COMPUTER CONTROL of FLEXIBLE MANUFACTURING SYSTEMS

RESEARCH AND DEVELOPMENT

Edited by
Sanjay B. Joshi
and Jeffrey S. Smith

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Sanjay B. Joshi

Department of Industrial and Management Systems, Pennsylvania State University, Pennsylvania, USA

and

Jeffrey S. Smith

Department of Industrial Engineering, Texas A&M University, Texas, USA

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Contributors

James S. Albus, National Institute of Standards and Technology, Building 220, Gaithersburg, Maryland, USA.

David Ben-Arieh, Dept. of Industrial Engineering, Kansas State University, Manhattan, Kansas, USA.

Eric D. Carley, Dept. of Industrial Engineering, Kansas State University, Manhattan, Kansas, USA.

Jarir K. Chaar, IBM Research Division, Thomas J. Watson Research Center, P.O. Box 704, Yorktown Heights, New York, USA.

Ai-Mei Chang, Department of Management Information Systems, University of Arizona, Tucson, Arizon, USA.

Hyuenbo Cho, Dept. of Industrial Engineering, Texas A&M University, College Station, Texas, USA.

C. Thomas Culbreth, Dept. of Industrial Engineering, North Carolina State University, Raleigh, NC, USA.

Edward S. Davidson, EECS Dept., The University of Michigan, Ann Arbor, Michigan, USA.

Annap Derebail, Dept. of Industrial Engineering, Texas A&M University, College Station, Texas, USA.

Gabriele Elia, Dipartimento di Automatica e Informatica, Politecnico di Torino, Corso Duca degli Abruzzi, Torino TO, Italy.

Sebastian Engell, Dept. of Chemical Engineering, Universität Dortmund, D-44221 Dortmund, Germany.

Frank Herrman, Fraunhofer-Institute IITB, D-76131 Karlsruhe, Germany.

Janette M. Hopkins, Dept. of Industrial Engineering, North Carolina State University, Raleigh, NC, USA.

Leslie Interrante, Industrial and Systems Engineering, The University of Alabama in Huntsville, Huntsville, Alabama, USA.

Sanjay B. Joshi, Dept. of Industrial and Management Systems Engineering, 207 Hammond Building, Pennsylvania State University, University Park, Pennsylvania USA.

Manjunath Kamath, School of Industrial Engineering and Management, 322 Engineering North, Oklahoma State University, Stillwater, Oklahoma, USA.

Russell E. King, Dept. of Industrial Engineering, North Carolina State University, Raleigh, NC, USA.

Thomas R. Kramer, National Institute of Standards and Technology, Building 220, Gaithersburg, Maryland, USA.

V. Jorge Leon, Texas A&M University, College Station, Texas, USA.

Grace Y. Lin, IBM Research Dvn., Thomas J. Watson Research Center, P.O. Box 218, Route 134 and Kitchawan Road, Yorktown Heights, NY 10598, USA.

Giuseppe Menga, Dipartimento di Automatica e Informatica, Politecnico di Torino, Corso Duca degli Abruzzi, Torino TO, Italy.

Colin L. Moodie, Purdue University, School of Industrial Engineering, West Lafayette, Indiana, USA.

Manfred Moser, ABB FLT GmbH, D-68309 Mannheim, Germany.

Richard Quintero, National Institute of Standards and Technology, Building 220, Gaithersburg, Maryland, USA.

Steven R. Ray, National Institute of Standards and Technology, Building 220, Gaithersburg, Maryland, USA.

Anthony D. Robbi, Discrete Event Systems Laboratory, Dept. of Electrical and Computer Engineering, Center for Manufacturing Systems, New Jersey Institute of Technology, Newark, New Jersey, USA.

David Rochowiak, Cognitive Science, The University of Alabama in Huntsville, Huntsville, Alabama, USA.

M. Kate Senehi, National Institute of Standards and Technology, Building 220, Gaithersburg, Maryland, USA.

John P. Shewchuk, Purdue University, School of Industrial Engineering, West Lafayette, Indiana, USA.

Jeffrey S. Smith, Industrial Engineering Dept., 239A Zachry Engineering, Texas A&M University, College Station, Texas, USA.

James J. Solberg, School of Industrial Engineering, Purdue University, West Lafayette, Indiana, USA.

Ben Sumrall, Acustar Inc., Huntsville Electronics Division Complex, Huntsville, Alabama, USA.

Dharmaraj Veeramani, Dept. of Industrial Engineering, University of Wisconsin-Madison, 1513 University Avenue, Madison, Wisconsin, USA.

Richard A. Voltz, Dept. of Computer Science, Zachry Engineering Center, Texas A&M University, College Station, Texas, USA.

Theodore Williams, Purdue Laboratory for Applied Industrial Control, Purdue University, West Lafayette, Indiana, USA.

S. David Wu, Lehigh University, Bethlehem, Pennsylvania, USA.

Richard A. Wysk, Dept. of Industrial Engineering, Texas A&M University, College Station, Texas, USA.

MengChu Zhou, Discrete Event Systems Laboratory, Dept. of Electrical and Computer Engineering, Center for Manufacturing Systems, New Jersey Institute of Technology, Newark, New Jersey, USA.

Preface

With the approach of the 21st century, and the current trends in manufacturing, the role of computer-controlled flexible manufacturing will take an integral part in the success of manufacturing enterprises. Manufacturing environments are changing to small batch (with batch sizes diminishing to a quantity of one), larger product variety, production on demand with low lead times, with the ability to be 'agile.' This is in stark contrast to conventional manufacturing which has relied on economies of scale, and where change is viewed as a disruption and is therefore detrimental to production. Computer integrated manufacturing (CIM) and flexible manufacturing practices are a key component in the transition from conventional manufacturing to the 'new' manufacturing environment.

While the use of computers in manufacturing, from controlling individual machines (NC, Robots, AGVs etc.) to controlling flexible manufacturing systems (FMS) has advanced the flexibility of manufacturing environments, it is still far from reaching its full potential in the environment of the future. Great strides have been made in individual technologies and control of FMS has been the subject of considerable research, but computerized shop floor control is not nearly as flexible or integrated as hyped in industrial and academic literature. In fact, the integrated systems have lagged far behind what could be achieved with existing technology.

Most shop floor control systems are focused on information and data collection and monitoring rather than on control. Many implementations of flexible systems are soft wired versions of hard automation and fail to employ the additional capabilities available through the use of computers for control. These systems lack the required flexibility to change without major effort. Further, manufacturers with flexible manufacturing systems do not use the systems in a flexible manner. Users of FMS tend to standardize products and increase batch sizes to ease the operation of the system, and to justify the economics of using the systems. The cost of such systems is often prohibitively high and hence justification of such systems has led to their use in high volume production which does not require or exploit whatever flexibility is available. Cost is the factor that has also kept such systems from being useful to small manufacturers, which will form the nucleus of the future manufacturing environments.

The following are viewed as critical needs for computerized flexible manufacturing systems if they are to become commonplace in today's manufacturing sector:

1. *Reduction in costs of systems.* To make such systems the core of all manufacturing will require that costs to develop, implement and maintain systems be of an order of magnitude that will permit widespread use and not require large volumes to justify cost. A key component of cost is software cost; it is expected that further research will focus on the key issue of making computer control of flexible manufacturing systems feasible for the small manufacturers that will be a part of the 'distributed' manufacturing environment of the future.
2. *Increased flexibility and the ability to use it.* As the product volumes and lot sizes drop, systems will have to be designed with greater flexibility, since changes will now be the norm rather than the exception. This will impose a tremendous burden on the control system which will now have to be built to handle changes as well as increased demand in flexibility. Today's control systems, although increasingly software based, are still too inflexible to respond to the new demands that will be imposed.
3. *Seamless integration.* Another factor that will impact future control systems is the capability of providing a completely integrated environment, where individual elements are designed and used in a manner such that complete integration is possible. Similar to the trend in computers, control systems will have to work with open architectures and application program interfaces to allow continued progress in the forward direction. Current systems in place are usually specific for an installation and sold/built as a monolithic turnkey system, and end users typically have no capability of modifying control systems in house, hence they are locked into proprietary systems. The control systems of the future will provide an open architecture, with well-defined modules and application interfaces which will allow users and third party vendors to provide different functional modules which would work together with other modules in an integrated manner.
4. *Reusability.* As the trend towards recycling and reuse continues, along with the need for frequent changes, manufacturing system elements – both hardware and software – will have to be designed with reuse in mind. Turnkey systems will be a thing of the past, as the need for reconfiguration will lead to modular systems that can be easily put together and taken apart and pieces reused when need to reconfigure arises.

Unless significant improvements are made in the control and operation of computerized flexible manufacturing systems, these inflexible manufacturing systems will prove to be the Achilles' heel of future manufacturing. With this view in mind, this book attempts to provide a glimpse of several aspects of the current developments in control of flexible manufacturing systems.

The chapters in the book address several important topics in the area of computer control of FMS. Individual researchers have addressed specific problems in isolation with the assumption that solution to pieces of the whole will eventually result in solution to the whole problem. This may not be as simple as once thought, and integration as a topic of research will take on a larger role in the future.

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CHAPTER 1

The role of CIM architectures in flexible manufacturing systems

Theodore J. Williams, John P. Shewchuk and Colin L. Moodie

1.1 INTRODUCTION

The needs of world-wide industry today require manufacturers to modify their operations to ensure:

1. a better and faster response to their customers' requirements;
2. ever-higher quality for their products;
3. increased flexibility and faster response in the introduction of new products and in responding to the needs of the marketplace.

At the same time, they face further requirements to increase their overall company earnings while

1. decreasing the environmental impact of their factory's operations;
2. decreasing the plant personnel;
3. improving plant personnel working conditions and job satisfaction.

Integrated manufacturing carried out with the aid of computers has been seen by many as the means by which much of the above could be accomplished. Studies almost universally show that if a manufacturing enterprise can integrate the operations of its plants so that all available information affecting them can be used, then very large economic returns over the best present-day, non-integrated methods are both possible and likely. Projects to achieve such an integration are generally collected under the pseudonym computer integrated manufacturing, or CIM. This is because extensive use of computers appears to be a universal necessity to achieve the task undertaken.

The expected gains have been so high that numerous projects in many industries have been undertaken to achieve them, but the results have been decidedly disappointing in many cases. There have been several major causes for this. Primarily, this has been due to the fact that those planning these projects have not realized the breadth and magnitude of the overall effort necessary and the resulting capital and other resources required. They have also not developed a total plan for the overall project necessary prior to commencing implementation, and thus, have neglected to outline the **total** effort needed.

What is needed, therefore, for each company contemplating a major computer-based integration effort, is for the company to develop a master plan covering **all** of the anticipated efforts required to integrate the whole of the company or factory operation.

After this, smaller projects within the monetary and personnel resources capability of the company can be initiated with the knowledge that the sum of these and all succeeding projects will result in the final total integration of the company's activities. This will be possible provided that the requirements of the initial planning effort, or master plan, be followed in each and every one of the resulting projects.

But the detail and effort required for even the master planning activity is itself large and if done improperly will only lead to difficulties later. Thus, there is a need for a methodology to assure that the master plan is complete, accurate, properly oriented to future business developments and carried out with a minimum of resources (personnel and capital) necessary. This methodology presents a detailed description of the tasks involved in developing the master plan including its continual renewal. It gives the detail necessary both as to specifics and to quantity of information and data. It specifies the interrelationship of the informational, the human organizational and the physical manufacturing aspects of the integration considered, the management considerations and concerns and the economic, cultural, and technological factors involved, as well as the details of the computer system required. This planning effort is greatly aided by the use of a reference architecture to guide the project.

An **enterprise reference architecture** models the whole life history of an enterprise integration project, from its initial concept in the eyes of the entrepreneurs who initially developed it, through its definition, functional design or specification, detailed design, physical implementation or construction, and finally operation to obsolescence. The architecture becomes a relatively simple framework upon which all the functions and activities involved in the aforementioned phases of the life of the enterprise integration project can be mapped. It also permits the tools used by the investigators or practitioners at each phase to be indicated.

At the same time, the architecture provides the framework for all

Table 1.1 Benefits of the use of an architecture

1. Verification of completeness and consistency for all described functions and objects (business processes, data, material, and resources, including tools and fixtures) at any detailing level.
2. Simulation of the enterprise model at any level of detail.
3. Easy and fast change of the model in case of changing business processes, methods, or tools.
4. The use of the model to initiate, monitor and control the execution of the enterprise's daily operation.
5. Repeated resource allocation during the execution of business processes to enable better and more flexible load distribution on the enterprise's resources.
6. Model generation for existing enterprises as well as for enterprises yet to be built.

master plans and CIM program proposal activities. It also explains better than any other tool the relationships of the elements of the CIM system. It is thus the 'glue' that holds all aspects of the project together.

An architecture should illustrate clearly all the following aspects of the enterprise:

- enterprise decision making;
- enterprise activities;
- enterprise business processes;
- enterprise information exchange;
- enterprise material and energy flows.

If it does not, it cannot give a complete picture of the enterprise and its activities. The overall benefits of the use of an architecture are given in Table 1.1.

1.2 TYPES OF ARCHITECTURES

An architecture can be defined as a description (model) of the structure of a physical or conceptual object or entity. Thus, there are two and only two types of architecture which deal with the integration of manufacturing entities or enterprises. These are:

1. The structural arrangement (design) of a physical system, such as the computer control system part of an overall enterprise intergration system.
2. The structural arrangement (organization) of the development and implementation of a project or program such as a manufacturing or enterprise integration or other enterprise development program.

Most of the previous work on CIM architectures has involved Type 1 architectures. Some examples of these works are:

- The CAM-I Advanced Factory Management System model, developed in the late seventies by CAM-I (Computer Aided Manufacturing International), a non-profit organization promoting co-operative R and D efforts in CAD/CAM.
- The AMRF (Advanced Manufacturing Research Facility) hierarchical control model, developed by the National Bureau of Standards in the early eighties.
- The RAMP (Rapid Acquisition of Manufactured Parts) architecture, developed for the US Navy (Litt, 1990).

There are only **three** major architectures known at this time which are Type 2 architectures. These are:

1. The **open system architecture for computer integrated manufacturing – CIM-OSA**, in development by the European CIM Architecture consortium (AMICE (backward acronym)) under ESPRIT projects 688, 2422, and 5288 of the European Community. This work was initiated in 1984.
2. **GRAI-GIM**. The **GRAI integrated methodology**, developed by the GRAI Laboratory of the University of Bordeaux in France. This work resulted from the production management studies initiated at the GRAI Laboratory as early as 1974, and has its current form since about 1984.
3. The **Purdue enterprise reference architecture** and related **Purdue methodology**, as developed at Purdue University, Indiana, USA, as part of the work of the Industry-Purdue University Consortium for CIM. The work started formally in 1989, but bears on the **Purdue reference model** started in 1986 and earlier work of the Purdue Laboratory for Applied Industrial Control dating back to the mid-seventies.

In this chapter, we are concerned with Type 2 architectures and their role in FMS. Each of the Type 2 architectures is briefly described below.

1.2.1 CIM-OSA

CIM-OSA consists of an **architecture** and an **integrated methodology** which supports all phases of a CIM system life-cycle, from specification of requirements through system design, implementation and operation. The architectural framework is the well-known 'CIM-OSA cube' (Fig. 1.1), which specifies models in terms of three dimensions (attributes): modeling level (requirements definition, design specification and implementation description), level of solution specificity (generic, partial and particular), and view (function, information, resource and organization).

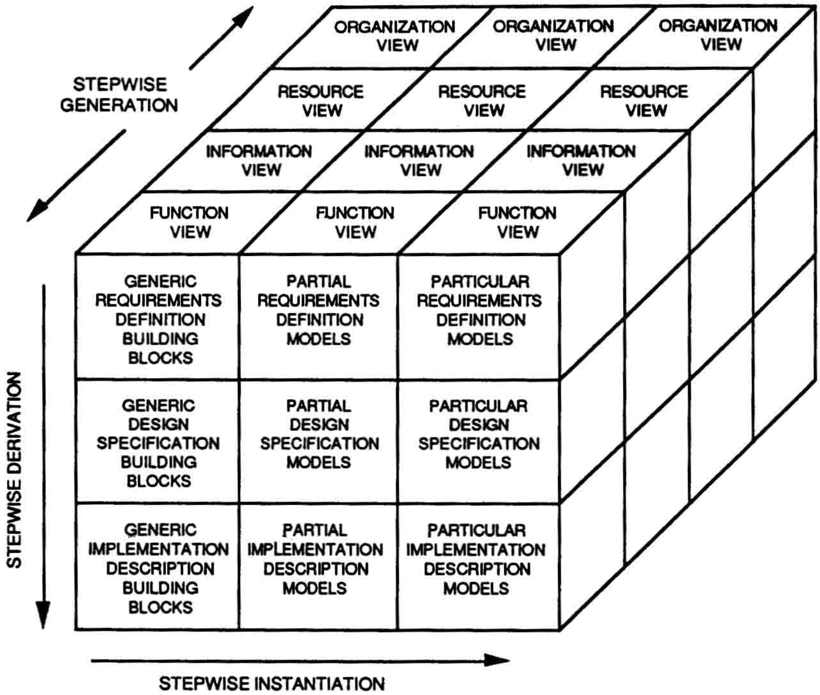

Fig. 1.1 CIM/OSA modeling framework (after Jorysz and Vernadat, 1990a).

The integrated methodology is based upon the concept of three levels of integration in a CIM system: physical system integration, application integration and business process integration. The models which are constructed during execution of the methodology and their order of construction, are determined by three model creation processes: **instantiation**, **derivation**, and **generation**. Each of these processes corresponds to movement along a cube axis, as shown in Fig. 1.1.

The methodology is built upon a top-down approach (derivation) to achieve integration between each of the three integration levels. The business requirements of an enterprise are first captured in a requirements definition model (set of models formed by stepwise instantiation and stepwise generation at the requirements definition level). From these requirements and consideration of all specific constraints of the particular enterprise, the design specification model is then constructed. Finally, based upon this model, the implementation description model, a description of the actual CIM system to be implemented is developed. These models are constructed in the **integrated enterprise engineering environment**, a comprehensive set of modeling concepts, tools and support for model creation. Once the implementation model has been completed, it is released to the **integrated enterprise operation**