Overview of the Special Issue on Intelligent Manufacturing Systems

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The concept of an ''intelligent manufacturing system'' (IMS) is a very broad one that has come to play a major role in manufacturing research in recent years. It is a concept that defies precise definition because one major research objective is to couple almost human levels of intelligence with advanced manufacturing technology in order to develop new generations of manufacturing systems that are agile in their capabilities, as are people. However, science does not yet provide us with deep and widely accepted models of how people achieve such agility, and researchers in IMS must therefore adopt engineering pragmatism and target their research on improvement and innovation in manufacturing processes that address the weaknesses of existing systems that are *not* agile, *not* intelligent, *not* adaptive, and so on. Intelligence is a term more readily defined in terms of its absence than in the particular characteristics that define its presence.

Problems of definition have not impeded research, however, and the international manufacturing research community is collaborating highly effectively in a wide-ranging series of projects under the aegis of intelligent manufacturing. This special issue presents the background to these projects, the structure of the international IMS research program, and a range of examples of advanced research on, and practical applications of, intelligent manufacturing systems.

Much of the inspiration for the international IMS research program came from concepts developed by Dr. Yoshikawa, President of Tokyo University, who saw the need for a ''post mass production paradigm'' that was capable of sustaining economic growth without depending on mass production and consumption. Tomiyama develops the case for such a paradigm shift in his paper ''A Manufacturing Paradigm Toward the 21st Century.'' This paper is the latest version of a technical report that was circulated widely during the inception of the IMS program and influenced many of the research projects. In particular, the notions that ''soft artifacts'' should be designed which were dynamically reconfigurable, and that a post mass production paradigm would be knowledge-intensive, resulted in major themes in the GNOSIS test case.

Gaines and Norrie provide an overview of the international IMS research program drawn primarily from the final report of the International Steering Committee in their paper ''Coordinating Societies of Research Agents—IMS Experience.'' They describe in greater detail the activities of the IMS consortium that undertook Test Case 7, ''GNOSIS: Knowledge Systematization: Configuration Systems for Design and Manufacturing.'' The GNOSIS test case made heavy use of the Internet to coordinate its research activities, and tools developed to support manufacturing were also used to coordinate research in manufacturing. The paper suggests that the IMS research program is itself an example of a new distributed agent research paradigm in which information technology is used to aid the systematic acceleration of scientific research.

Another of the research consortia in international IMS research program focuses on the development of ''holonic manufacturing systems''. These systems involve autonomous intelligent entities called holons dynamically collaborating to satisfy both lo-

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cal and global manufacturing goals. A "holon" differs from the increasingly popular "intelligent agent", as commonly defined, in being not only a software module but also, optionally, including a hardware module. Valckenaers et al in "Holonic Manufacturing Systems," describe the historical background and concepts behind holonic systems and summarize work carried out by the consortium during the initial phase of the IMS program. They then describe a holonic control system developed for a flexible assembly system involving four robots and an integrated transport subsystem. In their first implementation, the holonic system showed promise in several areas, but, as the authors point out, the testing involved only a limited range of situations and further development and testing over a wider range are required.

Further work on holonic systems is described by Heikkilä, Järviluoma, and Juntunen in "Holonic Control for Manufacturing Systems: Functional Design of a Manufacturing Robot Cell." Here the focus is on developing a functional architecture for a holonic system and evaluating its application to a plastics moulding and fabrication workcell, using simulation. A generic structure is used for each holon, comprising Proposer, Planner, Requestor, Executor, and Monitor modules. The workcell, involving a molding machine, welding machine, two robots, conveyor, and AGV was modeled as a holonic system in considerable detail. The simulation showed that the holonic system was able to adapt to unexpected situations (e.g., conveyor jammed) by reallocating the tasks locally, resulting in robust and interruptable behavior.

For complex agent-based systems, the common approach to the necessary cooperation between entities involves some form of negotiation. This may be single-step negotiation as in the Contract Net or a more sophisticated multistep negotiation and in either case may involve a Mediator (Facilitator, Coordinator). An alternative approach to collaboration is behavior-based, and this has been used in studies of collective or emergent behavior ("intelligence"). Tharumarajah and Wells use this approach in their paper "A Behavior-Based Approach to Scheduling in Distributed Manufacturing Systems."[3] Their novel scheduling model which involves adaptive mechanisms with learning showed a scheduling performance comparable with well-known heuristics under extremes of balanced and unbalanced load conditions. Further development of this very interesting model is in progress.

Schweyer is another member of the GNOSIS consortium, and her paper focuses on "Multiagent Design of a Role-Based Model for Project Management." It models the project life cycle through a transition system describing its behavior in time together with the feedbacks and roles representing the project organisation. This paper represents philosophies that have become accepted in much IMS research: that the entire enterprise must be taken into account when designing intelligent manufacturing systems; that project management is at the heart of the enterprise; and that enterprise modeling and project management involve representing both the human and the technological agents within the enterprise.

The international IMS research program is designed to be a long-term activity with a mandate extending over at least the next decade, and with many ambitious and far-sighted projects that involve fundamental changes in manufacturing. It might be thought that participation in the research program only involves potential long-term gains and hence is only appropriate to the advanced research divisions of large corporations. However, experience during the IMS Test Cases showed that international collaboration has side-effects which produced short-term benefits for all involved including small and medium-sized enterprises. The final paper by Dagnino and Morgan on "A Virtual Factory Model for Manufacturing Graphite Composite Natural Gas Vehicle Tanks"[3] describes an application of concepts and technologies derived at EDO Canada from the GNOSIS Test Case for the immediate needs of a small manufacturing company.

[3] Article to appear in the next issue of Integrated Computer-Aided Engineering, 4(4), 1997, due to space limitation.