Information Technology for Automated Manufacturing Enterprises: Recent Developments and Current Research Issues

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Information Technology for Automated Manufacturing Enterprises: Recent Developments and Current Research Issues

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Information technology has played an important role in the continuing efforts of industries worldwide to make their manufacturing systems, processes, and overall enterprises more agile and productive. It is important that researchers and practitioners working in areas related to flexible manufacturing systems (FMS) address the ramifications of these emerging information technologies and their impact on manufacturing system development and operations.

In view of these developments, we see a need to strategically describe both the potential of the leading information technologies for the FMS research community and their future trend. Enterprise information technology is having a major impact on all manufacturing organizations, large or small. It especially has had an impact on the system applications for coordinating the complex array of manufacturing data, business decisions, work flows, and processes, which have become increasingly important for today's enterprises to maintain their competitive edge. From that standpoint, information technology has played an important role in the effort to make organizations more integrated and productive.

With the capability of computer software, hardware, and communications growing rapidly, the technological bottleneck gradually has shifted toward enterprise integration and interorganizational coordination. We identify the following agenda for research in the targeted areas:

- Artificial intelligence methods for flexible manufacturing
- Data and knowledge structures for design, process planning, and control
- Data modeling for process design and flow control
- Empirical analysis of CIM and related automated programs
- Economic and strategic analysis of information technology (IT) investments in flexible automation

- Enterprise modeling and system integration
- Flexible networking of automated manufacturing systems
- Information infrastructure for agile manufacturing enterprises
- Information technology for simultaneous manufacturing and rapid manufacture of prototypes
- Information technologies for supporting supply-chain management
- Knowledge-based reasoning for manufacturing decision support
- Neural-network methods for automated manufacturing systems
- Process re-engineering in manufacturing enterprises using IT
- Technology road map for industrial system integration
- Production databases for job loading and scheduling in CIM

The problem of system integration has been with us for a very long time (Shaw, Solberg, and Woo, 1993), but some recent changes have occurred in the way that we think of the problem. Until recently, we operated under the assumption that large, complex problems could be dealt with effectively by working on smaller pieces. Most of our research has been based on "reductionism," or the practice of decomposing a problem into smaller, more manageable pieces, with the implicit assumption that the collection of solutions to these smaller problems would somehow combine to yield a solution to the larger problem.

Increasingly, the research community is abandoning this paradigm in favor of one that recognizes a need for explicit treatment of integration (Seidmann, 1993). We are still in the early stages of this paradigm shift. Indeed, most of the community continues to operate under the old paradigm, which, after all, still provides a rich set of opportunities for productive work. The evidence that something more is needed, however, continues to accumulate. In the past several years, several efforts have begun to address coordination and integration issues. These efforts were made possible largely because of the advent of information technology, in particular the technology for computer networking and the software for enhancing group productivity.

The recent popularity of the Web technology and the national attention paid to the construction of the information highway are all part of this trend. Out of the confluence of these ideas, several information system research areas stand out as being of particular relevance to manufacturing enterprises, such as collaboration technology and distributed artificial intelligence for integrated manufacturing (Shaw and Whinston, 1988; Shaw and Fox, 1993; Gupta, Stahl, and Whinston, 1997), multiagent systems for process integration (Tan et al., 1996), electronic document management for coordinating work flows (Dong, Dewan, and Seidmann, 1996), and the use of electronic data interchange (EDI) for links with suppliers (Seidmann and Wang, 1995), to name just a few.

One theme emerging from these developments is the need to achieve better enterprise integration through information technology. System integration has several objectives, such as establishing good communication and coordination procedures, promoting collaboration among a group of networked participants, sharing information among different entities across an information system, maintaining a variety of functional modules to make an information system flexible and adaptive, efficiently managing the coordination between different information systems in an enterprise, and consolidating various business functions in information systems to make the processes more efficient. Some crucial issues in system integration involve the identification of coordination mechanisms, the representation of different roles and functions, and performance measures. It also is important to identify the internal and external metrics of the information system and determine the impact of the internal metrics on the external metrics. This includes such performance measures as the turnaround time, throughput rate, decision outcome, solution quality, timeliness of delivery, and system robustness (Tan et al., 1996). The system integration problem has several dimensions, each of which has its own set of objectives. We list them here in terms of their different levels of abstraction:

- Integration of heterogeneous information systems, databases, and application software to facilitate the data flow among them and make the overall system robust and efficient. Such integrated enterprise information systems can serve as the information infrastructure for managing corporate "data warehouses" as well as provide the connectivity necessary for sharing corporate information resources.
- Integration of the tool management system with the material handling system and the MRP-II planning system. This includes finite scheduling with machine tools and finite tools requirements for cutting tools, jigs, and fixtures resources (Gray, Seidmann, and Stecke, 1993).
- Integration of different physical stages in business processes to improve the internal performance metrics, for example, information systems (IS) for the integration of the design, engineering, manufacturing, and assembly stages to improve the coordination between them and increase organizations' ability to react to any emerging demands. This integration can be extended further to improve the coordination of different functional units. For example, information systems can integrate of the marketing, product design, R&D, and production functions of an organization to improve the performance of the product development life cycle.
- Integration of subsystems into a well-coordinated, networked system; for example, an information system for the integration of a network of suppliers, producers, and distributors to reduce the inventory buildup in the supply chain. Such an information system can provide the basis for enterprise-level and interorganizational coordination to support core business processes such as order fulfillment.
- Integration of networked information resources through the Web technology. As the Internet and World Wide Web gain importance, managing them has become an important aspect of enterprise information management. The Web can be used to display corporate information, support interactive query processing, distribute application software, manage intra- and interorganizational transactions, and help share the global network of information resources. All these functions point to the need for integration. This is a rapidly growing area, and we are bound to see more and more research done on the topic.

To deal effectively with the problem of system integration in all the dimensions just outlined, we need a general framework that can be used as a formalism to represent and analyze the structure of the enterprise activities involved and their interactions. The common feature of system integration is that it requires coordination among physically or logically distinct and sometimes complex processes, component units, and subsystems. For example, plants now are integrating the process of planning tasks with a production plan. Machining parameters are optimized according to the desired production file and the tool database (Kim, Schweitzer, and Seidmann, 1995).

Generally, the need for automation can be viewed as coming from three levels: the interorganizational level, the enterprise level, and the process level. The articles published in this special issue touch on all three levels and provide a comprehensive set of issues and perspectives that will help set the future research agenda.

One result of automating manufacturing enterprises usually is the increasing use of computer networks to link each of the functional and value-adding areas. This in turn has transformed the enterprise environment into one characterized by distributed control and asynchronous activities, leading to the need for new paradigms for planning and control. Gupta et al. (1997) describe a new approach to the planning and control of flexible manufacturing systems that, using the concept of stochastic equilibrium, will provide the true manufacturing costs associated with an organization-wide, activity-based costing system through appropriately calculated priority prices. They perform simulation analysis to compare the effect of using a pricing mechanism as well as priority classes. Furthermore, actual implementation of the pricing mechanism also is addressed.

Veeramani and Wang (1997) focus on the use of "resource prices" as the basis for coordinating real-time manufacturing activities in a manufacturing enterprise. As in the first article in this issue, the underlying manufacturing model is based on queueing networks while the resource allocation is based on the concept of bidding and auctioning (of manufacturing jobs). Asymptotic bounding analysis, mean value analysis, and simulation are used to evaluate the control schemes from the communication system's perspective. Some interesting insights resulting from the simulation study are provided.

Moving to yet a higher level of the manufacturing enterprise, Moynihan (1997) describes the real use of an enterprise model to integrate corporate information management. The traditional manufacturing operation management literature, true to its operations research roots, has been dominated by issues related to optimization problems on the operational level. However, one of the most needed skills in managing today's manufacturing enterprises is knowing how to manage the diverse arrays of manufacturing, work flow, product, customer, market, and cost information. Furthermore, an information system needs to be in place in the enterprise to consolidate and integrate these various types of corporate data, which when used appropriately can ensure the efficient uses of manufacturing resources and proper responses to market demands. This shifting of emphasis from process optimization to information management defines the new core competency of today's automated manufacturing enterprises.

Companies in the United States in recent years gradually have spent more on information technology than on traditional machinery and other capital equipment. In that light, it is of great importance to ensure that such large investments pay off. However, the exact contribution of information technology to productivity gains is still unclear, hence the so-called IT productivity paradox. Barua and Lee (1997) take on the challenge of explaining this paradox. They raise a concern for a theoretical modeling issue in IT productivity studies and provide empirical evidence in support of the concern. Moreover, they demonstrate that input measurement problems, which probably cause the counterintuitive productivity outcome when IT is used, can be attributed to IT productivity estimates in an important prior study by Loveman (1994). Their thoughtful analysis indicates that, although some researchers questioned the gains from IT investments in the early phases of computerization because of a lack of systematic evidence, very significant productivity gains have been realized by large corporations in the manufacturing sector.

Looking ahead, the emerging electronic commerce will play an important role in the research areas concerning information technology for automated manufacturing enterprises (Kalakota and Whinston, 1996). Globally connected information networks will enable manufacturing enterprises to be more agile, adaptive, and flexible (Strader, Lin, and Shaw, 1996), keeping the whole supply-chain network well integrated (Lin, 1996; Hinkkanen, Kalatota, Saengcharoenrat, Stallaert, and Whinston, 1997). In that light, understanding the role of this global electronic Web in the implementation of enterprise processes, the coordination between business units as well as channel partners, and the interface with customers for automated manufacturing enterprises will become ever more critical.

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