Institut für Mechatronik

Autor(en) des Beitrags:
Shea, Kristina

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The cognitive factory

Abstract:
Research in the area of the Cognitive Factory explores the unique intersection of artificial cognition and production that is vital for creating next-generation manufacturing systems. Factories are inherently complex, dynamic, highly-coupled and interactive environments that are subject to many potential disturbances, some foreseen and some unforeseen. In the past, a common approach was to create a highly structured, deterministic and closed environment that can operate autonomously for long periods of time. However, changing such a rigid system to meet new requirements, e.g. a new product, is time, cost and knowledge intensive, often involving large amounts of human effort. Further, no matter how well planned, errors and unforeseen events are always bound to occur during operation. The main aim of the Cognitive Factory is to be able to robustly react and adapt to a wide variety of changes and uncertain events, coming from different sources, with human effort required only where advantageous. This includes market changes, e.g. increasing demand for more product variants, more customized products and smaller product volumes, and technology changes. Uncertain events include availability of materials, parts and machines as well as machine failures and errors in part fabrication and assembly. A key to creating such a highly adaptable and flexible manufacturing system is embedding on-line, cognitive capabilities in the machines themselves and the production control. This will enable the factory to, for example, reason from knowledge and models that are continuously
updated through on-line observation, autonomously plan its own actions, rather than only execute a pre-defined plan, and learn new models, new actions and new skills. This changes the manufacturing system from a deterministic one where all planning is carried out off-line to a dynamic one that can determine and reason about processes, plans and operations on-line in relation to the current system state and available capabilities and capacity. Further, the environment is opened to allow and improve interaction between humans and machines, for example in assembly tasks. By increasing flexibility and robustness, the Cognitive Factory aims to balance the high efficiency and cost-effectiveness of traditional automation with the flexibility and robustness of human-based production. The goals are vital economically for the manufacturing sector to remain competitive and much research is required and underway to achieve them. This is an exciting, developing research area that crosses the disciplines of mechanical engineering, production engineering, electrical engineering, computer science and psychology. From the scientific research perspective, the factory domain provides a highly relevant and complex test bed for new models and methods in artificial cognition, artificial intelligence and cognitive robotics. The Special Issue presents leading research in a range of areas within the Cognitive Factory. The papers included in this issue were all invited and selected based on critical reviews by three international reviewers each. Ian Smith carried out the independent review of the paper by me and my co-authors. The special issue starts with a unique proposal by Corney et al. to use the power of people, through Crowdsourcing, for complex geometric reasoning tasks, on-line, within the factory in the paper, “Putting the Crowd to Work in a Knowledge-Based Factory”. They aim to overcome current limitations of AI technologies with their approach and present examples including 3D shape similarity and 2D part nesting. Next, my co-authors and I present a new integrated framework for automating and embedding fabrication planning within the factory in the paper, “Design-to-Fabrication Automation for the Cognitive Machine Shop”. The approach proposes knowledge models, reasoning and planning methods for automated workpiece selection, generative CNC machining planning and fixture design to enable autonomous fabrication of customized part geometry. Continuing in the area of process planning, the paper, “Enabling Cognitive Manufacturing through Automated On-machine Measurement Planning and Feedback”, by Zhao and Xu, presents a consolidated data model and system framework for automatic process planning for machining, inspection, and feedback. Real-time acquisition of process data through in-process measurement and its feedback to process control is targeted at enabling a manufacturing system to react promptly to errors in part fabrication. Moving onto the area of production control, Puttonen et al. propose using semantic web services for controlling a production system in their paper, “A Semantic Web Services-Based Approach for Production Systems Control”. Their approach includes describing production equipment and their dynamic states using an ontology to determine which actions should be taken and finding current available web services capable of completing these actions. Since the descriptions of services are retrieved dynamically, production control can react to changes. The article, “A Holistic Approach for the Cognitive Control of Production Systems”, by Zaeh et al., presents a concept for a cognitive production planning and control where products store in a data model, which is physically integrated using RFID technology, the production process and current state to provide improved anticipatory transport control. The approach introduced is targeted at enabling production control to better react to uncertain events, e.g. missing material and insufficient product quality, and reduce idleness and waiting time of resources. Finally, Maier et al. address the question of how likely a given manufacturing process plan, which is determined off-line, is to succeed on-line. In their paper, “Automated Plan Assessment in Cognitive Manufacturing”, they present a model-based approach that uses on-line observations and computes the success probability of a plan to provide advice to production control so that it can avoid error-prone operations and parts. The special issue finishes with two papers in the areas of manual and hybrid assembly. First, Stork and Schuboe explore human cognition aspects in their paper, “Human Cognition in Manual Assembly: Theories and Applications”. They discuss the effects of task complexity and related attention demands on mental workload and task performance and present studies of assistive systems for manual assembly that use augmented reality and spatial cueing. Finally, the paper, “A Skill-Based Approach Towards Hybrid Assembly”, by Wallhoff et al. investigates how humans and robots can achieve efficient cooperation in a shared workspace. It presents a hybrid assembly station where a robot learns new tasks from worker instructions using a knowledge-based system controller and multi-modal communication channels including speech, gaze and haptics. These articles provide a compilation of papers presenting current and developing research in a growing area that is targeted to create the foundation for the factories of tomorrow. I hope that you will find them useful and insightful. Finally, I would like to thank Ian Smith for his guidance and effort in preparing this special issue and acknowledge support from the Cluster of Excellence, Cognition for Technical Systems, CoTeSys.