Complex Autonomous Systems – A new challenge for control engineers

The growth of the process and of the infrastructures complexity as a support for developing and sustaining a global competing economy requires the design, the development and the implementation of complex control systems that assures high performance and increased functioning autonomy, as well.

The self-governing evolution of some complex processes (infrastructure) supposes a superior context adaptive capacity, self-organization and total fault tolerance. A new category of complex autonomous systems is rising from joining the modeling difficulties of the complex systems and high performance request imposed to the autonomous control systems. The autonomy, as a crucial demand of the complex systems, assumes the development of intelligent control systems for processes whose models contain significant uncertainties and operate into unstructured environments.

The relevant results obtained by integrating and hybridizing the intelligent methodologies and the substantial progress in the domain of the information theory and technology and communications led to a new class of systems, which are being imposed in an increasing area of applications. The paradigm of Cyber-Physical Systems (CPS), that involves integrating computers, communications, control and the representation of physical processes, gets valuable significance and extends, with remarkable results, from nanotechnologies to processes and infrastructures of huge complexity.

When selecting and dimensioning the information and knowledge processing and transmission systems, the dynamics and the energetic resources specific to physical processes are considered. These lead to a special class of complex intelligent systems with high autonomy, within the framework of an embedded, space distributed and different time scales functioning architecture working as intelligent networked control systems.

The major challenges of the 21st century, such as global warming, strong reduction of the energy and food resources, population ageing, climate changes and environment protection, require advanced control solutions. The major objectives of these control solutions are autonomy, robustness and safety functioning.

The automatic control is facing many difficulties regarding the characterization of the complex systems, the design of high autonomy control architectures, where the intelligence level need to be more and more increased. The paradigm “Smart Cities” represents a real challenge for ICT domain and especially for CPS. It means the assurance of the optimal conditions in order to exploit the infrastructures of transport, energy supplying, water and food providing. The automation level of these infrastructures demands complex autonomous systems with high level of intelligence. By considering formal aspects in representing the complex infrastructure, features related to the life quality and the human existential safety, a new theory is developed regarding the time variant non linear stochastic systems. Consequently, new methods and instruments embedding the most recent results obtained in the ICT domain need to be developed.

New advances in computers, communications and cognitive sciences create a new vision about Advanced Control Systems integrating some attributes of the intelligence (perception, planning, learning, communication and reasoning).

Integration of intelligent agents into hierarchical and heterarchical architectures with different time-scale and resolution generates a new class of autonomous complex systems with high applicability for complex infrastructures. The complex autonomous systems can reach intelligence and flexibility on changing operating conditions and demands from the surrounding processes.

Integrative technologies, such as high confidence CPS design could be a real challenge for the academic and industry environment to create new architectures and powerful autonomous control systems.

An autonomous Complex System as a system of systems includes new spatial and temporal constraints, dynamically reorganizing, reconfiguring capabilities and real capacity to be autonomous into unstructured and unknown environment.

In order to construct and design such complex systems, the development of a new formal support for studying the time variant non linear stochastic systems is necessary. The formal framework allows understanding and managing the heterogeneity in complex structures when considering all the physical properties, computational and communication properties.

New generation of intelligent systems must be characterized by increasing functionality, integration and networking interoperability with self-aware, self adapting, self-repairing and self-sustaining capabilities.

The complex autonomous systems such as Cyber Physical Systems need a new theory of system of systems, new architectures of distributed, multi level in space and time, dealing with uncertainties and adaptability, environment and resource availability.

We need to develop new foundations to consider scalability, reliability, robustness, stability of system of systems, new formal models and logics for reasoning in complex Cyber Physical Systems with high level of autonomy. We need new engineering design techniques and tools to capture and optimization of interdependencies of different requirement, validation and certification.

In this framework with these major challenges, the community of control engineers must take into account new directions of action to develop and implement new generation of control autonomous control systems:

- a new Control Theory to analyze and design the complex CPS, including marriage of control, information an communications, and theoretical computer science and physical processes;
- to develop new architectures of autonomous control systems by integration of all intelligent methodologies as an associative hybrid system with large applicability for control infrastructures;
- to develop the agent technology, the distributed embedded systems and create a new support for intelligent networked control systems;
- to integrate intelligent agents into hierarchical and heterarchical architectures with different time-scale and resolution and create new generation of Autonomous Complex Control Systems.

The future oh the automatic control is more connected with the new challenges of science and technology given by the Cyber-Physical System Paradigm. The next generation of complex autonomous systems will have to consider all scientific achievements in the areas of CPS.

The next generation of complex autonomous systems will integrate more knowledge from biology and the brain behavior must be a real support to develop new advanced and complex control systems with high level of intelligence.

One of the main challenges of the next generation of engineers will be to develop the suitable complex emergent structures, having more and more self-organizing capacity dynamical reconfigurability with high level of performances.

We have to develop new methods and tools for analyzing and design of complex systems, new programming language and reason algorithms for formed validation of complex integration of computers, communications, know ledges with physical properties of processes.

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