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Cyber-physical robotics – automated analysis, programming and configuration of robot cells based on Cyber-Physical-Systems

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Abstract

This paper shows a Cyber-Physical-System based approach which allows the efficient utilization of the entire flexibility of reconfigurable, modular robot cells in assembly. Robots cells are automatically programmed, configured and optimized based on the solution independent virtual requirements of the individual product. A detailed virtual representation of the entire robot cell eliminates uncertainties regarding the feasibility of the assembly process in a defined robot cell during the design phase of the product with a CAD program. The necessary virtual representations of the robot cell components and the products to be manufactured are defined and the information interchange is explained.

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Keywords: Cyber-Physical-Systems; reconfiguration and programming of robot systems; task description language; assembly; computer aided design

1. Introduction

Industrial robots have a great inherent flexibility due to their kinematical degrees of freedom and the versatility of manageable tools, sensors and other periphery devices. The effort needed to program and configure the entire robot system, for example at the introduction of a new or altered product, is high and is limiting the utilized flexibility.

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Therefore robots in the industrial environment are mostly used for repetitive, pre-defined tasks with little variance and adaptability [1].

This conflicts with the trends, the manufacturing industry faces nowadays: growing uncertainty about product life-cycles, increasing product variance, globalization and shrinking lot sizes [2]. These demands have to be met with new approaches to program and configure robot systems, minimizing the required time and operator experience [3].

When a new product or a new variant is designed, there is no certainty about the feasibility of the manufacturing process on the existing installations. Descriptions of the manufacturing process are generated and analyzed manually. In a next step human robot programmers write the control code. If the product cannot be manufactured, either the product is altered or the robot system has to be changed. The communication between the operators and the designers lacks continuity due to the usage of no or incompatible types of software, resulting in a try-and-error proceeding. Time to market is increased and the planning reliability is reduced [4].

In order to facilitate the reconfiguration of robot cells, the Plug&Produce approach was introduced. By adding a storage device to the components containing its virtual description and corresponding drivers the effort for the reconfiguration of components from heterogeneous manufacturers could be reduced. The exchangeability of actuators and tools can be increased significantly. [5, 6, 7]

In this paper the Plug&Produce approach is brought to the next level by adding a virtual representation of the product to the system, which contains its individual properties and requirements. The robot cell components and the product to be manufactured are defined as Cyber-Physical-Systems (CPS) [8, 9], allowing them to store data, to process data intelligently, to interact and to communicate with each other. The aim of Cyber-Physical-Robotics is the development of a method for an automated analysis, programming and configuration of every kind of robot cells. The necessary information is provided by solution independent data from the product. An economic automated production of all facility-adequate products and the utilization of the entire flexibility of robot cells are to be achieved.

In order to not only shift the effort of programming and configuring robot cells to the manual generation of the virtual representations of the products to be manufactured, its automated generation from CAD files and sensor data is researched and described. By connecting the virtual representation of the robot cell, which fully describes its skills, with the CAD program, the feasibility of the automated manufacturing process of the product can be analyzed without the need for real world testing.

To reach the before mentioned goals, a new system integrating partial solutions already existing in scientific literature has to be developed. Operations inside its necessary subsystems as well as the data exchange between them are explained and additionally new approaches, required to reach the technological vision, are presented in this paper. The paper focuses on the information exchanged and stored by various CPS in the robot cell and does not address data exchange technologies.

2. Vision

The presented approach can be seen as a necessary step to reach the vision of the future of industrial robots, which is explained in this chapter. A possible scenario could be: a product designer finishes the work on his project in his CAD software. The virtual representation of all product requirements towards the assembly process is generated from a CAD file. The designer sends the virtual description to a service provider for automated assembly. The service provider has a shop floor with a modular Cyber-Physical-Production-System (CPPS) with a variety of tools, sensors, mobile and fixed robots. All these devices have a virtual representation of their skills and properties. These are linked to a network and communicate with each other. Analysis of mutual interferences and interdependencies of the devices in the modular production system allow a precise determination of the available processes with the corresponding constrains. Processes required by the product can be automatically compared with the available processes. Information about product requirements exceeding abilities of the CPPS can be used to alter the product or be used by the service provider to add more appropriate devices to the CPPS. After determining the requirement fulfillment of the production process, the designer, being the client, can choose the optimization criterion (e.g. time, price, energy efficiency) for production planning. The designer can compare offers from various assembly service providers. The flexibility and modularity of the production systems allows the efficient production