Experience with Holonic and Agent-Based Control Systems and Their Adoption by Industry

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Abstract. Currently industrial automation systems are built using a hierarchical top-down approach, yielding tightly coupled and low flexibility systems. Holonic and intelligent agent-based industrial control systems have the potential to be much more highly robust and flexible systems with very loose coupling between subsystems. Despite this potential these systems are slow to be adopted by industry. This paper explores Rockwell Automation’s current agent philosophy, application experience, the obstacles to widespread adoption of agent technology in industrial automation systems, and its recent activities to overcome some of the obstacles.

1 Agent Philosophy

Holonic manufacturing systems (HMS) represent a novel paradigm to address some critical problems faced by manufacturing businesses in the twenty-first century. Ever increasing customer requirements are calling for new manufacturing strategies satisfying the needs for (i) open and dynamic structures to allow the on-line integration of new subsystems or removal of existing subsystems from the system without the need to stop and reinitialize the working environment, (ii) agility to adapt quickly to continuous and unanticipated changes in the manufacturing environment, and (iii) fault tolerance to detect and recover from a failure by minimizing its impact on the whole system.

Distributed intelligent manufacturing can meet these requirements. The more traditional sequential and centralized solutions, used within the scope of such agile environments, do not work since they are slow to react, impose operational bottlenecks and are a critical point of failure. Holonics is a decentralized ‘bottom up’ approach and provides principles to ensure a higher degree of responsiveness and handling of system complexity. The fundamental building blocks of a HMS are called holons, fundamentally as presented in [1], to reflect the fact that these entities: (i) are both parts and wholes and (ii) behave simultaneously in an autonomous and cooperative fashion.
The vision of a holonic factory, in which all the operations (including product ordering, planning, scheduling, manufacturing, and invoicing the customer) are based entirely on holonic principles, covers several levels of information processing for manufacturing. At least three separate levels can be distinguished:

- **real-time control**, tightly connected with the physical level of manufacturing equipment
- **production planning and scheduling** both on the workshop and factory level
- **supply chain management**, integrating the particular plant with its external entities (suppliers, customers, partners, sales network, etc.)

The particular research results in the holonic field are connected mainly with real-time control. In the other two subfields, the research centers on the philosophical or architectural level, but the particular implementations exclusively use the research results of multiagent systems (MAS). The HMS community has fully realized that the function block based real-time control (utilizing the IEC 61499 standard described, for instance, in [2]) is applicable to control tasks only, i.e., they are not the best way to implement the higher level reasoning of agents. Thus it is necessary to leverage the results achieved in the MAS field to widely exploit the visions of a holonic factory. Several general architectures for combining both the function block and MAS technologies have been designed. The most popular new holon model encapsulates one or more function block oriented devices into a wrapper containing a higher-level software component (see Figure 1).

![Fig. 1. Model of a PLC-based automation controller with holonic agents using 61499 function blocks for real-time control](image)

Rockwell Automation (RA) has realized that the 61499 function blocks are not as ubiquitous as the IEC 1131 programmable controller languages described in [3], and therefore has implemented its multiagent system using standard relay ladder logic (one of the 1131 languages) instead of 61499 function blocks. The RA model for its holonic agents (or simply, agents) is still one containing a higher-level intelligent software component, as shown in Figure 2.