Digital Twin

Bi-Weekly 5 (05/12/2022)

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Agenda

- An overview of State-Of-Art
- Literature Gap
- What-If Analysis
- Architecture review: As Is
- Architecture review: Questions & Suggestions
- MindSphere progress
- Timeline and Next steps

An Overview of State of the Art

An Overview

- 3500+ titles queried on Scopus.
- 220+ Papers reviewed.
- 10+ academic articles analyzed in depth.

- 5+ architectures for Digital twin configuration and implementation in industrial scenarios.
- Focus on open architectures in the field of manufacturing and assembly lines.
- Review on automated model generation and its verification on 2 case studies.

Top 10 Papers

- Lugaresi, G. and Matta, A. (2021) **‘Automated manufacturing system discovery and digital twin generation’**, Journal of Manufacturing Systems, 59(February), pp. 51–66.
- Lugaresi, G. and Matta, A. (2021) **‘Automated digital twins generation for manufacturing systems: A case study’**, IFAC-PapersOnLine, 54(1), pp. 749–754.
- Yang, M. et al. (2022) **‘A Novel Embedding Model Based on a Transition System for Building Industry-Collaborative Digital Twin’**, Applied Sciences (Switzerland), 12(2).
- Leng, J. et al. (2022) **‘Digital twins-based flexible operating of open architecture production line for individualized manufacturing’**, Advanced Engineering Informatics, 53(January), p. 101676.
- Xu, L. Z. and Xie, Q. S. (2021) **‘Dynamic production scheduling of digital twin job-shop based on edge computing’**, Journal of Information Science and Engineering, 37(1), pp. 93–105.

Top 10 Papers

- Hyre, A. et al. (2022) **‘Digital twins: Representation, Replication, Reality, and Relational (4Rs)’**, Manufacturing Letters, 31, pp. 20–23.
- Sakr, A. H. et al. (2021) **‘Building Discrete-Event Simulation for Digital Twin Applications in Production Systems’**, IEEE International Conference on Emerging Technologies and Factory Automation, ETFA, 2021-Septe.
- Heindl, W. and Stary, C. (2022) **‘Structured Development of Digital Twins—A Cross-Domain Analysis towards a Unified Approach’**, Processes, 10(8).
- Traoré, M. K. (2021) **‘Unifying digital twin framework: Simulation-based proof-of-concept’**, IFAC-PapersOnLine, 54(1), pp. 886–893.
- Zhang, Y. F. et al. (2020) **‘Digital twin-based production simulation of discrete manufacturing shop-floor for onsite performance analysis’**, IEEE International Conference on Industrial Engineering and Engineering Management, 2020-Decem, pp. 1107–1111.

Conclusions & Reflections

- Presence of **multiple** digital twin **definitions** which are not entirely aligned with our concept of a digital twin.
- Presence of **multiple** digital twin **architecture**. Some are verified by implementing on testcase scenarios like assembly lines.
- **Process mining** approach has been verified as comparable way to generate physical twin configuration and estimate parameters.

Conclusions & Reflections

- Various **digital twin use case scenarios** are already available, such as dynamic scheduling, predictive maintanence, reconfiguration of flexible machine production lines.
- A wide set of authors agree that further study has to be done on **increasing the efficiency** of the digital model and its **reliability**.
- Further study to be done from the **safety** and **sustainability** point of view.

Literature Gap

Literature Gap

Main DT components

	Architecture	Model generation	Syncronisation/ Validation	Monitoring	DT Services
Paper 1	1	0	0	1	1
Paper 2	0	1	0	1	0
Paper 3	1	0	1	0	0

(224 papers)

Literature Gap

Main DT Services

	Scheduling	Planning and control	Forecasting	What-if analysis	Performanc e evaluation
Paper 1	1	1	0	0	0
Paper 2	0	1	0	0	0
Paper 3	0	0	0	0	1

(224 papers)

Literature Gap

Literature Gap

Literature Gap

What-If Analysis

What-If Analysis

F. Pires, B. Ahmad, A. P. Moreira, and P. Leitão, **“Digital Twin based What-if Simulation for Energy Management”** in 4th IEEE ICPS2021 (Accepted), 2021.

Architecture Review: As is.

Initial Understanding

Framework: Big Picture

Framework: Detailed

Framework: Detailed

Framework: Simplified

Architecture Review: Questions & Suggestions

Questions & Suggestions

- How far is the What-If Analysis service implemented? How are the predefined solutions for What-If scenarios determined?
- What is the purpose of Analyzer? Why is it connected to Supervisor?

Questions & Suggestions

- The thesis on synchronization says *"The simulation is run until Tnow so the instant conditions are aligned, the positions of the pallets and the parts produced are uploaded in the Database"*. Since the part production (processing time) in the station is a stochastic behaviour, why is it updated as an instantaneous condition to sync?

Questions & Suggestions

- The thesis on synchronization says *"..... a configuration file is given as input to the conversion procedure. Transportation time, conveyor capacity, buffer capacity and unload times have to be specified"*. Is there a possibility to automate these parameters also?

Questions & Suggestions

- Rule of Frequency?
  - If probability -> What-if decision making
- Transportation Time

- Calculating the predict cycle time and remaining cycle time with machine learning model

Framework: Simplified

MindSphere Progress

Timeline and Next Steps

Timeline and Next Steps

Timeline and Next Steps

1. Physical Twin and Introduction

- Learn how to use the Lego System (EV3 components)
- MQTT communication
- Influxdb database
- Proof of Concept ("Supervisor")

Timeline and Next Steps

2. Refresh of The State of the Art

- Research Framework
- Query Search
- Paper Selection (algorithmic, manually score, and skimming)
- Reading selected papers
- Highlights

Timeline and Next Steps

3. Framework Review

- Review of existing Framework (1 week) - See the DT (we are here!)
- implementation and scientific work review (2 weeks)
- Alignment analysis and update framework (1 week)

Timeline and Next Steps

4. Break

- Christmas and New Year break
- From 19/12/2022 to 05/01/2022

Timeline and Next Steps

5. Development | MindSphere

- Data collection (check compatibility)
- Model generation (check compatibility)
- Synchronization and Validation (check compatibility)
- Digital Twin's Services **(Need to be done)**
- Feedback implementation **(Need to be done)**
- Alignment with MindSphere

Timeline and Next Steps

6. Buffer | Testing

- Buffer in case of delay
- Testing bench for validation of the development

Timeline and Next Steps

7. Report

- Report (middle-term)
- Report submission for Pedro's university
- *Paper submission?*

Timeline and Next Steps

8. Alex's Thesis

- Alex keeps going with the Thesis
- Pedro keep helping Alex
- Improvements in previous steps and academic refining the work

Timeline and Next Steps

An Opportunity for Collaboration

- Development of Digital Twin Services specifically in What-If Analysis.
- With Chalmers University of Technology.
- Contact person: PhD. Paulo.
- Probability of publishing a paper for next winter conference.

- Deep dive into the codes
- Writing first chapters of Literature Review

Thank You