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Automatic modeling and simulation of robot program behavior in integrated virtual preparation and commissioning

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Abstract

This paper presents a method where the behavior of a robot cell is automatically modeled based on existing robot programs and a simulation model of the cell. Robot programs from the shop floor are uploaded into a virtual manufacturing tool, and a formal model is then generated from the robot programs. Then, control logic is automatically calculated, and the fastest possible execution order is found by using the generated model to formulate an optimization problem. The result is continuously analyzed and validated by simulation in the virtual manufacturing tool.

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1. Introduction

Production systems evolve during their life cycle. On-line changes of the control code, fine tuning, and system maintenance, gradually change the system from what was originally prepared off-line. With the ongoing heavy

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investment in virtual manufacturing [1], it is important that the virtual manufacturing models (VMMs) evolve together with the system.

Being able to simulate existing production systems using existing virtual manufacturing models is crucial for example when introducing new product types into an existing system. Updating a VMM to accommodate *physical* changes is already being done with laser scanning into point clouds [2], but proper tools are also needed to work with the system *logic*.

Off-line robot programming has since long been used in industry, and most of today's virtual manufacturing tools support both downloading programs to robots and uploading them back into a virtual model. However, the robot programs usually contain handshaking (e.g. interlocking) with an external control system (e.g. a PLC), so before the introduction of virtual commissioning (VC) --- which enables a virtual model of the system to be controlled by an external control system [3] (see Section 2) --- simulating this handshaking of the uploaded robot programs required manual intervention.

Most VMMs in industry today were created before the advent of VC. In plants with many hundreds if not thousands of robots (e.g. in the automotive industry) manual intervention needs to be kept at a minimum. For production cells that are mainly robot based, this work proposes a method that instead of performing a costly migration of existing VMMs to full VCs, a formal model of the system including the handshaking with the control system can be generated automatically. This formal model contains all possible combinations of executions, and can be used to visualize, study and simulate the system. A formal model also enables verification and optimization of the system behavior. For stations that contain mostly robots, this approach requires very little human intervention. Models for other devices (e.g. clamps, turn tables) can then be added manually, depending on how detailed the preparation work needs to be. With the addition of VC support in virtual manufacturing tools in recent years, the formal model can be used to control the simulation, in effect acting as a high-level control system. This enables far greater opportunities to simulate things like disruptions, running maintenance programs, and executing programs for different product types in sequence compared to the traditional way of creating sequences for different cases manually. Fig. 1 shows the software Sequence Planner [4], which hosts the generated models, controlling the virtual manufacturing software Process Simulate[1]. The depicted production cell with four robots is used as an example throughout Sections 4 to 6.

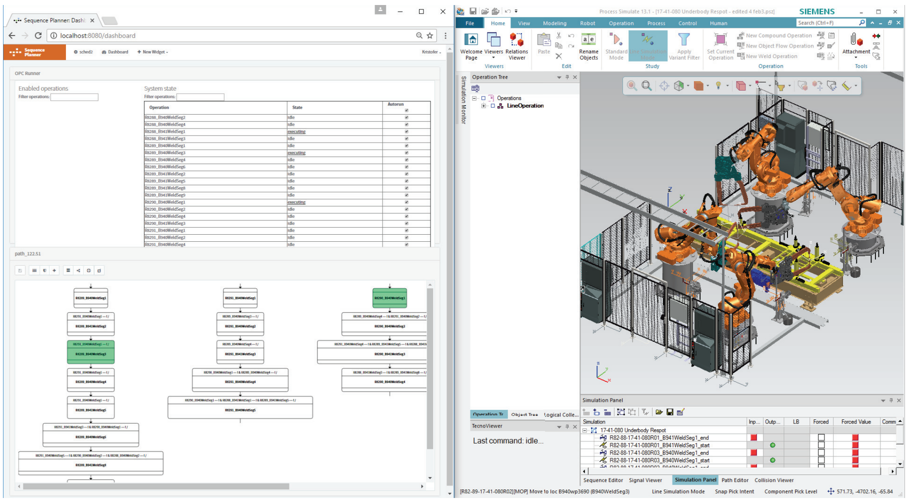

Fig. 1. Graphical user interface of the software Sequence Planner to the left shown controlling a simulation of four robots in a virtual manufacturing software to the right. Currently executing operations are shown in green color.

[1] Siemens PLM, http://www.plm.automation.siemens.com/, 2017