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Flexible and Modular Control and Manufacturing System

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Abstract

The trend in production industry is going away from mass-produced products, towards individual products, which are adapted to the customer requirements. Thus flexible, modular production systems that can be adapted to individual use-cases are necessary. Within this paper, a flexible and modular control for a modular production system with the ability to use manufacturer-independent functions and modules is proposed. A new approach for a standardized description and an open interface for functions and modules is developed. This includes a decentralized control system architecture. The self-configuring control system identifies all functions and modules automatically and a specifically defined memory set (the CIMory data) is used to enable the self-configuration of the control system. Combining a real-time bus system and a SOA-based communication enables the decentralized approach of a future cloud based control system architecture.

Keywords: customized products; flexible and modular production system (FMPS); self-configuring control system

1. Introduction

Modular system-based engineering is the key to a quick, customized machine and plant configuration. This approach is seen as the best method to implement different functional requirements with a minimum amount of resources [1], as well as the possibility to optimize the operational capacity of the whole system, by adding modules to slow production steps [2].

Today’s modular production systems are not designed for online reconfiguration. For a fast reaction on new products, which have low lot sizes because of shorter and shorter product lifecycles, a fast and cost efficient reconfiguration, as well as the adding of functionality, is of huge importance.

2. Modularization of a production system

A flexible modular production system (MPS) is the key for producing companies to react to the trend of individual produced products which are preferred or even needed by their costumers [3, 4]. To achieve this goal of a MPS, able to adapt to a use case, changes in the engineering process compared to the classic machine engineering had to be made. Both, the hardware, as well as the software engineering were developed in the past, but have not achieved the high level of real modularity yet.

In this paper, an approach for a modular control system for a MPS is described. Within the research project CassaMobile a realization mock-up of the MPS is developed [5].

2.1. Modularization of the hardware

The modularization of the hardware components and modules of a MPS are developed so far, that a reconfiguration is possible within a few hours [6]. According to [7] the choice of system boundaries determines the complexity of the module interface, as well as the reconfiguration efficiency. In this context, a module is by definition a sub-system which has a stronger relationship to the inside as to the outside [8]. Module system boundaries should be chosen so that they have as few external interfaces as possible. To achieve this, functions to be performed have to be integrated instead of being added by external periphery. This reduces the number of module interface elements. The module forms a self-contained, autonomous unit.

According to this, modules described in this papers are defined as whole machines which can be used stand-alone but will be combined to an MPS.

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Another approach for modular and especially micro production system is presented by Hoffmeister et al. [9] for small machine tools for small work pieces. Their production modules are based on a predefined hardware frame onto which either process or kinematic modules can be mounted. This hardware frame in combination to the suitable hardware interfaces of the mentioned modules leads to modularity. The effort for the control software adaption, particularly for the combination of multiple production modules towards an entire production is not considered.

An alternative, but partially similar approach is given by Järvenpää [10] that defines a base module for production modules containing the control cabinet and clean room supply system enabling a workspace with clean room capabilities. To enable a production process, each base module can be equipped with different – but one at a time - production modules (e.g. robot, laser or machining unit). By combining multiple process integrated base modules, an entire production system can be established. This approach ensures a mechanically reconfigurable system, but the automatic adaption of the control system is not taken into account.

2.2. Modularization of the software

Today, all control producers and compatible third-party producers support some elements of the modular design (see product catalogs of e.g., Beckhoff, Bosch Rexroth, Siemens, Wago, Phoenix, Weidmüller, …). They offer control families, which provide a continuous control system. Within these families, the control system manufacturers offer warranty on function. A modular extension within the control family is usually possible (e.g., Siemens SIMATIC S7).

A problem occurs, if a control family is not able to offer a needed functionality. This needed functionality can only be added by applying components of another control family or a functionality of another manufacturer. In many cases the different product families are not compatible and a lot of manual configuration is necessary.

The modularization within the control functions, as described in the project OSACA [11], is not very developed. The exchange of software functionality (OSACA calls this functionality "architectural objects"), is currently not possible. For this reason, control software must be configured depending on the manufacturer of the functionality.

This is one reason why manufacturers of production systems and machines, that have evolved the modularization very far, are caching the configuration and parameter data for the functional module, defined by them, centrally by a manufacturing system configuration system (e.g. EPLAN [12]). By using a kind of bill of materials, the configuration and parameterization of a production system will be generated automatically.

This approach necessarily implies that all needed data for all used functional modules is available in the manufacturer specific plant configuration system. Therefore, appropriate data must be created for new, previously unknown function modules by time consuming work. This includes, among others:

- Configuration and parameterization
- Change options for configuration and parameterization
- PLC and, if needed, CNC program parts
- Information on the development level of intelligence of the function module (either only I/O technology or own intelligence available)
- Sensor processing
- Access protocol for I/O and drives
- Documentation of the function module
- diagnostic possibilities

The machine and system manufacturers require this function module information compatible with their in-house company standard. Thus, a high amount of self-work of the system manufacturers is necessary, which cannot be offered by the function module manufacturer.

An adapter needs to be created (see Fig. 1a, orange, left top to right bottom hatched boxes), which adapts the communication from the standard of the function module manufacturer to the standard of the machine or system manufacturer.

But not only the Control System of a MPS but the whole MPS and its environment can be designed modular. Within the "Industrie 4.0" project, a system is envisaged, in which the function modules bring all necessary information for their use in any control system with them [13]. A service oriented architecture (SOA) is used for communication between manufacturing module and control system [14, 15, 16, 17, 18]. The function modules offer services that are used by the guidance system for the production of the product required. The central plant control systems will continue to develop evolutionary and at the same time the possibilities of decentralized self-organization are increasingly being used [17, 19].

3. Design of a modular production system for plug & use of functions and features

To modularize control functions and to be able to combine them vendor-independent, it is therefore necessary to create a vendor-uniform interface. Function modules from any manufacturer can thus be obtained and integrated into the control system, based on the function performance.

This approach shifts the object of compatibilization from the control system manufacturer to the function module manufacturer (see Fig. 1b).

With this approach it is possible, that the function module manufacturer not only provides the function module, but also the function module information. Thus, the function module is independent from the control system type.

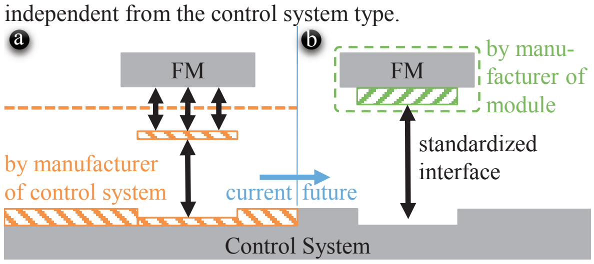

Fig. 1: Current (a) and future (b) integration of function modules (FM) to the Control System by standardization of interfaces