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Foundations & Principles of Distributed Manufacturing

Elements of Manufacturing Networks, Cyber-Physical Production Systems and Smart Automation

Springer

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Foreword I

Industry in general and the metal and electrical industry in particular are subject to highly dynamic forces which have a direct impact on advances in technology and breakthrough innovation. Industry is on the brink of a radical shift in technology—the areas of development and commonly used concepts have already established themselves as part of this sea-change. Innovations such as radio-frequency identification (RFID) chips, smart controls, smart metering, the Internet of Things and embedded cyber-physical production systems are already household terms and represent new, intelligent capabilities within manufacturing. In addition, rapidly evolving new areas, such as big data and cloud computing offer tremendous opportunity while also posing a wide variety of challenges across business organizations.

Südwestmetall—the Baden-Württemberg Employers' Association of the Metal and Electrical Industry—has made these various new developments and technologies the focus of intensive internal discussions and proposed joint initiatives for pursuing these issues with other industry associations. The Industry 4.0 initiative is an important initiative among several that have emerged across Germany. It is designed to prepare enterprises for future developments in this area. As the concept of distributed manufacturing already indicates, ever-increasing globalization will lead to widely distributed organizational structures as well as decentralized manufacturing principles. Because there is still a lack of clearly formulated general concepts in this new area, Südwestmetall welcomes fundamental work and studies which focus on the fast-growing issues underlying the Industry 4.0 revolution. This book presents a comprehensive theoretical discussion of distributed manufacturing in this context. The theme of the book is valuable for the work of our association because the case studies presented can serve as a guideline for management, raise critical questions as well as present possible approaches for working out solutions.

Companies that want to lead the way as this technological shift unfolds and closely follow developments can thus be sure they have a solid basis for making decisions and successfully deal with all the aspects of this new technological challenge.

Peer-Michael Dick
Director General Südwestmetall
Head Office Stuttgart, Germany

Foreword II

In order to successfully operate a globally active organization such as the Constantia Flexibles Group, it is particularly important not only to network the individual production plants, but also the product requirements, production processes and the financial control data and analyses as a basis for decision making.

Only by doing so can client requirements be met in line with market standards, and a sustainable competitive advantage for the company be maintained.

The required global network of the production process, with fast reactivity and flexibility, demands high levels of competence in the set-up, operation and optimization of the production networks. Rigid regulations and operating guidelines are either insufficient or simply incapable of adapting to increasing demands. The operative intelligence of the individual production units needs to be linked in such a way that a context-dependent optimum is achieved at an overall level.

Forward-looking solution concepts need to be designed in such a way that the technological or client-specific adjustments—e.g. in the networking and communication of intelligent sub-components—can either be integrated step-by-step into existing solutions, or existing solutions extended to include them.

The book concerned provides the theoretical basis necessary for these processes, and also gives practical examples of successful implementation.

We are pleased to be able to take some food for thought from this book for the further development of our own organization, for approaches to solutions for existing and future challenges, and, last but not least, for decision-making support.

Dr. Gerold Riegler
Member of the Executive Board, COO
Constantia Flexibles GmbH, Vienna

Foreword III

We live in a world where everything is connected. The network is no longer peripheral—it is central. And that is opening up possibilities—for enterprises and governments, for individuals and society.

With everything connected, distance no longer sets limits on what we can achieve. Mobility gives people tremendous flexibility and freedom, while the rapidly growing Internet of Things (IoT) brings intelligence to billions of objects. The potential—for growth, speed and agility—is limitless.

By using technology more creatively, organizations can achieve stunning business outcomes, and address four key requirements: deliver a great performance, realize possibilities in the cloud, work in harmony and perform anywhere—any time.

In order to deliver a great performance, organizations need to manage a mix of different network technologies—combined with applications performance management and security services. To realize possibilities in the cloud, they require improved performance and availability of multiple cloud-based applications. They connect to different cloud providers and, at the same time, data in the cloud has to remain secure at all times. For an organization to work in harmony, collaboration must happen at any time, on any device. And in order to perform anywhere, they need to deploy great mobility applications on a vast array of devices. But it is not the device that is important, it is the data. So they need the latest security technology to ensure that both data and devices remain secured at all times, regardless of where or how they are accessed or used.

It is all about orchestrating intelligent hybrid systems with a high level of security, while maximizing the performance, flexibility and control offered by the cloud, collaborating with existing Information and Communications Technology (ICT) service providers. This is what we call the art of connecting.

Companies in the manufacturing and logistics industry still move on unstable ground when investing in ICT and outsourcing decisions. As developers of cutting-edge technologies and providers of the above-mentioned services, we understand their needs for support to find their way in this connected industrial world. Value chain

networks and manufacturing processes can benefit enormously from the potential the art of connecting delivers. Within the broad domain of distributed manufacturing, it is important to present, discuss and demonstrate the impact of the latest technological developments on the fundamental settings of manufacturing in general.

Distributed Manufacturing articulates the principles and properties of the basic theory and, at the same time, offers examples to facilitate and speed up decision-making. It fulfils all expectations by:

- Proposing the most important insights into upcoming structures and behaviour of distributed manufacturing and illustrating how the intelligent hybrid network brings coherence, how distributed processes integrate and interact with each other
- Demonstrating how mobile and wireless technologies can change manufacturing set-ups in practice and showing how real-time negation of resources—people, technologies and products—configure and enhance the efficiency of manufacturing
- Consolidating impact and trends of the real-time enterprise and cloud-based services anywhere any time, generating innovative principles of concurrency for manufacturing structures and providing examples of successful implementations, verifying at the same time the theory, principles and fundamentals.

Distributed Manufacturing will provide hints to decision-makers and managers. It will support researchers and university teachers to train engineers. The book contains the right mix of theory and practice for promoting the art of connecting in general, and in manufacturing in particular.

In our connected world, the creative use of technology can deliver stunning business outcomes. IT is increasingly an art as much as a science. The objective is to use the power of communications to make a better world. The book focuses on what has been accomplished in the field of collaboration and distributed manufacturing for the benefit of enterprises and governments, individuals and society.

Juergen Meissner
Stuttgart, Germany
BT Global Services

Keith Sherry
Irving TX, USA

Preface

Lector amice salve

Quid mundus, quae causa Deo, ratioque creandi,

Unde Deo numeri, quae tantae regula moli,

Quid faciat ser circuitus, quo quaelibet orbe

Intervalla cadant, cur tanto Jupiter et Mars,

Orbibus haud primis, interstinguantur hiatu

Hic te Pythagoras docet omnia quinque figuris.

Scilicet exemplo docuit, nos posse renasci,

Bis mille erratis, dum fit Copernicus annis,

Hoc, melior mundi speculator, nominis.

Riemannus et Poincarеus possunt continuere,

Etiam Hausdorffus et Mandelbrotus

At tu glandibus inventas noli postponere fruges.

Post Mysterium Cosmographicum

Joannis Keplerus

An emerging universe of networkable objects is about to lead Manufacturing into another fascinating phase of development. As the number of smart devices is already counted in trillions, we actually witness their broad introduction into

factories. Manufacturing emerges as a set of loosely coupled, smart, autonomous units, which is restructuring configurations and gravitating towards optimising processes and efficient output. Satellites and triangulating transponders are continuously positioning and localising for best transformation steps that are at the centre of interest rather than fixed technological units. Cyber Physical Production Systems, context-aware equipment and networkable manufacturing units become the key assets for industrial value creation. Their agility is orchestrated via intensive aspect motivated interactions, which occur on well-defined orbits with corresponding granularities.

Distributed Manufacturing establishes efficient versatile constellations of skills, advanced technologies and effective processes. It exceeds the simple revising of processes and functions; it incorporates entirely new ways of producing that completely reshape all manufacturing sectors right from the base of collaboration for all involved persons, machines and resources. Attached Cyber Physical Production spaces, Cloud Manufacturing and Smart Objects will evolve to the point where manufacturing needs little prearrangement; it will just happen. Distributed automation has already anticipated the geometry of manufacturing networks in a nutshell; due to pattern similarities, it is now expanding into manufacturing in total. Digital dimensions, which unify virtual worlds with real worlds via interconnected smart mobile devices, make manufacturing once again profit from a number of novelties in the ways we interact with both, the physical and the digital world. Convergence of technologies keeps adding improvements in equipment abilities, in manufacturing productivity and in quality of work life, so networked intelligent units will make Distributed Manufacturing a common way to produce. This book proposes a first solid theory base by outlining overall principles and by detailing the complex nature of smartness of units in Distributed Manufacturing. Especially, the coalescence of people and machines' smartness, now invading manufacturing, is strongly promoted. Outside disciplines are given more credit and easier access to manufacturing. Interdisciplinary work, properly embedded and put together in the right way, paves smooth ways for more and better research results. The outline highlights key outcomes of a number of IMS and ERA Projects, national and regional activities as well as from cutting-edge industrial implementations of Distributed Manufacturing. The results have been consolidated with global engineering communities involving renowned researchers as well as leading manufacturing, telecommunications and software companies. Our thanks go to many university colleagues as well as to a large number of practitioners in different industries from many regions of the world, especially the pilot companies, for their support and insights into recent developments and up-coming concepts.

Stuttgart
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Hermann Kühnle
Günter Bitsch

Contents

Acronyms

AI	Artificial Intelligence
AML	Automation Markup Language AutomationML
AR	Augmented Reality
BAN	Body Area Networks
BOM	Bill of Materials
BOO	Bill of Operations
CAD	Computer-Aided Design
CAE	Computer-Assisted Engineering
CBDM	Cloud-Based Design and Manufacturing
CEP	Complex Event Processing
CIM	Computer Integrated Manufacturing
CIMOSA	Computer Integrated Manufacturing Open System Architecture
CM	Cloud Manufacturing
CPPS	Cyber Physical Production System
CPS	Cyber Physical System
DAMA	Design Anywhere Manufacture Anywhere
DCPS	Distributed Cyber Physical System
DIN	Deutsches Institut für Normung (German), German Institute for Standardization
DMMM	Distributed Manufacturing Maturity Model D3M
DMU	Digital Mock Up
DR	Dual Reality
DSS	Decision Support System
E2AMM	Extended Enterprise Architecture Maturity Model
EA	Enterprise Architecture
ECS	Engineering Client for automation System
EDA	Event-Driven Architecture
EDP	Electronic Data Processing
EE	Extended Enterprise
EPICS	Experimental Physics and Industrial Control Systems Standard
ERA	European Research Area

ERP	Enterprise Resource Planning
ETSI	European Telecommunications Standards Institute
GDTA	Goal Directed Task Analysis
GERAM	Generalised Enterprise Reference Architecture and Methodology
GIS	Geographic Information System
HaaS	Hardware as a Service
HMS	Holonic Manufacturing Systems
IaaS	Infrastructure as a Service
ICT	Information and Communications Technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IFAC	International Federation of Automatic Control
IFEAD	Institute For Enterprise Architecture and Development
IFIP	International Federation for Information Processing
IoT	Internet of Things
IP	Internet Protocol
IPSO	Internet Protocol for Smart Objects
ISO	International Organization for Standardization
KAI	Key Alignment Indicator
KPI	Key Performance Indicator
LOD	Level of Detail
M2M	Machine to Machine
MAR	Multiple Augmented Realities
MAS	Multi-Agent Systems
MES	Manufacturing Execution System
MNs	Manufacturing Networks
MR	Multiple Realities
MRP	Manufacturing Resource(s) Planning
NFC	Near Field Communication
P2P	Person-to-Person
PaaS	Platform as a Service
PABADIS	Plant Automation Based on Distributed Information Systems
PDA	Personal Digital Assistant Devices
PERA	Purdue Enterprise Reference Architecture
PLC	Programmable Logic Controllers
POA	Point-Of-Action
POC	Point-Of-Creation
RCE	Resource Cloud Encapsulation
RCM	Remote Cloud Manufacturing
RFID	Radio-Frequency Identification
RTB	Real-Time Business
RTE	Real-Time Enterprise
SA	Service Agent
SaaS	Software as a Service

SCADA	Supervision, Control and Data Acquisition
SCM	Supply Chain Management
SEI	Software Engineering Institute
SIC	Statistical Inventory Control logic
SLP	Service Location Protocol
SO	Smart Object
SOA	Service Oriented Architecture
SoA	Space of Activity
SOAP	Simple Object Access Protocol
STL	Standard Triangulation Language
UC	Ubiquitous Computing
UDDI	Universal Description Discovery and Integration
UPnP	Universal Plug and Play
VAN	Virtual Automation Network
VDI	Verein Deutscher Ingenieure (German) for Association of German Engineers
VM	Virtual Machine
VR	Virtual Reality
WBAN	Wireless Body Area Networks
WSN	Wireless Sensor Network