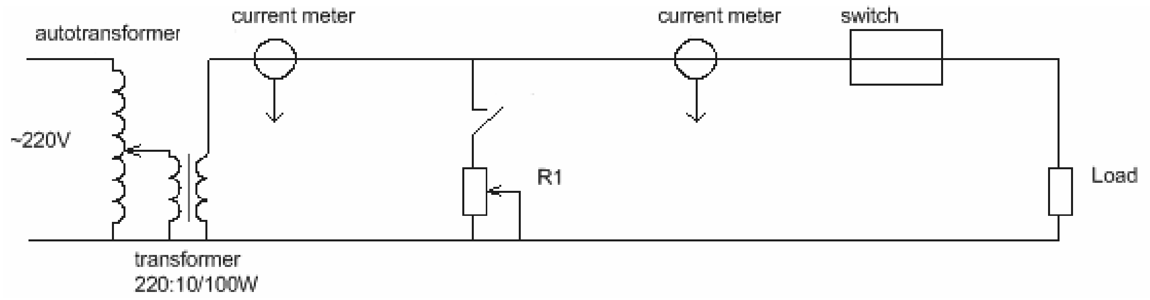

Fig. 12 Scheme of current measurement for operation of current protection

As a result of tests following results are received:

1. The protective system from current leakages in electric power network is developed.
2. «The Local device» allows to measure currents up to 10A with accuracy of 50mA.
3. The minimal operation current of longitudinal current differential protection – 50mA.
4. Speed of an exchange between modems in a network is 380 Bods.
5. The system allows to operate with10 loadings.

2.1. Characteristics of protective and control system.

Item	Parameter	Value
1	Power supply	220 V±15%, ~50Hz
2	Working temperatures	-40+55 dgr C
3	Max. measured current	10 A±50 mA
4	Operation time for current protection, not more	0,5 sec
5	Communication range, not less	100 m
6	Max. current of commutator, not less	10 A
7	Number of devices in system, not less	100 pieces

All our projects are patented in Russia patent system.

Wireless Sensor Networks: standards and driving forces

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Abstract. The paper will provide a state-of-the-art report of Wireless Sensor Networking technologies, including ZigBee, WirelessHART, LowPower Bluetooth and others. The main advantages and drawbacks of these technologies will be described, focusing on application-driven requirements. Special focus will be put on standardization activities in the areas of WSN design itself, as well as domain-specific WSN-related standards (Energy, Industry, Healthcare and Environmental). A review of application frameworks will also be provided, including OS-level platforms (TinyOS, Contiki OS).

1 Introduction

Following a period of relative stagnation, Wireless Sensor Networks now enjoy time of rapid growth, facilitated by renewed interest in conservative resource consumption and increasing usage of service infrastructures. Applications of WSN adopted now in many areas, including Energy, Industry, Healthcare, Environmental Monitoring and others. Among numerous advantages, provided by Wireless Sensor Networks, a special emphasis can be put on possibility to create systems, optimized for environment and thus consuming less of resources, easily deployable and offering non-intrusive behavioral characteristics.

Introduction of WSN into the real life applications is following a number of trends, including industrial efforts for standardization of technologies, governmental activities to promote certain application scenarios, scientific research in the areas of technological platforms for WSN (including radio data transmission, communication network architectures and protocols, energy harvesting techniques, etc.). In this paper, we will try to sketch a global picture of WSN technologies and applications from a point of view of industrial adopters.

2 Communication Technologies

Wireless Sensor Network communication technologies include results of research and development activities in the areas of radio communication, networking protocols, software architectures and platforms. Development and standardization of WSN is driven by several communities, including:

1. Internet community
2. Industrial associations
3. Technology groups

Often, standards development is going in similar directions and some standards overlap significantly in purpose and/or approach to implementation. Therefore knowledge of existing WSN options, taking into account technical and marketing aspects, is essential to select the right approach for a project or product.

2.1 IEEE 802.15.4

IEEE 802.15.4 is one of the most promising standards for Wireless Personal Area Networks (WPAN). It is available since 2003 and serves as a basis for several higher level protocols, including ZigBee, WirelessHART and 6LoWPAN. IEEE 802.15.4 [1] defines physical and MAC layers (including security) and supports star and peer-to-peer topologies. Data transfer rate is up to 250 kb/s. Supported bands and modulations are changing depending on a standard version (2003, 2006 and 2007 versions available), but the most common is 2.4 GHz band with 16 channels. IEEE 802.15.4 can be used “as is” only for very simple applications].

2.2 6LoWPAN

IPv6 over Low power WPAN (6LoWPAN) is IETF working group, aiming to bring IP networks (IPv6) and sensor networks together. The problem with integration of IP and sensor networks is in significant overhead of IP protocol headers, which are not suitable for IEEE 802.15.4 networks (with 127 bytes data frame). 6LoWPAN WG has completed IETF RFC 4944 [2], defining a way for transmission of IPv6 packets over IEEE 802.15.4 networks, basically using stateless headers compression. Usage of IP is promoted by IP for Smart Objects (IPSO) Alliance as a native way for integration of sensor networks and smart objects with existing IT infrastructure.

2.3 ZigBee

ZigBee Allience is an industrial association, developing and promoting ZigBee protocol standard [3]. ZigBee protocol is a layer above IEEE 802.15.4, which provides networking layer with support for different architectures, including star, tree and most interesting – mesh topology. ZigBee specification is a mature one, first version released in 2004 and used by some commercial products. Special focus of the Alliance is on application level standardization, i.e. definition of standard interfaces for different application domains, including Home Automation, Smart Energy, Building Automation, Health Care and others.

2.4 Wireless HART

HART is an industrial protocol for communication between field instrumentation and host systems. Wireless HART is a part of HART 7 Specification [4], and as ZigBee, provides extension over IEEE 802.15.4 layers with industrial specifics, such as necessity for real-time operations. It defines communication network structure and necessary components, such as Network Manager. Wireless HART uses channel hopping TDMA protocol with 10 ms communication slots. HART specification includes also application level elements, such as definition for formats of diagnostic information, which are applicable for Wireless HART devices also.

2.5 ISA100

ISA100 Wireless Compliance Institute aims to define a complete set of industrial wireless standards. One of these standards, ISA100.11a [5], is covering wireless process control applications. From the maturity point of view, it is rather new (2008) and very similar to Wireless HART from the technical perspective. This is also based on IEEE 802.15.4-2006, uses channel hopping to increase robustness and provides star topology for better response time and mesh topology for reliable communication. Very interesting particularity of this standard is that it provides inter-networking routing and frame format in accordance to IETF RFC 4944. Special attention is also paid to interoperability with other families of standards (ZigBee, Wireless HART, etc.).

2.6 Bluetooth Low Energy

Development of Bluetooth Low Energy is currently ongoing and specification is planned in the beginning of 2009. It is based on Nokia Webree and targeted to similar applications as IEEE 802.15.4; advantage of Bluetooth Low Energy is availability and cost of radio hardware (existing Bluetooth radios can be used in many cases). However, applicability of this standard is limited to consumer devices, i.e. industrial scenarios are not covered.

2.6 Other solutions

There are many other solutions exist on a market, most of them proprietary and targeted to certain specific applications. The list includes, but not limited to Z-Wave (the main competitor to ZigBee), KNX RF, EnOcean and others. Often development of particular technology is driven mostly by one company, and this makes investments into this technology rather risky.

3 Wireless Sensor Platforms

Wiireless Sensor Platforms are hardware/software solutions to enable development of WSN applications. These solutions usually have very special architecture due to application requirements, i.e. include very low-power hardware (this means low performance and small amount of memory) and low overhead software components, including OS, drivers, protocol stacks, application services, etc. Usually, platforms are centered around particular operating system, which is adopted for WSN needs.

3.1 TinyOS

TinyOS is an open source component-based operating system, designed for embedded Wireless Sensor Networks. TinyOS is written on nesC, a dialect of C designed for sensor applications with limited resources. Due to openness, portability and component architecture, TinyOS used in many projects and some ZigBee stack implementations use it as an underlying platform. However, TinyOS networking model is not standard and without usage of some common protocol is more suited for research activities, rather then industrial applications. Another limiting factor is usage of nesC language – with all simplicity it is a new programming language to learn by developer.

3.2 Contiki OS

Contiki OS is another open source embedded platform for WSN applications. It is implemented in C and similar to TinyOS, provides a broad spectrum of supported hardware architectures, system modules and user tools. Very interesting particularity of Contiki is IP networking stack, which actually led to IETF standard development and IPSO Alliance creation. Contiki also used by Freaklabs FreakZ open source ZigBee stack implementation project, so it has potential to cover both most perspective WSN networking directions.

3.3 Linux

Linux is traditionally considered as a backbone for a modern networking infrastructure. In our days it is not only adopted in server equipment, but also used in network appliances, such as routers, media streaming centers, etc. In the same time it is selected by some manufacturers as a platform for mobile handsets. From author point of view, this makes Linux an ideal platform for gateways between wireless sensor networks and traditional network infrastructures, including computer and mobile networks. The main blocking factor is the absence of proven implementations of WSN protocols for Linux operating system. However, this situation is being changed by Linux-ZigBee SourceForge.net project, which aims to develop a ZigBee (and more generally – LoWPAN) protocols stack for Linux kernel.

4 Application Domains

Adoption of Wireless Sensor Network technologies is driven by application requirements. There are some “natural” areas where need in WSN obvious – for example home automation, environmental monitoring or tracking applications. Other applications are “triggered” by specific governmental actions; a good example here is smart metering technology.

4.1 Energy (Metering)

Advanced Metering is a very hot topic in US and Europe, due to governmental plans to update electricity grid and facilitate energy saving technologies. Electricity metering, is not connected directly to WSN topic, however there is a synergy with home automation, which could bring significant benefits by enabling smart meters to communicate with in-house smart appliances, for example to schedule or control energy consumption. This was understood by ZigBee Alliance and triggered development of Smart Energy profile. However, state-level standards for metering are not yet developed, so it is not clear if WSN will be adopted at the end as an enabler technology for Advanced Metering Infrastructures.

4.2 Industry (Manufacturing)

Wireless technologies in industrial automation are adopted rather slowly due to significant products lifecycle and conservative approach to engineering. This area has many specific requirements for reliability and real-time operation; main standardization activities are done by International Society of Automation. However advantages of WSN for industry are so significant, that 2 of most mature WSN standards (Wireless HART and ISA100.11a) are targeting industrial process control applications.

4.3 Health Care

In healthcare industry, most of the advantages of Wireless Sensor Networks are usually connected to “personalized healthcare” concept. Development of standards in this area is mostly driven by Continua Health Alliance, defining technologies and interoperability requirements for the industry. There are specific requirements for healthcare applications, mostly in the area of security and reliability of operation. However from technology point of view, mostly common approaches and standards are adopted, for example careful attention is paid to possibility of mobile technology integration with healthcare services, and this means usage of Bluetooth (at the time of writing, evaluation and selection of wireless technology by Continua was still in progress).

4.4 Environmental Monitoring

This is a native application of Wireless Sensor Networks and it has a lot of attention from research community. However, there are no significant moves to define common standards in this area, probably due to significant diversity of possible use cases. For example, wireless sensor networks are adopted for pipeline infrastructures monitoring, dikes, bridges and pollution control.

5 Conclusion

Wireless Sensor Networks standardization process is rapidly progressing, driven by introduction of new application scenarios, market forces and governmental regulation activities. The number of already published standards, often for similar (or same) applications, raises concern for interoperability of different networking technologies. Usage of common platforms for networking infrastructure may help to overcome this potential problem and help to create single world wide “Internet of Things”.

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Universal wireless sensor networks technology platform and its applications

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Abstract. Wireless sensor networks (WSN) are becoming more and more popular due to the growing area of their application. However, finding a single approach to different tasks is rather difficult, as each task has its own peculiarities. In this paper we propose a universal hardware platform as the first step to a quicker development of finished solutions based on WSN. We demonstrate the use of our platform in different types of applications.

1 Introduction

A wireless sensor network [8] is a distributed self-organizing network, consisting of miniature electronic devices, which exchange data through wireless channels. These devices (nodes) do not require special installation and do need to be serviced. The key feature of a sensor network is a possibility of retranslating messages from one node to another, which allows covering large territories without using high-power transmitters.

A common node of a WSN uses the ZigBee standard for wireless data transmission. The ZigBee is an international open standard, which was developed by the ZigBee Alliance. This standard allows using wireless connection with low-power consumption for different applications for monitoring and/or management. The Zigbee supports different network topologies, it has special network functions for self-organization as well as several methods to ensure secure transmission.

The most popular applications for WSN are different monitoring systems (e.g. security monitoring), different management and control systems (climate-control, home automation systems etc.), remote access control and positioning systems (tracking systems).

2 Universal platform for WSN [1]

A proprietary universal wireless sensor network (WSN) platform was proposed, developed and released by the Wireless Sensor Networks Lab (VEK-21 Ltd.) of the Department of Computer Systems and Networks at Moscow State Institute of Electronics and Mathematics (MIEM) (Fig. 1) because now it’s necessary to use similar devices in different application areas. We also can save resources by using our platform because of the universality. It also allows us quickly change priorities of the system, which makes possible using our platform to achieve different goals by working with all popular COTS sensors.

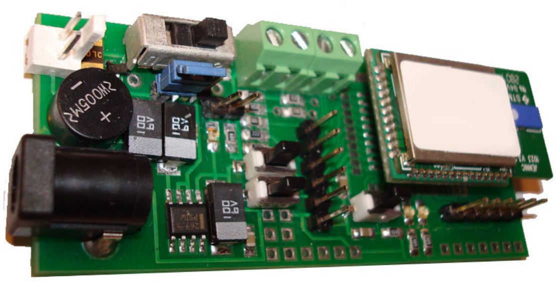


Figure 1: Universal platform for WSN.

3 Energy consumption and lifetime

As sensor network applications depend so much on energy efficiency we want to analyze energy consumption and lifetime of our platform with microcontroller. Typical energy consumption for the sensor node: 37 mA – energy consumption for receiving, 37 mA – energy consumption for sending, 9mA – energy consumption for the CPU while transceiver is off, 0,002 mA – energy consumption in sleep mode. The time which is taken to wake from sleep mode is 15 ms and energy consumption 9mA (from the microcontroller data sheet):

$$9 \times 0{,}015 = 0{,}135 \text{ mAs (milli Ampere seconds).} \quad (1)$$

The microcontroller is running at a clock rate of 16MHz which means that a single cycle takes $1/10^6$ seconds. Let's assume that the average instruction takes 3 clock cycles and that we need 7,000 instruction for the measurement, for data processing and for preparing a packet for transmission over the network. This would result in

$$\frac{7000 \times 3}{16 \times 10^6} = \frac{21}{16 \times 10^3} = 1{,}312 \text{ ms.} \quad (2)$$

The amount of energy consumed at a current of 37mA would be:

$$37 \times \frac{21}{16 \times 10^3} = 0{,}0486 \text{ mAs .} \quad (3)$$

This means that the battery has to supply amount of energy which is equivalent to 1mA for 48.6ms.
And also the time to transfer data from I2C (for instance) is 5 ms with energy consumption – 9mA:

$$9 \times 0{,}005 = 0{,}045 \text{ mAs .} \quad (4)$$

Sending data takes place at a speed of 250,000 bits/s. We assume that our own measurements occupy 32 bytes of memory. A single bit takes 1/250000 seconds to be sent which sums up to:

$$32 \ \ mA \times \frac{32 \times 8 \ \ bits}{250000} s \approx 0{,}033 \ \ mAs \ . \quad (5)$$

Time of calculating and sending took:

$$21/16 \text{ ms} + 1\text{ms}+15\text{ms}+5\text{ms} \approx 22{,}3\text{ms.} \quad (6)$$

This means that the node can sleep for about:

$$1-0{,}022 = 0{,}978 \text{ s.} \quad (7)$$

The node consumes:

$$0{,}978 \times 0{,}002 \approx 0{,}002 \text{ mAs.} \quad (8)$$

The total amount of energy is:

$$0{,}135+0{,}0486+0{,}045+0{,}033+0{,}002 \approx 0{,}262\text{mAs.} \quad (9)$$

We assume the AA battery delivers about 2300 mAh:

$$\frac{2300 mA \times 3600 s}{0{,}262} \approx 31{,}6 \times 10^6 s \text{ (365 days).} \quad (10)$$

4 Our projects based on WSN

We used our platform in implementation of some "standard" WSN applications as monitoring systems, SCADA and remote identification systems. Also some "unusual" applications to WSN technology were demonstrated built around proposed platform. These include autonomous system of secured wireless audio transmission and a wireless real-time 3D visualization system (WSN-based Motion Capture application for virtual environment simulation).

Security monitoring system [3]. Security monitoring system based on WSN, which can work with different security sensors and integrated with GSM, can be used with existent security systems to increase reliability, it's easier to install this system and it uses cheap data transmission channel than, for instance, Wi-Fi.

It consists of hardware (WSN devices) and special software (for devices and PC), which allows you to control object status through Internet.

Examples of using: private home security systems, offices security system.

Climate control system (Home automation system) (temperature, illuminance, humidity) [4]. Climate control system based on WSN is a multifunctional system which gives us possibility to work with different electronic devices (air conditioners, light systems etc.) and might be integrated with other systems to increase efficiency of using electricity, water etc.

The main difference of this system from other monitoring applications is the use of special profiles that allow for using diverse devices with diverse algorithms. It also can use GSM channel.

Examples of using: climate control systems, home-automation systems etc.

Remote identification system. Mobile objects wireless identification.

Figure 2: Wearable sensor for wireless remote identification system.

We've developed a prototype of the system, which consists of different number of sensors. Each sensor measures power level of radio signal and sets up critical power level. If there is pair of sensors – one of them (base station) always measure power level, other – sends testing data packets. When someone is trying to walk between pair of sensors, one of them receives weak radio signal compare it with critical level, and if power level of the signal is less than critical level it sends interruption information to the central server and turns on alarm system. But if there is someone with special WSN device (Fig. 2) is trying to walk between pair of sensors, our system analyses situation and position of that person with WSN device and if that WSN device is registered at one of the sensors from that pair, system make a decision that there is no interrupt.

Base stations can be easily connected to GSM-channel or Internet.

Examples of using: security systems, special exhibition systems, home-automation systems.

Intellectual system of wireless audio transmission [5]. This system is our first attempt of using WSN in "unusual" way – multimedia transmission. We have developed a prototype of a system, which will provide wireless access to different services using a WSN.

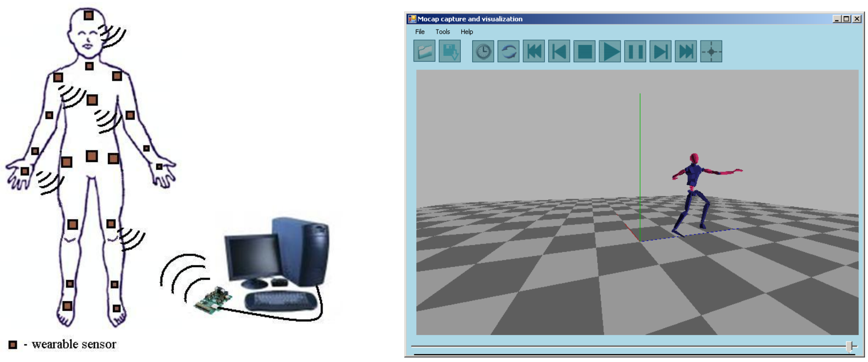
It consists of several base blocks (stations) and portable devices (handsets). A base block can be connected to a public telecoms network (throw special "bridge"), internet (VoIP service) or to a mobile phone. A portable device is a low-power handset using a 10 mW transmitter. Each element of this system is a node of a WSN. Therefore it contains an internal processor, which allows local data processing. For example, when a person talking on the phone listens to his (her) interlocutor, the data from his handset is not transferred thus minimizing the amount of traffic in the WSN.

General features:

- base station translates incoming calls to portable devices;
- portable devices can accept incoming calls, close connection, call a Skype-account;
- 400 meters distance between base station and portable devices;
- Internet-radio translation with reasonably good quality – up to 100 meters distance.

Bodynet system [7]. A wireless bodynet system consists of multiple wearable sensors and a central stationary module, each being a node of a sensor network. This system has two main applications – telemedicine and motion capture. The first one has focus on remote health monitoring of people with chronic diseases, patients in hospitals and elderly people. The task is solved with the use of sensors that measure blood pressure, pulse rate and other vital parameters.

A wireless tracking system [2] makes it possible to transform real movements of a person into a virtual 3D environment and visualize them in real-time. This is actually a first completely wireless system, which means that every sensor has a radio transmitter attached to it. In comparison, most existing solutions have a single communication module, which is usually placed in a rucksack, and all the sensors are connected to it with the help of wires. The system hardware consists of many end devices equipped with sensors for capturing acceleration and rotation of a certain part of a human body. A central unit collects all the data and transfers it to the computer, which performs all calculations and visualization. To measure all parameters we use MEMS-based accelerometers and gyroscopes, which are notable for their miniature size, low costs, low energy consumption and high performance. Apart from visualization, our software can also save all captured information for its future analysis in simulation programs, e.g. Autodesk 3ds Max, Maya, Blender.



a) b)

Figure 3: Wireless bodynet system.

The main applications for the motion capture system include:
- interface to 3D virtual reality;
- research in human-computer interaction;
- remote control of robots and manipulators with real movements;
- motion capture systems for character animation in films, games or television studios.

A combination of different wearable sensors can be used for efficient control of police or fire squads during dangerous operations.

5 Future work.

We're planning to continue our work and we're going to develop:
- real time virtual reality system which will provide all possibilities of computer-human interface interaction;
- full home-automation system;
- sports-monitoring system;
- conveyor monitoring system (getting and analyzing all information about conveyor and environmental influence on it);
- home gaming systems, which will provide real interaction with the game;
- professional motion capture system for movie-making companies.

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Note

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