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GRAND CHALLENGES IN MODELING AND SIMULATION OF COMPLEX MANUFACTURING SYSTEMS

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ABSTRACT

As a result of a 2002 Dagstuhl Seminar (Fujimoto *et al.,* 2002), Fowler and Rose (2004) discussed grand challenges in the modeling and simulation of complex manufacturing systems. In this presentation, we will review the progress on the grand challenges identified by Fowler and Rose(2004) and point out some new challenges.

1 INTRODUCTION

In August 2002, a group of academic and industrial researchers came together at Schloss Dagstuhl (https://www.dagstuhl.de/) to discuss *grand challenges* related to modeling and simulation in several domains including the manufacturing systems domain (Fujimoto *et al.*, 2002). The entire group agreed on the following definition of a grand challenge. A grand challenge is a problem that (1) is difficult, with the solution requiring one or more orders-of-magnitude improvement in capability along one or more dimensions; (2) should not be provably insolvable; and (3) has a solution that results in a significant economical and/or social impact. After several days of discussion, The manufacturing systems subgroup spent the week discussing challenges faced in the modeling and simulation of complex manufacturing systems which led to the Fowler and Rose (2004) paper. The grand challenges will be presented in the next section.

There have been considerable advancements in computing and advanced manufacturing systems since the 2002 Dagstuhl seminar. Much of this change is captured in the Industry 4.0 concept, also known as the Fourth Industrial Revolution. Industry 4.0 encompasses three technological trends driving this transformation: connectivity, intelligence, and flexible automation. Industry 4.0 converges IT (Information Technology) and OT (Operational Technology), to create a cyber-physical environment. This convergence has been made possible thanks to the emergence of digital solutions and advanced technologies, which are often associated with Industry 4.0 (https://cio-wiki.org/wiki/Industry_4.0).

2 GRAND CHALLENGES FROM 2002 DAGSTUHL SEMINAR

Here are the grand challenges from the 2002 Dagstuhl Seminar.

- Grandest Challenge 1: *An Order-of-Magnitude Reduction in Problem-Solving Cycles*
- Emerging Grand Challenge 2: *Development of Real-Time Simulation-Based Problem-Solving Capability*
- Emerging Grand Challenge 3: *True Plug-and-Play Interoperability of Simulations and Supporting Software within a Specific Application Domain*
- Big Challenge 4: *Greater Acceptance of Modeling and Simulation within the Industry*

3 REVISITING THE GRAND CHALLENGES IN LIGHT OF INDUSTRY 4.0

In this presentation, we will reflect on the progress made on the previous grand challenges to see if they have been solved or need to be modified. We will also examine the requirements of Industry 4.0 and determine if new grand challenges have emerged. Modern highly automated factories like semiconductor fabs generate massive data from numerous sensors, make decisions from the data, and learn and optimize the decision rules by AI or humans. We, therefore, have new challenges of deriving an explainable, interpretable, or executable model from the data, identifying and modeling complex decision rules that can be explained and simulated, and developing high-fidelity simulation models like digital twins to be used for learning and training for AI or humans.

REFERENCES

Fowler, J. and Rose, O. 2004 "Grand Challenges in Modeling and Simulation of Complex Manufacturing Systems", *Simulation: Transactions of the Society for Computer Simulation International*, 80(9): 469-476.

Fujimoto, R., Lunceford, D., Page, E. and Uhrmacher, A.M., 2002. Grand Challenges for Modeling and Simulation. *Schloss Dagstuhl*, 350.

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