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Creation of a Learning Factory for Cyber Physical Production Systems

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Abstract

The development of Cyber Physical Production Systems (CPPS) is currently the dominant research topic in production and automation engineering. Therefore the underlying objective of this paper is to upgrade an existing centralized production laboratory to a CPPS learning factory. Key aspects of CPPS are interconnection on system level and with superordinate structures. This implementation, the comparison with state of the art production control systems and the utilization in university seminars are subjects of the paper. For example the enhancement enables the realization of manufacturing various products at the same time, mass customization aspects and automatic production of new products.

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Keywords: Coordination; Adaptive control; Reconfiguration

1. Introduction

Production systems face a profound technological conversion through the implementation of modern information and communication technologies. [1] Former reacting machines will be equipped with additional self-guiding technologies for self-contained execution and decision making. This conversion is part of an upcoming industrial evolution including subjects like Cyber Physical Production Systems (CPPS), industrial internet and factories of the future. This conversion was among other things triggered by the customization-movement of products. Fulfilling individual customer demands with affordable products require flexible and adaptable production processes. This flexibility and adaptability can be reached through a technological penetration of modern information and communication technology [2, 3]

Current automation solutions cannot face these challenges and therefore new approaches for production planning and control, manufacturing processes and automation technology are necessary. These new forms of production control and flexible manufacturing increase the complexity of production systems especially concerning information processing and software engineering.

To meet these challenges and prepare aspiring engineers for related issues, a learning factory for dealing with Cyber Physical Production Systems was created. An existing centralized PLC-controlled production laboratory was upgraded to a decentralized controlled Cyber Physical Production learning factory. This decentralization was implemented through the application of single-board computers with proprietary controlling heuristic. The single-board computer enhance existing control units regarding connectivity and condition monitoring. Each equipped machine knows its own status and has access to information of the production system. By adding controlling heuristic to every single-board computer a self-controlling production planning and control system is achieved. To teach the differences between the decentralized system for CPPS and the PLC-based centralized controlling system, the new system was developed as an extension, respectively alternative to the existing one. Working with both, centralized and decentralized controlling system, within learning factory seminars makes experiencing the differences according to performance, traceability and controllability possible.

This paper describes the underlying concept of the learning factory for Cyber Physical Production Systems. After a description of the former production laboratory and the state of

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the art of similar learning factories the CPPS learning factory is described. Finally the teaching concept of the learning factory is illustrated.

2. Laboratory for flexible industrial automation

The former laboratory for flexible industrial automation served as a research platform for current automation and production subjects and for academic courses. The laboratory consists of two manufacturing cells (a turning machine and a machining center) and an assembly station with a human-robot-collaboration robot. The machines are connected through a material flow system and additional industrial robots for workpiece handling and material supply.

The components are linked with each other by computer systems. The production procedure can be executed automatically. Figure 1 shows the laboratory in the current expansion state.

In the past several courses were carried out in the laboratory:

- *Exercise Robotics*

Students learn online and offline programming methods for different robots. The online programming is lectured via the teach-in procedure directly on a 6-axis robot. The first task is to implement a pick-and-place operation. For learning offline robot programming the existing robot cell shall be modeled and the same procedure of the online programming shall be programmed. After finishing this, the task of the students is to model a robot cell to execute different tasks (e.g. paint job, assembly, etc.). The last task is programming another pick and place operation on the collaborative two-arm robot.

- *Exercise PLC-technology*

In this exercise basics of pneumatic drives and programmable logic controllers (PLC) are taught in a practical manner on three different test rigs.

- *Exercise NC-programming*

NC manufacturing is taught via operating a turning machine, a milling machine, machining accessories and different CAM and CAD-programs. After learning the basics of machining with pre-defined demonstrators the students develop their own parts and deploy the resulting machining tasks on the machines.

- *Lecture Industrial Production*
- *Lecture computer-integrated manufacturing*
- *Project Laboratory "Digital Factory"*

In the project laboratory students work on a single project for four weeks as teams of at least five. The project consists of a planning or optimization task which is usually provided by an industrial company and can be simulated partially in the laboratory. Usually material flow simulation, workflow simulation and workstation simulation tools are used for processing the task. In addition to the modeling and simulation of the system, project management, teamwork, and presentation skills are trained.

At the moment a remote controlled car is used as a demonstrator. The demonstrator consists of the following produced parts:

- Additive manufactured chassis
- Milled car-platform
- Turned rims

All other parts like motors, wheels and motor control are bought separately. The concept of the demonstrator is based on a configurator model. Each part can be chosen and modified by the customer. For example motor power, chassis geometry, color, battery capacity can be changed according to customer needs.

After manufacturing the RC-car is assembled. All machines are connected through a single PLC: The PLCs main task is to control the material flow system via Profibus and to communicate with all subordinate machines (e.g. milling and turning machine). Through RFID-chips the position of all shuttle are determined. The production orders for the laboratory are entered in a pc and are transmitted to the PLC through an OPC-connection. The PLC tries to execute these orders based on their finish date and a user-defined priority by controlling machines, material flow shuttle and production sequence for assembly. In the beginning the raw material is placed on a workpiece carrier system on the shuttle. Afterwards this raw material is processed through the different machines.

3. State of the art

3.1. CPPS

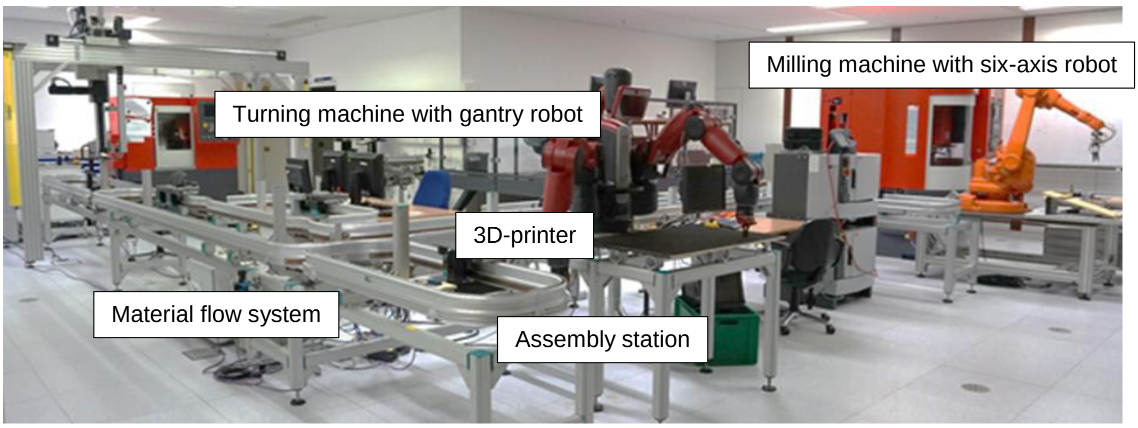

Figure 1. Laboratory for flexible industrial automation