Building Blocks as an Approach for the Planning of Adaptable Production Systems

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Abstract. Global trends demand the design of adaptable production systems. The department of Factory Planning and Factory Management at Chemnitz University has proven its extensive competences in this field. On this basis the concept of Building Blocks for Adaptable Production Systems was developed. It is implemented in the existing Experimental and Digital Factory of the department. This includes an integrated design of product and production system. The approach is modular. In result, planning/visualization modules of the Digital Factory as well as modules for machining, material flow, information flow and energy flow are investigated. Fields of application are shown.

Keywords: Adaptability, changeability, Digital Factory, Component-based Planning.

1 Introduction

Such trends as the reduction of product life cycles, individualization of customer demands and globalization lead to increasingly dynamical and incalculable markets. In result, the design of adaptable production structures is required from factory planning.

The department of Factory Planning and Factory Management at the institute of industrial sciences and factory systems of Chemnitz University of Technology has proven its extensive competence in this field (e.g. Component-based Development [1], Component-based Planning [2], PLUG+PRODUCE [3], HIPER [4], Collaborative Research Center (CRC) 457 [5], Project Cluster 196 [6]). The results of this research are now consistently implemented in the project "Building Blocks for Adaptable Factory Systems". Further basic research and a transfer to industrial practice will be realized at selected factory subsystems. The general target is to achieve an adaptability, which meets the requirements, by elaborating the so called change drivers universality, mobility, scalability, modularity and compatibility.

Therefore, the mechanisms of the change drivers have to be understood and made assessable. Concepts and methods for the design of future adaptable production systems need to be developed.

The main component of the building block is an assembly/production plant, which will be connected to the logistics system of an already existing Experimental and Digital Factory (EDF) through appropriate interfaces.

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The adaptability of the system shall be supported amongst others by tools of the Digital Factory, innovative identification and positioning systems, concepts for the supply of material and autonomous control of logistical objects as well as man-machine interfaces.

2 Basics, Problem, Scientific Questions and Need for Research

2.1 Basics

The process of adaptation results from the permanently changing production environment. From a system theoretical point of view it is mainly driven by the three factory properties dynamics, complexity and cross linking, which catalyze adaptation. Adaptability can be understood as a meta-property which bundles these three system properties [7]. Change drivers are amongst others universality (neutrality of function and usage), mobility, scalability (extensibility and reducibility), modularity and compatibility (ability for networking, ability to (dis-)integrate) [7-9].

Different types and dimensions of adaptability are distinguished; spatial adaptability, temporal adaptability, structural adaptability and technical adaptability.

Adaptability can be also connected in an object oriented way to products and services, technologies and processes as well as to production systems (man, technology, organization);

- Adaptability with regard to products/services, which have to be generated
- Adaptability with regard to functions and processes which can be realized
- Adaptability with regard to elements and structures of the factory

2.2 Problem, Scientific Questions and Need for Research

The research on production plants and factory planning is lead by increasingly urgent requirements like flexibility and reactivity or adaptability, agility, handling of complexity as well as orientation on the demands of customers/markets. Decisive driving factors for the satisfaction of such requirements are amongst others universality, modularity, mobility, compatibility/ability for networking, scalability and availability. (see e.g. [3, 10-22])

A study about adaptable production systems [9] identified the following demand for research and development;

- Optimization of interfaces(robust, inexpensive and standardized interfaces, plug & produce strategies, and methods are needed to reduce complexity.)
- Harmonization and holistic design of the value chain(methods for identifying the need for adaptability in the whole value chain and for the design and continuous optimization of adaptability are needed.)
- Making adaptability assessable(Evaluation models , which enable every enterprise to execute a cost-benefit calculation for planned investments in adaptability, are needed.)

In addition to the expressed need for research, this study led to a publication of the Federal Ministry of Education and Research (BMBF) from March 30, 2009 to the topic "Safeguarding Competitiveness by adaptable production systems" [23].

Building blocks for adaptable production systems are meant to contribute to the answering of the scientific questions.

In order to investigate adaptability, the factory building blocks are so designed that

- The change drivers universality, mobility, scalability, modularity and compatibility as well as
- The types and dimensions of adaptability can be comprehensibly and systematically researched,
- A large scope of adaptable production systems can be provided by freely combining a selected number of components,
- Conclusions about the design of factory systems, which meet the requirements and the current situation, can be drawn.

3 Concept Building Blocks for Adaptable Production Systems

Building blocks for adaptable production systems should make it possible, to investigate almost any factory configuration (e.g. order driven, flexible layouts of machines (figure 1) in connection with production and logistics concepts for optimal lot sizes such as one-piece-flow) prototypically and emulate them close to reality. Conclusions about the behavior of the factory and its components shall be drawn in anticipation of an actual realization. Innovative concepts, technologies and solutions shall be evaluated with regard to their suitability for industrial practice. New and further developments of components of factories, such as energy-saving solutions for materials handling technology, and their interaction with other components, shall be tested. Last but not least the interaction and the behavior of humans in the factory as well as their acceptance of technical innovations will be researched.

In addition to adaptability the following trends and research areas of industrial science will be covered with the factory building blocks;

- Demography, group work and working environment
- Information and communication, man-machine interfaces
- Handling and supply concepts
- Energy efficiency
- Unity of planning and operation of a factory
- Digital factory, further development of methods and tools for factory planning.

According to the approach of the Digital Factory, the research will be carried out on one hand virtually at the computer and on the other hand real in a small model factory. In result, the factory building blocks, which enhance and complete the existing Experimental and Digital Factory (EDF), consist of the components Digital Center (DC) and Experimental Center (EC). The components can be combined via defined interfaces (figure 1).

The following modules are planned to be integrated in the building blocks (figure 1);

- Components of the digital center (DC)
  - Modules for planning/visualization (component configurator, visualization (VR, interaction))
- Components of the experimental center (EC)
  - Machining modules (manufacturing/assembly modules (4+1), test module)
  - Material flow modules (handling module (gantry robot), transport module)
  - Information flow modules (control center, control, interface modules)
  - Energy flow modules (supply, energy management modules)

Figure 1 illustrates the concept of the integration of building blocks for adaptable production systems in the EDF.

The planning and visualization modules are integrated in the Digital Center (room D19). The machining modules as well as the material, information and energy flow modules are integrated in the experimental center (rooms D17 and D18).

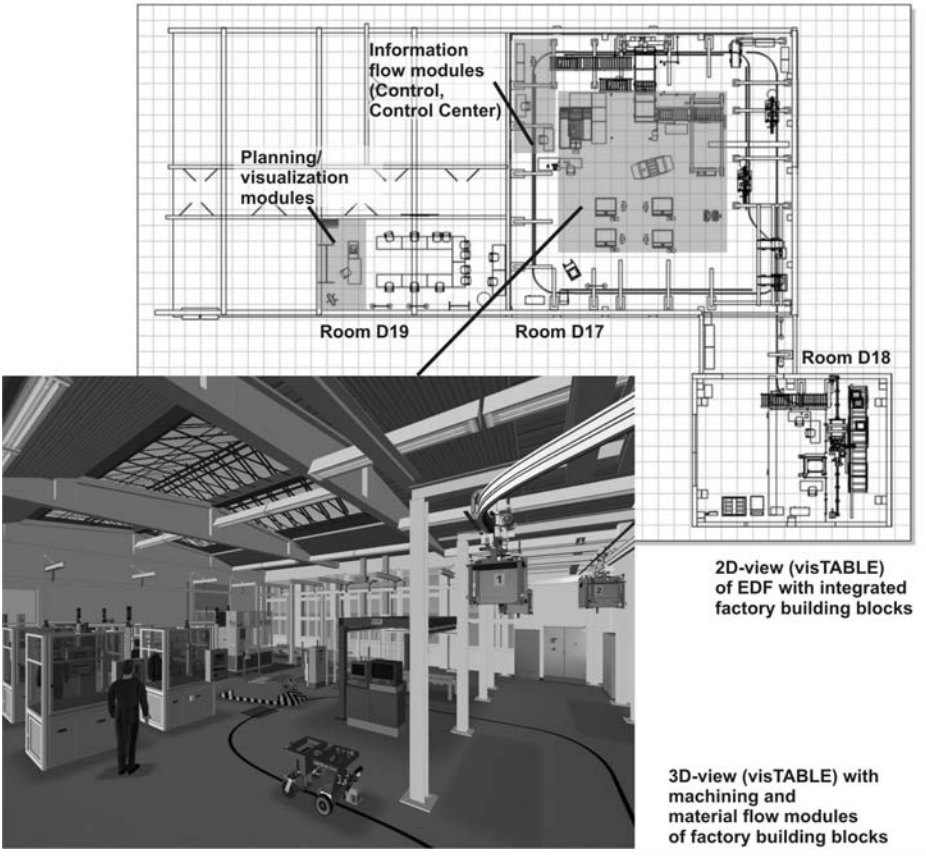

Fig. 1. Concept of the integration of building blocks for adaptable production systems in the EDF

3.1 Planning/Visualization Modules

The planning and visualization modules component configurator and visualization base on such concepts as Component-based Development [1], PLUG+PRODUCE [3] as well as Component-based Planning [2, 5, 24, 25]. The modules ensure that the designed factory can be planned and displayed efficiently, rapidly and in high quality on a computer.

The general idea of the method of Component-based Planning (figure 2) is that catalogues of components are not only provided for the object domain/production process (object components) but also for the method domain/ planning process (planning components). A standardization of the planning process and the production process as well as a reduction of the complexity can be achieved by the stringent application of the building block principle. Hence, through the use of proven and tested components, a rationalization and acceleration of the planning process is targeted, at the same time increasing quality.

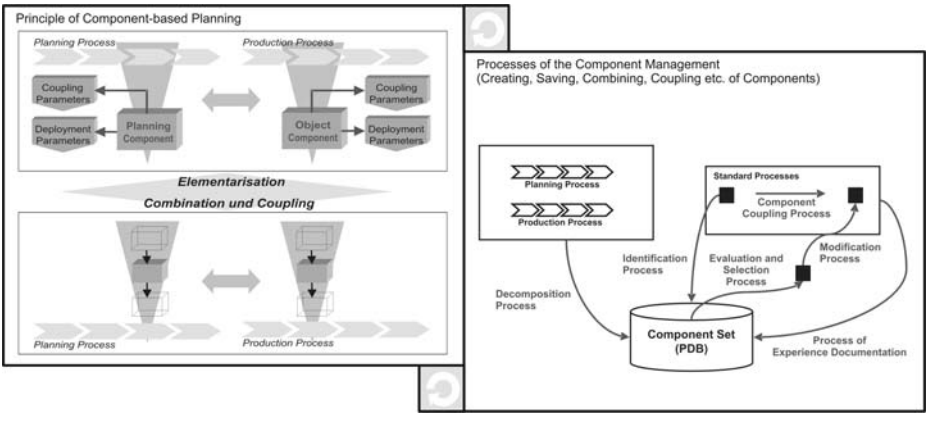

Fig. 2. Method of Component-based Planning (Principle) with component management processes [5]

Components of the planning process (planning components) are standardized units of the process of transformation of information. These components mainly integrate the planning functions, the relevant planning methods and competences as well as input and output information. On the contrary components of the production process (object components) refer rather to physical objects as well as the necessary competences. There are predefined procedures for the identification, selection and coupling etc. of building blocks. On the base of these procedures generated building blocks can be used for the Component-based Planning of production plants. They can be combined to obtain planning processes as well as production processes for production plants. The experiences from the application of the building blocks are used to improve the building blocks. That leads to the optimization of the building blocks, which at the same time store the acquired knowledge.

Therefore, not only the particular parts of factory equipment (object components of the Component-based Planning), but also the interdependent steps of the planning

process (planning components of Component-based Planning) itself are cataloged in the component configurator (figure 2). In addition, it must be possible to parameterize and modify both types of components in a comprehensive way. Components of lower order should be possibly joined to components of higher order. The configuration of the planning process should be done graphically. Its implementation should be guided by a planning manual. The visualization should provide a realistic mapping of the factory in an easy way. In addition to technical considerations, also issues of work science (e.g. working environments, interactions of humans) should be addressed.

3.2 Machining Modules

Four functionally universal manufacturing and assembly modules are the core of the building blocks for production systems. They can be placed arbitrarily in the layout and are meant to represent the machining equipment of a factory. Figure 1 illustrates one possible layout variant in the EDF.

That way it becomes possible to produce different products (e.g. variants of a wing mirror as an automotive mechatronical product) with different process chains on laboratory scale. The vision is to copy the EDF as a factory model (e.g. with LEGO building blocks).

In addition an automatic assembly machine, which has been already installed in the EDF (as fifth cell), should be integrated in the overall concept as well as an existing test station. The automatic assembly machine illustrates control, disassembly and packing processes, while the test station illustrates control and test processes.

3.3 Material Flow Modules

Material flow modules have to connect the manufacturing and assembly modules as well as already existing components such as the high-rack storage in the material flow technical aspect. Therefore, an automatic guided vehicle (AGV) and a gantry robot are integrated in the building blocks for adaptable production systems. By means of its controlling unit, the AGV can recognize the cells, which can be arbitrarily arranged in non central configurations, at their position and supply or collect material. The gantry robot can handle the material supply of the four cells in a central configuration. It can as well be used for complex storage and commissioning assignments. Additional handling equipment supports amongst others the handling to manufacturing and assembly modules as well as the implementation of supply concepts.

3.4 Information Flow Modules

The information flow modules ensure the interconnection of the manufacturing/assembly, material and energy flow as well as the planning and visualization modules in the information aspect. This includes the architecture of the control center module, the installation of additional components as part of the control module as well as the incorporation of innovative identification systems (e.g. RFID) in the machining and material flow modules (amongst others definite identification and routing of the load units).

The adaptability of products, processes and equipment, will be supported amongst others by information and data flows for;

- Factory planning (CAD (product) <-> process design <-> CAD (equipment)),
- Automation (CAD (product) <-> process design <-> CAD (equipment) <-> NC/PLC/…),
- Order Processing (CAD (product) <-> ERP <-> NC/PLC/…).

3.5 Energy Flow Modules

A supply module, which was designed as an overhead media line, has to assure the flexible discharging of energy by the mobile manufacturing and assembly cells. Especially the media electrical energy and compressed air should be provided area-wide.

An energy management module provides the elicitation of energy-related information from the machining, material flow and energy flow modules. Inversely a well-directed simulation and regulation of energy-relevant parameters is enabled by the energy management module. The energy management control will be incorporated in the control module. It will help to investigate the interdependencies between adaptability and energy efficiency as part of the building blocks for adaptable production systems.

4 Fields of Application and Deployment

The building blocks for adaptable production systems are primarily used for basic research about adaptability. At Chemnitz University of Technology the factory building blocks serve as research environment.

Secondarily the factory building blocks shall however establish the transfer of results and technologies to industrial practice at an early stage. Hereby the factory building blocks serve as test environment for regional system producers, manufacturers and service providers.

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