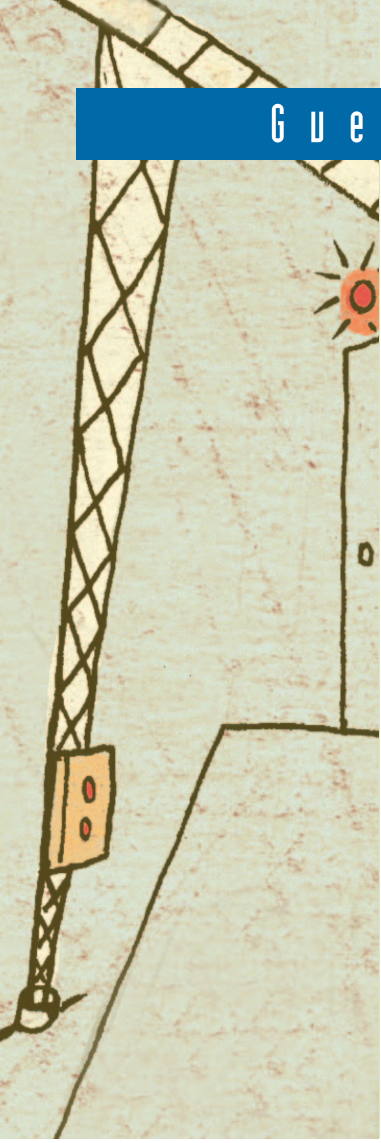

Intelligent Control in the Manufacturing Supply Chain

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Today's consumer is the most demanding in history. He or she requires frequent product improvements, immediate delivery, guaranteed reliability, and ever-decreasing prices if at all possible. Consider the relative evolutions of the VCR and the DVD recorder. While the VCR was the dominant mode of video recording for almost 20 years, the DVD recorder has moved from novelty to low-priced commodity in just three years, with many major enhancements and extensions being announced as we go to publication. For the manufacturer, this places enormous pressures in terms of limitations on capital investment, requirements for changed machine and factory configurations, and the need to minimize stock levels.

So who would be a manufacturer? Well, on a positive side, the world economy each year consumes a greater amount of manufactured goods than it did the previous year. So, despite what the newspapers say, manufacturing hasn't declined on a global level. What this means for manufacturers is that to be successful, they must "turn their business on a dime," adapting swiftly to product design changes, absorbing disruptions as though they were part of business as usual—all at a decreasing cost per item. For manufacturers who maintain their operations in developed economies, cost reduction generally means labor reduction, which leads to increased factory automation. But the pressure to manage continual change can also be a challenge for industrial automation and control systems.

Dealing with these pressures has placed a huge strain on the computer control systems that manage the automated decision and information processes required to run a manufacturing business. Traditionally, these systems conform to a strictly specified, fixed hierarchy of decisions (for example, planning, scheduling, shop floor execution, and machine control). They originated in an era of long-steady production runs, infrequent changes to product specifications, and more understanding customers. Algorithms for planning, scheduling, and so on were designed for monthly or weekly updating at best, product processing instructions were rarely altered, and control and equipment configurations were set in place for the life of the factory. As the pace of change increased into the 1990s, it was inevitable that researchers would seek ways to develop more adaptable, responsive manufacturing-control environments.

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Intelligent-control-system overview

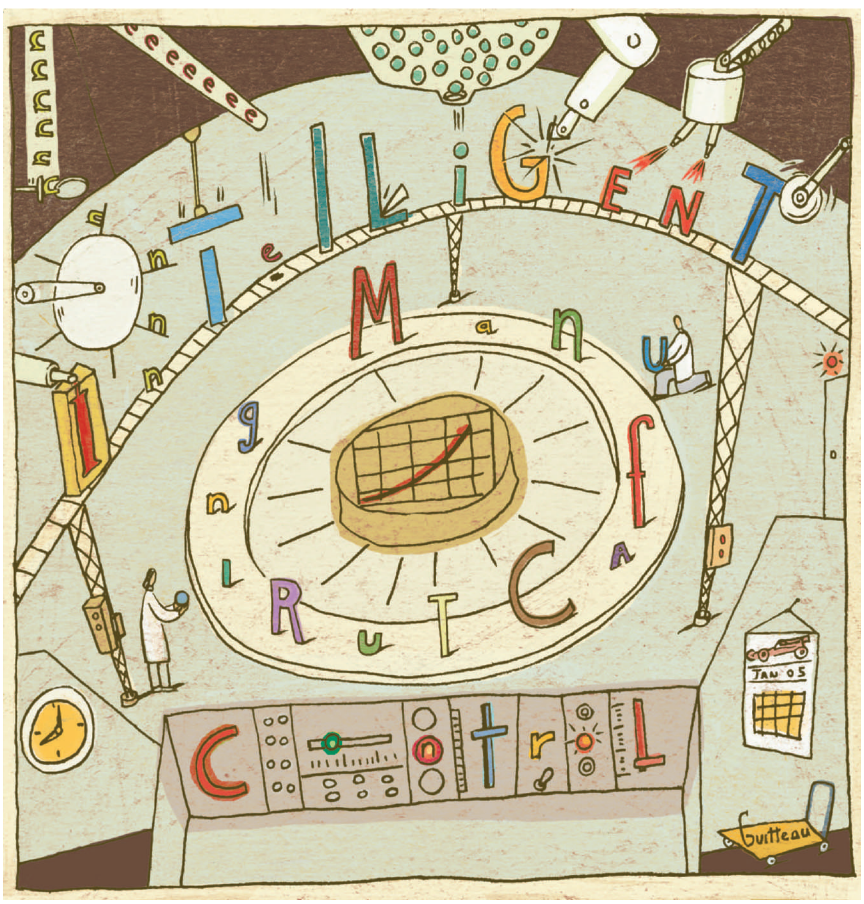
In recent years, a major thrust in addressing the requirements of adaptivity and responsiveness has been the application of tools from distributed artificial intelligence. In this special issue, we loosely refer to these tools as *intelligent control systems*. Typically, these tools are

- Adaptable to a changing environment
- Resilient to disturbance
- Distributed, in the sense that typically more than one decision-making element exists
- Dynamic in decision making

This special issue covers a wide spectrum of these tools. They range from modeling tools such as neural networks, fuzzy logic, and evolutionary programming, which have provided new routes for tackling complex problems in manufacturing processes' scheduling and control, to new distributed forms of manufacturing control and management systems. In particular, multiagent-based manufacturing control and management systems receive significant attention in this issue. Such approaches bring new features of flexibility and easy reconfigurability to industrial-control solutions. These features result from agent-based systems' basic properties such as a high degree of autonomy for decision-making units, the ability to communicate complex messages asynchronously, the capability to negotiate and cooperate, and, mainly, the ability to achieve complex global goals without a central decision element.

A development closely related to agent-based control is the holonic-manufacturing-systems methodology, which couples intelligent software elements such as agents with physical entities such as equipment, orders, and products to effectively provide a "plug and play" factory. Much of this technology is at the point where industrial deployment is a serious possibility, and several major systems vendors are considering integrating intelligent-control capabilities into their product offerings.

These new paradigms for control system design offer highly desired industrial breakthroughs because they promise to provide a high level of flexibility and easy reconfigurability in manufacturing and supply chain management processes. So, they really do represent a substantial deviation from the "traditional," strictly hierarchy-oriented system philosophy.



Current and future trends in intelligent control

The articles in this issue reflect four important trends in the development of intelligent control systems for the manufacturing supply chain.

A multilevel perspective

Developments in this application area have previously tended to focus on one of three distinct levels of operation: real-time control systems, factory operations management, or supply chain coordination. They've rarely considered all three collectively. In "Industrial Adoption of Agent-Based Technologies," Vladimír Mařík and Duncan McFarlane point out that many similarities exist between problems at these three levels. They propose that the consideration of common methods and development approaches might enable simplified development and results that can be more readily integrated. In "ADACOR: A Collaborative Production Automation and Control Architecture," Paulo Leitão, Armando Colombo, and Francisco Restivo propose the Adaptive Holonic Control Architecture for distributed manufacturing systems as a model for examining the multiple levels of distributed decisions in a single framework. In so doing, they take prior holonic-manufacturing research one step further. The significant developments in industrial communications and distributed computing systems in recent years have been a key enabler for this progress.

Industrially viable solutions

Developments in intelligent-control-systems research were for some time the domain of academic simulation only. The development of industrial-strength software development environments, particularly for software agents, is making their integration into industrial hardware an increasing possibility. In "Methodologies and Tools for Intelligent Agents in Distributed Control," Francisco P. Maturana, Raymond J. Staron, and Kenwood H. Hall introduce a detailed case study of deploying agent technology in the design of a highly distributed shipboard water-cooling system. They describe that system's implementation and a set of tools for supporting its implementation. At a higher operational level, in "ExPlanTech: Multiagent Support for Manufacturing Decision Making," Michal Pěchouček, Jiří Vokřínek, and Petr Bečvář describe a series of industrial case studies in which an agent-based planning system has undergone trials and evaluation. This reflects the general point that many control systems vendors appear to be seriously examining the role of technologies such as software agents, along with neural networks and fuzzy logic, in their product portfolio.

Intelligent-control-systems methodologies and evaluation approaches

Methodologies and evaluation might not be the most glamorous aspects of any technological development. However, evidence of objective, thorough evaluations, coupled with the availability of detailed, repeatable methodologies, is a key reason for the increasing confidence in considering industrial deployment. Many early papers in intelligent systems for manufacturing applications focused heavily on new architectures and different algorithms; fewer focused on evaluation and methodological development. Notably, several articles in this issue feature detailed evaluations. For example, "Aggressive Pricing to Exploit Market Niches in Supply Chains," by Sabyasachi Saha and Sandip Sen, and "Holonic Job Shop Scheduling Using a Multiagent System," by Scott Walker, Robert Brennan, and Douglas Norrie, give you an opportunity to benchmark the distributed, intelligent control approaches they each propose. Furthermore, Maturana, Staron, and Hall offer detailed guidelines on development of an agent-based system for real-time control, and Leitão, Colombo, and Restivo provide direction in the development of their multilevel ADACOR system. It's important to note that simulation is currently the only way to evaluate the emergent (aggregate) dynamic behavior of the global agent-based industrial solutions.

Software environments for agent-based control development

Linked with the dependency on simulation is the need to move to more user friendly and efficient software environments for developing intelligent control systems. Two critical concerns are reusable software and effective simulation. To limit repeated development of common control functions, intelligent-control-systems components must be reusable so that we can move away from the need to develop, debug, and validate each instance. Also, to test, validate, and evaluate intelligent control systems, an important enabler is such systems' simulation, coupled with appropriate emulation of the physical environment. In practice, an appropriate simulation study should precede each implementation. Bringing these two points together, a challenge for today's agent-based-control developers is the direct reuse of the simulation code in the runtime implementation. In this issue, the articles by Maturana, Staron, and Hall, and Pěchouček, Vokřínek, and Bečvář address this challenge.

This special issue features articles addressing the development of intelligent control systems for all levels of operation in the manufacturing supply chain—from real-time control to supply chain coordination. In particular, this issue aims to position this research in terms of its potential longer-term impact on industry and in terms of issues related to more widespread deployment. Additionally, we most keenly sought application studies—studies that could bring these methods to life and demonstrate their usefulness in an industrial context. We hope you will find this to be the case! The issue therefore aims to provide you with a unique position statement of the state of deployment of these intelligent-control methodologies across the manufacturing supply chain, giving a sense of where such applications are suitable, how the applications should proceed, and how you might evaluate the results. ■

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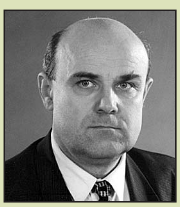

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