Distributed Manufacturing

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Editor

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Paradigm, Concepts, Solutions and Examples

Springer

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Foreword

In recent last years it has become obvious to many companies that, to succeed, they need more effective support for operations and to implement better organisational principles and practices. It is clear that the new industrial world is more complex and more difficult to manage. We need novel organisational and management paradigms in order to uncover and exploit new thinking. Innovation pressures have forced the emergence of Networked Organizations seeking to access innovation resources globally and to secure lasting efficiency competitive advantages.

The networked economy has been enabled and has developed as a result of information and communication technology (ICT) for interorganisational collaboration. Market environments have become much more agile and turbulent and organisations more open under the influence of the rapid advancement of information processing devices and network technologies. Therefore, business strategic and process management, which oversee the overall value creation of products, are the focus of many companies.

Nevertheless, companies have taken rather different approaches to respond to the changes. Some have formed strategic alliances to capture new market opportunities, some have improved existing relationships with their supply network members to enhance the entire value creation supply chains, and some are planning to make changes but in a rather slow manner. Actual cases of industrial implementation of Distributed Manufacturing have shown its effectiveness in responding to the new challenges of the current turbulent and competitive global market, although a number of various barriers still prevent their wider application.

The aim of this book is to promote the adoption of Distributed Manufacturing solutions already experienced by industry players as part of the realisation of the concurrent enterprise (CE) vision, established by the European CE community and represented by CE-NET, the concurrent enterprising network of excellence (CE-NoE), which aims at promoting top-notch European CE expertise from research, academy and industry. The CE-NET community, facilitated by the European Society of Concurrent Enterprise (ESoCE), has identified new paradigms and approaches to enable the adoption of concurrency principles at the level of distributed product development, networked enterprise and user driven innovation, under the new framework of concurrent innovation. For systematic approach to an ex-

amination of the whole body of CE knowledge, the issues have been organised into five main areas:

- Human aspects,
- Business model & organisation,
- ICT infrastructure,
- Product/service development and
- Policy and regulations.

This book provides a substantial contribution to the establishment of a concurrent innovation scientific base and thoroughly covers the first four areas with a stronger focus on technologies, platforms and standards characterising the Distributed Manufacturing context. This book addresses the main barrier that has so far limited the full adoption and exploitation of the emerging paradigms i.e. the issue of managing the complexity of Distributed Manufacturing, and it intelligently suggests how the theory of complex adaptive systems can provide some of the answers. It also sheds new light on the modes by which complex networks can manage parallelism, emergence, behaviour, iteration and encapsulation and in particular how the creative power of individuals and users can be integrated into the distributed processes with a multidisciplinary approach. Although enabled by technology, the initiators of the networked economy are people. Rapid and easy communication brings obvious benefits, but not all the increased communication is value-adding and people have less time to think. It is clear that there are many challenges for companies developing products and services. Some of these have been met; many more require additional efforts. In this book the editor has extracted and synthesized a carefully selected bundle of project results from the European projects PABADIS and PABADIS PROMISE and from closely related research. The invited authors present a number of theories and approaches that, adequately combined, may create suitable concepts for implementing highly workable solutions for Distributed Manufacturing.

In the new context of global industrial networks many concepts have been suggested to improve the base of support for geographically distributed networks and its effective collaboration. Mainly the proposals cover the socio-organisational field; some discuss information and communication technology impacts and options. This book draws from both fields and adds game theoretic and evolutionary elements pulling together principles, aspects and attributes that, even in industry, are mostly considered separate fields and entities that are difficult to unite.

Pick any random spot and you'll find inspiring ideas in this book. The book will serve as more than a detailed record of complex projects. It will provide an invaluable resource for all those wishing to enhance their understanding of changes in the manufacturing world in general and the introduction of new principles in particular. For that reason, I recommend that this book join the set of ready references available to you as together we practice and improve our profession of advanced manufacturing and extended enterprise.

Rome, April 2009

Roberto Santoro
President, European Society of Concurrent Enterprising (ESoCE)
Chairman, European Network of Living Laboratories (ENoLL)

Preface

"In anything at all, perfection is attained not when there is no longer anything to add, but when there is no longer anything to take away".
(Antoine de Saint Exupery)

Profound changes have already occurred in manufacturing within the last decades and the competitive environment for manufacturing will again be significantly different in the next 10 or 15 years. Major developments will occur in a number of different areas of manufacturing such as organisation, collaboration and globalisations resulting in Distributed Manufacturing in many cases. Distributed Manufacturing was originally focused on manufacturing architecture and control within single plants; later it was extended to the virtual manufacture of products and the networked organisation and includes all issues surrounding industrial networks. Key driving forces may be seen in all developments and trends in the fields of information and communication technology (ICT).

The gap between manufacturing automation and social actors' communication should be overcome.

This book represents a synthesis of selected key outcomes from the projects plant automation based on distributed systems (PABADIS) and PABADIS, based product oriented manufacturing systems for re-configurable enterprises (PABADIS'PROMISE), funded by the European Commission. The work on these projects was done through international collaboration over 8 years involving leading researchers as well as leading companies and renowned institutions in manufacturing systems control, embedded systems and network organisation world wide. The results have been consolidated with engineering communities and standardisation bodies.

The volume seeks to anticipate broadly emerging manufacturing structures and the respective information and communication technologies for organisations, their leaders and ICT strategists as well as researchers and technologists facing the challenges of their enterprises' geographical dispersion and network partners' dependencies. To this end, theoretical and application-oriented contributions have been included with a view to achieving the optimum breadth and depth of the relevant subject matter.

The book begins with on overview of methods and systems appropriate for concurrent product development in distributed structures. As many multisite companies and enterprise networks face competition in local contexts while having to keep the enterprises' advantages of common platforms and standards, co-evolution thinking has been chosen as a suitable new theoretical background and idea generator to cope with this growing challenge. The next part discusses new concepts

of manufacturing management and novel ICT applications which may be unfamiliar to readers and challenge the status quo. As ICT advances are evidently occurring more rapidly at the machinery and equipment level with the respective execution systems, the next large next is devoted to multi-agent systems (MAS) as the central part of the project. The final part, outlining the most recent project results, links the world of agents to products and flexible manufacturing technologies, leading back to the first part and giving substantial clues to further developments as well as hot research topics.

More and more enterprises are faced with the huge, and thus far unseen, challenges of doing manufacturing efficiently in collaborative networks and distributed structures, and operating beyond the consolidated state of the art. For their support and to provide insight into recent developments and emerging concepts, this volume presents a number of ideas, concepts and solution approaches that, when combined in the right way, gives considerable help in responding to those challenges.

Stuttgart, May 2009

Hermann Kühnle

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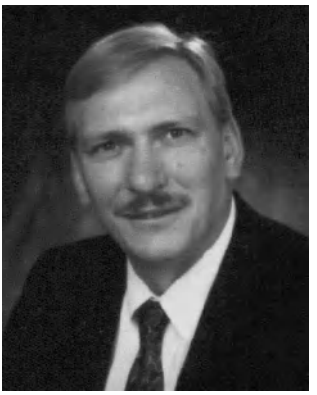
Acronyms

AARIA	autonomous agents at Rock Island Arsenal
AB	Ability Broker
ABMEI	agent-based manufacturing enterprise infrastructure
ADRENALIN	advanced fractal companies use information supply chain
AOA	Agent-Oriented Architecture
AR	augmented reality
BPM	business process modelling
BSCW	basic support for cooperative work
CAMAC	computer-automated measurement and control
CARE	c-agent runtime environment
CBA	component-based automation
CCITT	Comité Consultatif International Télégraphique et Téléphonique
CE	Concurrent Enterprise
CENELEC	Comité Européen de Normalisation Electrotechnique
CMU	Co-Operative Manufacturing Unit
CNO	collaborative network organisation
CSCW	computer-supported collaborative work communications
CSMA	carrier sense multiple access
CVE	collaborative virtual environment
CWE	collaborative working environment
DBMS	database management system
DCS	Distributed Control System
DEDEMAS	decentralised decision making and scheduling
DF	Device Function
DFP	Device Function Proxy
DIS	distributed interaction simulation
DM	Device Manager
DMU	digital mock-up
DMZ	demilitarised zone
DO	Device Observer
DP	Device Proxy
EA	expectation awareness
EDDL	Electronic Device Description Language

EM	Execution Manager
EN	events notification
ERP	Enterprise Resource Planning
FB	function block
FIPA	Foundation for Intelligent Physical Agents
FMS	Flexible Manufacturing System
GDP	gross domestic product
GPS	global positioning system
HLA	high-level architecture
HMI	human machine interface
HMS	Holonic Manufacturing System
I/O	Input/Output
IC	integrated circuit
IC	information collector
ICT	information and communication technology
IEC	International Electrotechnical Commission
IM	instant messaging
IMS	Intelligent Manufacturing System
IRC	internet relay chat
IRT	isochronous real time
ISO	International Organisation for Standardisation
JAKOBI	Java und komponentenbasierte Industriesteuerung
JVM	Java virtual machine
MAC	media access control
MAP	manufacturing application protocol
MAS	Multi-Agent System
MASCADA	managing production change and disturbance
MDE	Model-Driven Engineering
MES	Manufacturing Execution System
MMS	manufacturing message specification
MOM	manufacturing operations management
MRP	material requirements planning
MWC	mobile wearable computing
NO	node operator
NTP	network time protocol
OA	Order Agent
OAS	Order Agent Supervisor
OO	object orientation
OSI	open systems interconnection
P&P	plug & participation
PABADIS	Plant Automation Based on Distributed Systems
PABADIS' PROMISE	PABADIS based Product Oriented Manufacturing Systems for Re-Configurable Enterprises

PABADIS' PROMISE-CD	PABADIS based Product Oriented Manufacturing Systems for Re-Configurable Enterprises Control Device
PAHT	product and agent host tag
PDM	product data management
PDR	Product Data Repository
PID	proportional integral differential (continuous controller)
PIT	product identification tag
PLC	Programmable Logic Controller
PLM	product life cycle management
PO	Production Order
PROSA	Product-Resource-Order-Staff Architecture
PS	Process Segment
PTP	precision time protocol
PVC	professional virtual community
R&D	research and development
RA	Resource Agent
RAS	Resource Agent Supervisor
RFID	radio frequency identification
RFIT	radio frequency information technology
RMS	Re-Configurable Manufacturing System
SG	serious gaming
SIFB	Service Interface Function Block
SN	social networking
SOA	Service-Oriented Architecture
SW	shared workspace
TORERO	Total Life Cycle Web-Integrated Control
VAR	virtual and augmented reality
VR	virtual reality
WIP	Work In Progress
WO	Work Order

About the Editor



Hermann Kühnle holds a doctoral degree in mechanical engineering as well as a master's degree in mathematics, both from the University of Stuttgart. He joined the Otto-von-Guericke University Magdeburg, Germany, in 1994 as a full university professor for factory operations and production systems and as executive director of the Institute for Ergonomics, Manufacturing Systems and Automation, having previously served as lecturer, head of national applied research and responsible regional CIM coordinator and consultant. From 1994 to 2001 he was also foundation and executive director of the Fraunhofer Institute for Factory Operation and Automation, IFF, Magdeburg. Since 1995, Hermann Kühnle has been the spokesman for research on advanced production systems in Saxony-Anhalt. He is a member of boards of international journals, of companies and of venture capital groups.

0 Distributed Manufacturing: Paradigms, Concepts, Solutions and Examples

0.1 Introduction

A simultaneous presence in several regions and in different regional markets has become more and more essential for suppliers and manufacturers alike. These configurations are enforced by volatile market demands, fierce competition, and high innovation pressure in order to capture lasting advantages in efficiency. In particular companies that have experienced rapid international growth through mergers and acquisitions are suddenly faced with the challenges of structuring, managing and operating effectively a network of geographically dispersed factories with worldwide transfer of assembly and manufacturing operations for similar products between multiple production sites in different countries. This competitive global environment imposes the continuous need to identify and exploit new manufacturing paradigms, adapted methods and cutting edge technologies. Little attention has been paid so far to the fact that distributed manufacturing structures and their full advantages may be exploited best if concurrency of information flows and operations is strived for. The competitive power of distributed structures lies in their abilitiy to put entities all together and make the net concurrent customer-driven, involving organisation, processes and business models. As competition starts pressuring whole networks, fast linking and interoperability as well as adaptation abilities have become crucial attributes for manufacturing companies.

As production systems “disperse” their value chains, engaging more and smaller units all over the globe, value creation increasingly appears as a result of geographically distributed networked operations and services, representing in total at least the sum of all necessary resources. As the responsibilities for operations are strongly tied to organisational units and their socio-technical nature, Distributed Manufacturing also has all the features of human-influenced complex network building (e.g. trust, individual preferences) as well as the planning and execution of efficient processes within networks, fully engaging the scope of

information and communication technologies (ICT) for repetitive process routines and standardised functionalities. The optimum basis for collaboration using the least amount of resources and time is to take significant steps towards parallelism of all actions and operations. Distributed Manufacturing in enterprise networks dynamically combines core competencies and knowledge of different entities to fully meet specific, narrowly defined market opportunities. All activities in distributed, temporary alliances of independent, co-operating manufacturers, customers and suppliers use systematic approaches, methods and advanced technologies for increasing efficiency in the design and manufacture of products and services by concurrency, integration, standardisation and teamwork for achieving common goals in global markets.

Driving technology spheres are adaptable, integrated equipment and systems that can be readily reconfigured, technologies that convert information into knowledge for effective decision making, enhanced human-machine interfaces as well as software for intelligent systems for collaboration provide for completely new opportunities. Once manufacturing structures are distributed in this sense, all successful set-ups definitely point to the emergence of a strongly ICT supported networked manufacturing world. Adequate ICT applications for modelling and simulation are also considered as extremely important to be able to quickly innovate, design and produce the 'right product right the first time'.

This volume summarises the most important results of the EU projects Plant Automation Based on Distributed Information Systems (PABADIS) and the successor for implementation PABADIS based Product Oriented Manufacturing Systems for Re-Configurable Enterprises (PABADIS'PROMISE), which represent substantial advances in the field of control of Distributed Manufacturing network using concurrency principles. The consortia that have been led by the editor had involved 27 institutions and more than 150 researchers and experts from EU Europe, Switzerland and Canada. The project had been extended to the international context by joining the EU–Intelligent Manufacturing Systems program.

The project's key statement is clear: Distributed Manufacturing is a new pattern of interfirm relationships evolving networkwide integration by creating different forms of interentity processes. The underlying paradigms are a valid frame for next-generation planning systems and management procedures.

The major impacts on manufacturers enforcing these organisation patterns have been the higher availability of resources as low-cost labour and manufacturing capacity, increasingly compelling companies to move towards sourcing parts and components globally. Key driving forces have also been shortening product life cycle, placing a premium on speed to market, as well as rapidly declining costs of transportation and communications, atomising all resources for manufacturing. Within simple settings of collocated operations, the challenge of managing can still be achieved by conventional planning and decision mechanisms. For networks, control becomes much more complicated, as the involved units and their respective roles are not stable but evolve dynamically. However, these properties activate to incorporate changing external partners as well as varying capabilities

and knowledge, enormously increase a company's adaptabilities and strongly amplify differentiations and uniqueness.

On the long path to such enterprise networks a number of more advanced manufacturing principles and management approaches have been presented. The most important manufacturing philosophies that have been introduced may be considered Lean Manufacturing (Ohno 1988), Agile Manufacturing (Kidd 1994), Holonic Manufacturing (VanBrussels et al. 1998), and Fractal Factory (Kühnle 1995). More comprehensive interorganisational structures are supply networks, Virtual Enterprises, extended enterprises (E2), professional virtual communities (PVC) and collaborative network organisations (CNO) (Camarinha–Matos and Afsamanesh 2005). Emphasis has been placed on the renewal of companies' culture, organisation and management, making use of growing ICT possibilities, where human creativity and improvisation are given higher decision-making power to better meet the new objectives. However, the emerging enterprise nets are more than just the amalgamation of a number of entities. Such networks consist of numerous independent and geographically dispersed entities as well as subnets of complex behaviour; therefore, the manufacturing principles, addressed above, face difficulties in implementation amid this complexity.

As a consequence, the last few years have witnessed a resurgence of interest in the nature of networks and complexity theory as possible sources of solutions. Complex adaptive systems theory is increasingly concerned with the understanding of intrinsic interactions and non-linear dynamics of distributed systems with many entities. It has proven to be a highly suitable framework that accounts for the complex interactions among the various entities of manufacturing networks, which give rise to complex behaviour that cannot be attributed to a single unit as it is a collective effect. Analysing Distributed Manufacturing networks through the lens of complex adaptive systems is helpful due to the fact that contemporary operation set-ups rather resemble dynamic, complex, interdependent and globally distributed webs than the static well-determined systems which have traditionally dominated our thinking. Furthermore, understanding Distributed Manufacturing as complex networks reveals new potentials for improving decision-making for the management of processes and value chains. Network principles in manufacturing replacing hierarchical management undoubtedly give competitive advantages, as the "certainties" of command and control approaches evidently no longer seem to hold true. A company has to see itself primarily as a unit in a network, getting value out of this loosely coupled enterprise (Norri and Lee 2006) by focusing on distinct process segments and by attracting the maximum network resources towards its visions and objectives.

Entirely new devices from ICT have enhanced adaptabilities not only at the information-integration level but also at the resource and process levels. Working environments may consist of hybrid spaces composed of virtual and actual features. Moreover ICT devices applied for concurrent and intensive participation – plug & participate (P&P) – are available wordlwide. Mobile and wireless networks, seamless interconnection and the wide spread use of powerful systems ap-