Daydreaming Factories
An STC-O keynote proposal for 2022

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Manufacturing systems through revolutions

Optimisation dimension:

- Mechanical
  - The first industrial revolution
- Organisational
  - The second industrial revolution
- Computational
  - The third industrial revolution
- Connectivity
  - The fourth industrial revolution

Raw Material → Manufacturing System → Products
Static v ongoing optimisation

Most optimisation in the past was static: CIRP encyclopedia offers operations research as a synonym for optimization in manufacturing. With the emerging evolving factories of I4.0, ongoing optimisation of the factory may be necessary.
Daydreaming factories – always optimising
Daydreaming factories – always optimising
Reinforcement learning for adaptive order dispatching in the semiconductor industry

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ARTICLE INFO

Article history:
Available online 21 April 2018

Keywords:
Production planning
Artificial intelligence
Semiconductor industry

ABSTRACT

The digitalization of production systems tends to provide a huge amount of data from heterogeneous sources. This is particularly true for the semiconductor industry wherein real time process monitoring is inherently required to achieve a high yield of good parts. An application of data-driven algorithms in production planning to enhance operational excellence for complex semiconductor production systems is currently missing. This paper shows the successful implementation of a reinforcement learning-based adaptive control system for order dispatching in the semiconductor industry. Furthermore, a performance comparison of the learning-based control system with the traditionally used rule-based system shows remarkable results. Since a strict rulebook does not bind the learning-based control system, a flexible adaption to changes in the environment can be achieved through a combination of online and offline learning.

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Fig. 1. Overview of simulation-based learning framework.
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Daydreaming factories – examples in CIRP

Image courtesy of Professor Lutters
Daydreaming factories – examples in CIRP

Image courtesy of Professor Lutters
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Development and operation of Digital Twins for technical systems and services

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Abstract

Digital Twins are new solution elements to enable ongoing digital monitoring and active functional improvement of interconnected products, devices and machines. In addition, benefits of horizontal and vertical integration in manufacturing are targeted by the introduction of Digital Twins. Using the test environment of smart factory cells, this paper investigates methodological, technological, operative, and business aspects of developing and operating Digital Twins. The following Digital Twin dimensions are considered in scientific and application oriented analysis: (1) integration breadth, (2) connectivity modes, (3) update frequency, (4) CPS intelligence, (5) simulation capabilities, (6) digital model richness, (7) human interaction, and (8) product lifecycle. From this, design elements for the development of Digital Twins are derived and presented.

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Digital twin driven human–robot collaborative assembly
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ARTICLE INFO

Keywords:
Man-machine system
Robot
Digital twins

ABSTRACT

This paper discusses an object-oriented event-driven simulation as a digital twin of a flexible assembly cell coordinated with a robot to perform assembly tasks alongside human. The digital twin extends the use of virtual simulation models developed in the design phase of a production system to operations for real-time control, dynamic skill-based tasks allocation between human and robot, sequencing of tasks and developing robot program accordingly. The methodology combines lean methods of manual assembly in human–robot collaboration paving path towards flexible human–robot work teams. The study is validated with an industrial case study involving dexterous assembly tasks. © 2019 Published by Elsevier Ltd on behalf of CIRP.

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A problem-solving ontology for human-centered cyber physical production systems

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Article Info
Article history:
Available online 1 August 2018

Keywords:
CPS, Human
Problem-solving
Ontology
Industry 4.0

ABSTRACT
Cyber-physical-social systems (CPS/S) tend to integrate computation with physical processes as well as human and social characteristics. The fusion of cyber, physical, and socio spaces through Industry 4.0 emerges a new type of production systems known as cyber physical production systems (CPPS). CPPS enriches communications among cyber-physical-socio-space in the production environment. Utilizing human-centered CPPS in smart factories (ideally) results in a mutual transition from human-machine cooperation to active collaboration, which is characterized by cyber-physical-socio interactions, knowledge exchange and reciprocal learning. The shift from data workers or producers to problem-solver is, therefore, triggered to both humans and CPPS, respectively. Hence, their job rules and responsibilities cannot be independently defined. This paper approaches the collaboration of human and CPPS in problem-solving from the angle of complementarity whereby "human competences" and "CPS autonomy" together derive supplementary capability and reciprocal learning. In this research, "Problem" is an umbrella term that refers to both categories of "human-CPPS task" (i.e. a specific piece of work required to be done) and "failure event" (i.e. a state of difficulty that needs to be resolved). A holistic ontological framework is proposed, entitled PISP Ontology (Problem, Solution, Problem-Solver Ontology), which represents the logical relations between the three super-concepts of "Problem Profile", "Problem-Solver Profile", and "Solution Profile". Related entities are formalized by introducing (i) contingency vector, (ii) vector of competence and autonomy, and (iii) solution maturity index, respectively. PISP Ontology is utilized for semantic representation of the super-concepts and reasoning out the competence questions, i.e. in which situation and under which conditions human and/or CPPS is dominant or eligible to solve a problem (to accomplish a given task and/or to detect or eliminate a failure), which is qualitatively exemplified in the use-case of maintenance 4.0.

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Hybrid, AI- and simulation-supported optimisation of process chains and production plants

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Abstract

The paper describes a novel approach for generating multipurpose models of machining operations, combining machine learning and search techniques. A block-oriented framework for modelling and optimisation of process chains is introduced and its applicability is shown by the results of the optimisation of cutting processes. The paper illustrates how the framework can support the simulation-based optimisation of whole production plants. The benefits of substituting the time-consuming simulation by ANN models are also outlined. The applicability of the proposed solution is demonstrated by the results of an industrial project where the task was to optimise the size spectrum of the ordered raw material at a plant producing one- and multi-layered printed wires.

Keywords: Manufacturing Systems, Artificial Intelligence, Optimisation

Figure 4: Concept of the hybrid, AI-, ML- and simulation-supported optimisation of production plants
Daydreaming factories

– other examples

TWO MINUTE PAPERS
WITH KÁROLY ZSOLNAI-FEHÉR (KZF)

TRANSFERRING AI TO THE REAL WORLD

Disclaimer: I was not part of this research project, I am merely providing commentary on this work.
Daydreaming factories – Contents
Daydreaming factories – always optimising

Going from learning from experience (history) and predicting the future (prognosis) to learning from what could happen based on imperfect models.

Thank you for listening.
Proposed draft outline:

Chapter 1: Introduction
  1.1 Optimisation vs amelioration in industrial revolutions
  1.2 Cognition, semantics and knowledge models

Chapter 2: Preparation of the cyberspace - digital twins, shadows and prototypes
  2.1 Fidelity of digital models
  2.2 Domain randomisation

Chapter 3: Learning from Simulation
  3.1 Simulation methods
  3.2 Learning beyond “re-discovering” the model

Chapter 4: Learning from Analytics
  4.1 Minimal non-trivial analysis
  4.2 Mass analytics

Chapter 5: Bi-Directionally transferring learning between cyberspace and the physical environment
  5.1 Transfer from cyberspace to physical space
  5.2 Transfer from physical to cyberspace