Chapter 1

Introductory Chapter: Major Automatic Control Challenges in Multi-Agent Systems

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Additional information is available at the end of the chapter

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This book discusses the multi-agent systems (MAS), which we will consider as intelligent hierarchical distributed dynamic systems that consist of two or more intelligent agents, and each intelligent agent has its separate (local) goals that may match or contradict the goals of other agents. Also, each agent has a certain degree of autonomy.

Until now, there is no general consensus of what is meant by an "agent." However, one of the globally recognized definitions of the "agent" (or "intelligent agent") assumes a computerized system that is situated at some environment and that is capable of autonomous action in this environment in order to meet its objectives.

Based on the previously formulated concept of intelligent agents, we can define their basic properties:

- Active and passive reactivity, $Z(t) = [Z_1(t), Z_2(t),\ldots, Z_g(t)]^T$—vector matrix of the output variables characterizing the flow of physical processes in the system over time for each ith of q agents as a response to a combination of input constraints and set points $U_i(t) = [L_i, D^C_i, D^R_i]^T$, where L_i is the technological limitations of the ith agent, D^C_i is the vector of input commands, and D^R_i is the vector of input recommendations, $i = \overline{1, q}$.
- The ability for goal detection, $Y^{AG} = [Y^{AG}_1, Y^{AG}_2,\ldots,Y^{AG}_e]^T$—vector of objective functions of number l
- Goal-directed behavior, accompanied by the changes in the states of the ith agent $S_i(t)$
- Interaction ability between sending and receiving agents, i.e., senders and receivers, respectively, by exchanging $D_i(t)$ signal, which is perceived by the receiver agent as one of the input vector $D^C(t)$ components

In a multi-agent system, it is necessary to take into account that agents function under the conditions of some environment that may act as a source of measurable and immeasurable noise and disturbances, $V(t) = [v_1(t), v_2(t),\ldots, v_k(t)]^T$—vector of disturbances (immeasurable).

Based on the concept of homogeneous and heterogeneous systems, we will define both types as follows: agents are considered homogeneous if they have the same goals Y, are characterized by identical sets of possible states $S(t)$, and have similar set points and output constraints $Z(t)$. Otherwise, if they differ in one or more of the mentioned factors, the agents are considered heterogeneous.

Figure 1 shows the generalized structure of the MAS, taking into account the interaction of agents.

Recently, the representation of dynamic systems in the form of MAS and the use of appropriate methods for analysis and design are being applied more and more in various fields and applications. For example, we can find its implementation in processing control tasks in robotic systems, in intelligent electrical systems, etc. Although there are many examples in

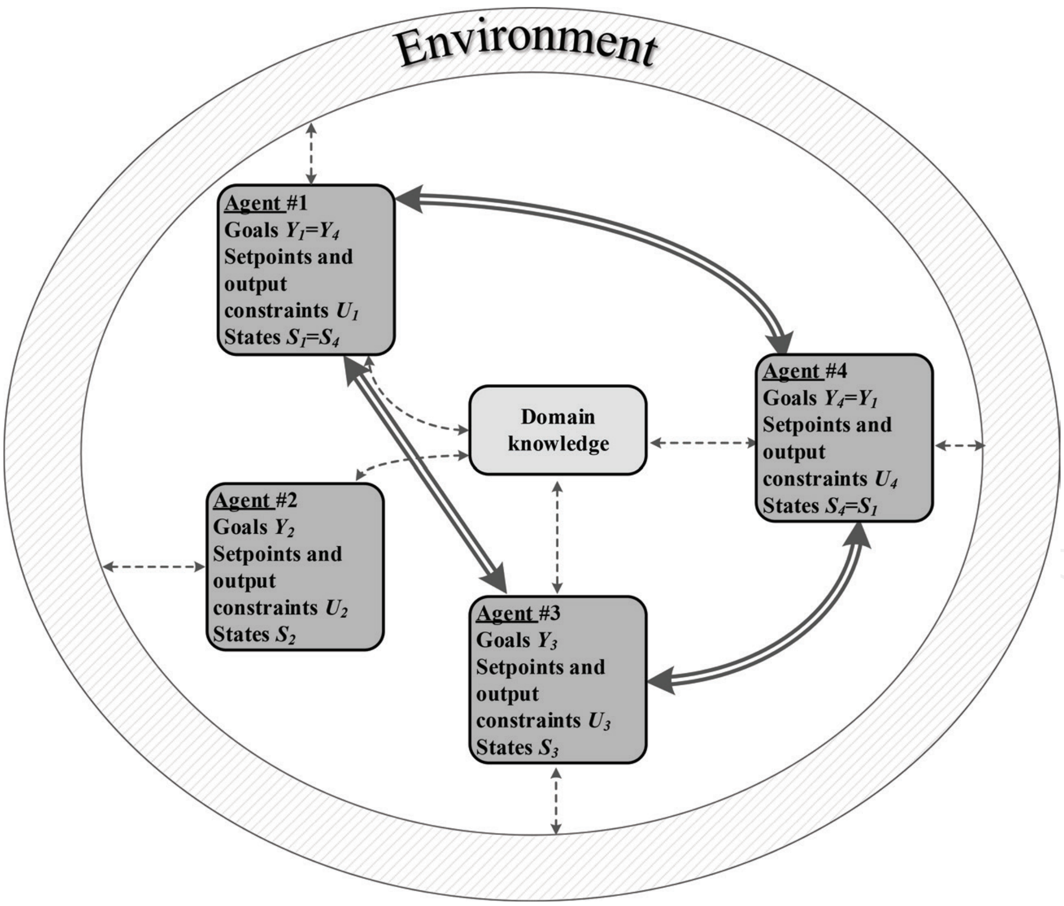

Figure 1. MAS consisting of homogeneous (#1, #4) and heterogeneous agents (#2, #3), communicating (#1, #3, #4) and noncommunicating (#2) agents.

the publications related to multi-agent applications, there are some numerical data of practical solutions. This makes it difficult to assess the efficiency of MAS-oriented approaches in comparison with alternative approaches.

Nevertheless, the development of agent-based technologies plays an increasing role in designing cyber-physical systems (CPS), allowing to create decentralized control systems based on the distribution of control functions between autonomous and cooperative agents, realizing such important characteristics as modularity, flexibility, reliability, reconfigurability, etc. Applying multi-agent technologies in the applications to cyber-physical systems leads to development of the new methods to execute control tasks by creating systems with a combined centralized and decentralized control.

Solving problems associated with multiple-criteria control can be associated with multi-agent representation, especially when there exist conflicting criteria and some uneven distributions between heterogeneous subjects of the dynamic system. Such approach introduces efficient methods for dealing with the corresponding optimization problems.

It seems promising to use a MAS-oriented approach to solve the problems associated with multi-purpose control, especially in the presence of conflicting criteria and some uneven distribution of criteria between heterogeneous subjects of the dynamic system.

Despite the existing problems, multi-agent approaches could be considered an effective tool for control and decision-making in systems where there are distributed control and uncertainty related to the control law implemented by each agent, poorly predictable environmental behavior, and possible losses in total observability and controllability of the subjects.

It is known that the solution of control problems in complex dynamic systems, which are usually understood as high-dimensional systems, containing branching and cross-links, and different types of uncertainties, nonlinearities, etc., is associated with approaches based on the decomposition of such systems. In this regard, multi-agent technologies offer particularly such a decomposition, for example, based on the individual and cooperating agents entering into consideration.

Regarding the content of the particular issue, “Multi-Agent Systems: Control Spectrum,” it can take several directions of theoretical investigations and different practical areas for applications as it follows from the variety of the presented chapters.

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