Digital Factory for Human-oriented Production Systems

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The Integration of International Research Projects

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Preface

The idea of a book about Digital Factory (DiFac) was born in May 2008 during the technical meeting in Seoul, Korea. This book represents more than three years of collaboration among partners from different corners of the world. It provides new concepts, frameworks and lessons learned targeting the future Digital Factory, which should integrate novel technologies, processes and humans to tackle the everyday challenges of the business environment.

DiFac is a common acronym for three research projects: one in Europe, the other in Korea and the third in Switzerland. Each one of them deals with the concept of the Digital Factory under different nuances. The Digital Factory is a paradigm dealing with the use of new technologies during the entire product lifecycle, 3D simulation for facility management and ergonomics, decision-making system, radio frequency identification (RFID), enterprise resource planning (ERP), knowledge-based management tool, virtual and augmented reality, and semantic web are only some of the topics with which DiFac deals.

The three theoretical sections of this book are not referred to the regions of the International Manufacturing Systems (IMS) project, but to more general topics organized in a coherent path. From its foundations, the three projects integrated under the DiFac umbrella looked forward to providing new tools and technologies for both big and small companies to enable them to be more competitive. Nevertheless, DiFac and its related deliverables presented in this book do not only represent the answer to technological challenges, but also define a new way of working by enabling workers to be more productive and empowering them to make better decisions thanks to the availability of information and knowledge, which in traditional environments is in most cases not available.

Information management, knowledge management, automation, ergonomics, production planning, RFID and factory simulation etc. are some of the key subjects embedded in this book that still represent a challenge for many manufacturing companies around the globe. Therefore, we as editors, on behalf of the complete DiFac project consortium, have integrated the different outcomes of this international project to provide the main trends, frameworks, models and potential solutions to practitioners and at the same time highlight the lessons learned providing an insight of the opportunities to still develop in future collaborative research projects. As a result, this book provides a section of case studies, which evidence the work done by academic partners in collaboration with the industrial partners to test, improve and further develop the different prototypes created during the project.

We take the opportunity to thank the South Korean Ministry of Knowledge Economy, the European Commission under the Framework Program 6 (FP6) and the Swiss Commission for Technology and Innovation (CTI) for funding the three projects in the different regions. We also express our gratitude to all our academic and industrial partners who contributed with their hard work to be able to develop the promised prototypes and share their findings in this book. Last but not least, we would like to sincerely thank Prof. Joung Hwan Mun from Sungkyunkwan University (SKKU, Korea) and Prof. Claudio R. Boër from Intelligent Manufacturing Systems (IMS) and University of Applied Sciences of Southern Switzerland (SUPSI) for proposing, facilitating, guiding, energizing and engaging the partners from the different corners of the world to make this project a reality.

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Introduction

This book describes how implementing various facets of the Digital Factory is possible to improve a series of processes, directly related to manufacturing activities or dealing with more general company organisational aspects. This is done in order to create a new generation of human-oriented production systems, where the "knowledge workers" can use specifically developed tools that enhance their safety and well-being while improving company effectiveness and efficiency. The methodologies and tools of the Digital Factory will also deal with new challenges related to the simultaneous shortening of time to market, shrinking of margins and increase in product differentiation. This implies the necessity to enhance new product development process and the consequent adaptation of production systems, processes and management policies. Three research projects enabled strong collaboration among 18 international partners with highly complementary competences, which resulted in an integrated multidisciplinary approach that provides the pillars of the Digital Factory.

The enhancement of the collaboration level is one of the key advantages obtained through the application of the Digital Factory concepts. On the one hand, this is obtained thanks to the development of tools allowing the elicitation, management and sharing of explicit and implicit knowledge as well as competence improvements, based on best practices identification, formalisation and dissemination. On the other hand, software tools for supporting some complex tasks have been developed in order to also facilitate their undertaking by distributed teams belonging to different supply chain actors and working collaboratively. For instance, one of the main objectives of FP7 DiFac is the development of an innovative Collaborative Manufacturing Environment (CME) for next generation digital manufacturing. The DiFac CME will be used as a framework to support group work in an immersive and interactive way, for concurrent product design, prototyping and manufacturing, as well as worker training. It will provide support for data analysis, visualization, advanced interaction and presence within the virtual environment, ergonomics analysis and collaborative decision-making. Within the DiFac CME, a systematic representation of product and process knowledge in a mixed 3D collaborative manufacturing environment will be provided to the user.

A distinctive point of the developed CME is to complement the common collaboration technologies for distributed design and manufacturing, based on networked collaborative decision-making and project management, with Virtual Reality (VR) and Augmented Reality (AR) technologies in order to lead to remarkable breakthroughs in enhancing manufacturing collaboration, from the development of digital mock-ups and virtual prototypes, to production simulation, maintenance and training.

The application of this innovative CME is oriented to the improvement of workforce safety and well-being, which are taken into account from product development to factory layout and processes design and evaluation. This is due to the integration of the VR/AR software tools with digital human models and software tools that incorporate ergonomic analysis into working conditions of the digital factory. These software tools will come in the form of a photorealistic digital human that moves and poses as a real person would, interacting with a industrial environment and ultimately providing feedback concerning, among other things fatigue, reach envelopes, discomfort, muscle and joint stress and energy expenditure. Two different task-based methods for Digital Human Modelling (DHM) simulation have been developed to simplify the motion generation procedure and inverse dynamic modelling as well as to analyse human motion more accurately. The proposed DHM aims at solving some shortcomings of the solutions currently available on the market because the motion generation procedure becomes less time consuming while still providing good accuracy even for the analysis of complex human tasks in dynamic working conditions. Workers safety and well-being are also enhanced thanks to the availability of reliable and updated information and best practices as well as their provision with innovative tools, such as AG training materials for maintenance and other activities.

The tools developed in the framework of DiFac have to be strongly integrated to each other, in order to fully deploy their benefits, but also have to complement the functionalities already offered by the legacy company information system ensuring a seamless adoption. For these reasons, a great attention has been devoted for ensuring a correct information formalisation and sharing. The PPR^{+H} (Product, Process, Resource and Human) Schema developed using XML and the PPR^{+H} Integrator constitutes the backbone of this information exchange ensuring neutral formalisms, compliant with the currently used standards and facilitating the communication with Product Data Management (PDM) and Enterprise Resource Planning (ERP) systems. In fact, many Digital Factory tools require input from and/or provide output that can be directly used by the legacy information system. For instance, production system discrete event simulation models can be filled with parameters stemming from the PDM/ERP systems, the same applies for some data concerning manufacturing processes required by the Digital Human Modelling for estimating fatigue. On the other hand, the RFID–ERP interfacing scheme provides a multitude of transactional data to the ERP system at a higher frequency and with an enhanced reliability. Other DiFac tools, such as the Factory

Constructor, can allow to adjust the parameters contained in the PDM/ERP systems in order to improve the characteristics of the production systems.

In a Digital Factory implicit knowledge also has to be carefully managed and shared. Furthermore, the "knowledge workers" should be stimulated to dynamically provide feedbacks and input in order to efficiently apply Business Process Management (BPM) practices. The Intelligent Web, being a synergic combination of Web 2.0 and 3.0 concepts and tools, is proposed as a suitable tool for collaborative and dynamic creation and sharing of knowledge, by means the owners' interaction and co-authoring where knowledge is systematically created and reused.

The creation of a Digital Factory, for achieving human-oriented production system, implies integrating ergonomics concepts in as many tools as possible, as well as to ensure a high usability of these tools. Presence and flow are two performance measures extremely important while evaluating the quality of VR and AR software tools and these can also be successfully applied to less interactive tools, such as the Intelligent Web framework proposed for managing information creation and sharing.

Collaboration, ergonomics and presence are considered among the foundations of the Digital Factory and are treated in the first part of this book.

The second part of this book is dedicated to the tools developed for enhancing knowledge acquisition, modelling and sharing. The PPR^{+H} Hub, which provides the reference data models allowing data interchanges among the various tools is, introduced in Chap. 4. In order to complement the rich description of physical process provided by the PPR^{+H} Hub and better covering business processes and implicit knowledge, an Intelligent Web tool, is developed and described in Chap. 9. In parallel the importance of BPM practices for building the knowledge-based Digital Factory is highlighted in Chap. 7. The remaining chapters of this part deal with transactional data and production system parameters exchange. Chapter 5 describes the potential applications of RFID and potential strategies according to the organisation and supply chain typology. Chapter 6 tackles the same problematic, adopting a more technology-oriented approach, focusing on the integration of the RFID infrastructure with the legacy ERP and proposing a versatile interfacing scheme. Finally, Chap. 8 concentrates on closed loop information system applications, especially those devoted to enhance the communication among ERP system and workshops.

Applying the Digital Factory concept can require significant modifications to the current production system and supply chain structure. A series of tools developed to support the design of the human-oriented production system are described in Part III. First of all, the Digital Human Modelling, allowing to integrating physical body constraints into the redesign of production systems, is presented in Chap. 10. Chapter 11 describes a bundle of VR tools for process planning and optimisation. Factory design is supported by the GIOVE Virtual Factory immersive viewer presented in Chap. 12. The performance of the various configurations proposed using the VR tools can then be easily tested using a web-based discrete event simulation (Chap. 14). The rich 3D representations of machines and layout are also used for more operational objectives, such as training. For instance, an AR application for remote maintenance is described in Chap. 13.

The industry-led vocation of the Intelligent Manufacturing Systems (IMS) program as well as the involvement of various companies in all the three research projects result in some applications already deployed. A series of industrial case studies are thus presented in Part IV to underline the potential benefits of the developed tools and methodologies and to better delimitate some application contexts.

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DiFac: Three Projects and an International Cooperation with IMS Framework

IMS, the Intelligent Manufacturing System program was born 20 years ago from an idea of Prof. Yoshikawa. Manufacturing, he was saying, should not be only competitive if we want to change the world and make it more sustainable. Manufacturing is contributing to the wealth and development of the world in great and many ways but it contributes also to its pollution more than any other human activities. A country alone cannot deal with this problem and that is when the IMS idea was born.

It took some time in order to agree on a term of reference for cooperation but then projects started to roll in from all regions (Japan, Korea, European Union, United States, Canada, Australia and Switzerland). All technologies were researched, integrated and tested. The IMS program is supported and coordinated by government but is lead by industry and therefore the results reached the heart of the manufacturing system and in many cases also the market. Because the program is precompetitive, companies could share important results and reach agreement about the standards.

Information technology applications were developed considerably in IMS projects as well as environmentally friendly technologies. But sustainability needs three 'E's: Ecology, Economy and Equity (social) to be really effective, and the DiFac project touches deeply in the social aspect looking at the implementation of information technology but respecting the human side of the factory.

IMS is now launching a new program called MTP, the Manufacturing Technology Platforms, that is looking at cooperation among manufacturing actors in more innovative way bringing together projects already ongoing around the world. The MTP program focuses on five main areas: sustainable manufacturing, energy efficiency manufacturing, key technologies, standards and education. The MTP program is very interesting for industry and academia, and it has seen a huge success in a just over a year of existence. DiFac will certainly contribute in one of the MTP initiatives already ongoing or in preparation.

DiFac Advantages in the International Collaboration

IMS DiFac—The DiFac project (Title: Digital Factory for human-oriented production system) was designed to develop digital factory for human-oriented production systems to consider the industrial safety factors from the initial stage of the development of the digital factory, because the industrial safety problem has been embossed dramatically in the international society.

For this purpose, it has been performed by different regional projects from Korea, EU and Switzerland regions with different focuses. Each regional project divides into four technical fields of production, process, resource and human information management and integration; human modelling ergonomics collaborative VR environment and digital factory management with ERP.

The developed technologies from each regional project will be shared to upgrade the existing solutions and reinforce the international R&D relationship. Therefore, there are added values derived from the international collaboration as follows:

- Sharing the technologies of human modelling and quantitative analysis of industrial safety
- Simulate and evaluate human postures and motions without any manual manipulation tasks
- Ergonomic and biomechanical analysis of human motions
- For simulating and evaluating the industrial working environments
- For evaluating work strategy considering human factors
- Sharing the technologies of VR
- A collaborative strategy for digital factory activities considering group presence and ergonomics
- Evaluate the virtualized collaborative manufacturing environment
- For collaborative product prototyping
- For constructing, simulating and evaluating the virtual digital factory
- For training, maintenance and commissioning
- Sharing the technologies of ERP system
- Implement an integrated company-wide information management system
- A new ERP–human interface for shop-floor information feedback
- For designing and validating an ERP–simulation interface to optimize the production process
- Exploration of the RFID technology integration with the ERP
- A new governance model to facilitate the implementation of new ERP functionalities in companies

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