Networked Embedded and Control Systems: Towards a Closer EU-Russian Collaboration

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Abstract. The paper presents the NESTER project "Networked Embedded and Control System Technologies (NECS) for Europe and Russia" funded by the European Commission under 7th Framework Programme, aimed to identify opportunities for deeper strategic cooperation between Europe and Russia in the field of NECS. Four sectors with highest potential for EU-Russian NECS R&D collaboration are analysed from the point of view of expected impacts and research challenges.

1 Introduction

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

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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 modeling.

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.

2 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 (Russian) 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 catalyze 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.

3 Identification of Four Industrial "Locomotive" Sectors with Highest Potential for European-Russian NECS Collaboration

The objective of the consortium was to analyze 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) Modeling, 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 optimization of actuators and sensors positioning for performance optimization; (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).

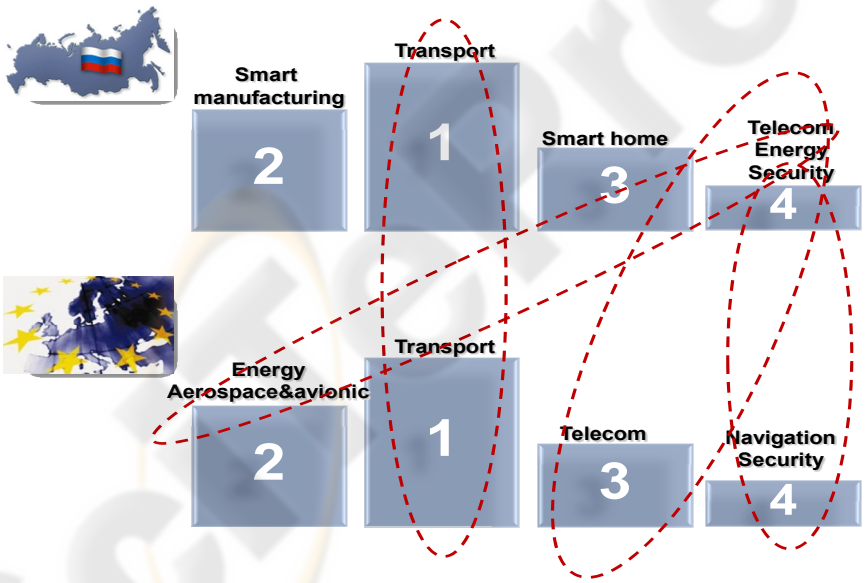

Fig. 1. Identification of four sectors with highest NECS EU-Russian collaboration potential: Russian and European visions.

4 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 (eg. 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 behavior
- 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 upgradable 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 modeling, 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, upgradable, 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.

5 Next Steps

The NESTER project will continue till Autumn 2009. The NESTER team will focus on condensing, evaluating and cross-comparing the information obtained from the previous phase, in order to:

- Develop a “competence map” of the most relevant technological areas for the European-Russian NECS R&D partnerships;
- Put in relation European and Russian research and industrials entities in order to encourage creation of partnership;
- Provide the recommendations to the European Commission on the strategic areas of cooperation between Europe and Russia in the NECS domain.

A 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 an opportunity to present their scientific results and discuss collaboration opportunities.

In summary, the NESTER project support and promote European competitiveness through strategic research partnerships with Russia in science and technology by engaging the best Russian scientists in the field of NECS to work with Europe.