



REAL-TIME ALGORITHMS FOR DIGITAL TWINS

Closing

UKACM Autumn School 2026
Prof. Dirk Hartmann



1

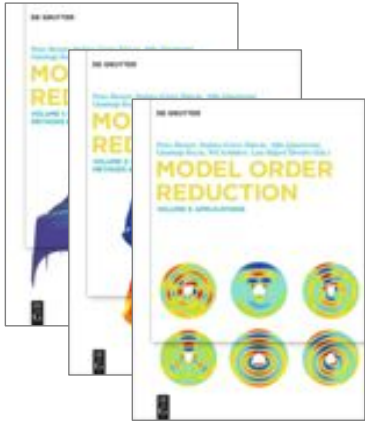
References & People

2

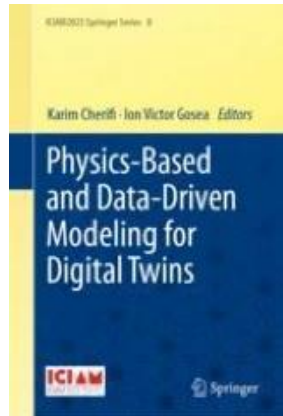
Wrap Up

Real-Time Algorithms for Digital Twins

Books



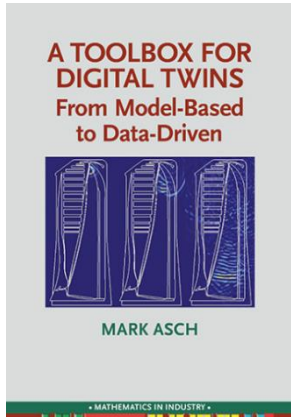
Peter Benner and et al.: Model Order Reduction
De Gruyter Brill, 2021 (Handbook). [Volume 1](#), [Volume 2](#), [Volume 3](#)



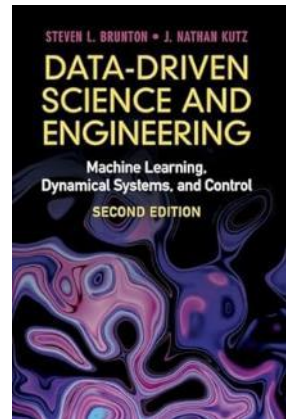
Karim Cherifi, Ion Victor Gosea.: Physics-Based and Data-Driven Modeling for Digital Twins
Springer, 2023, <https://doi.org/10.1007/978-981-96-9108-1>

Real-Time Algorithms for Digital Twins

Books



Mark Asch: A Toolbox for Digital Twins: From Model-Based to Data-Driven.
SIAM – Mathematics in Industry, 2022, <https://doi.org/10.1137/1.9781611976977>



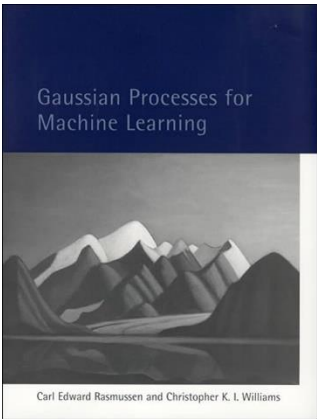
Steven L. Brunton, J. Nathan Kutz: Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control, Cambridge University Press, 2019, <https://doi.org/10.1017/9781009089517>

Real-Time Algorithms for Digital Twins

Books



A. Quarteroni, P. Gervasio, F. Regazzoni: Combining physics-based and data-driven models: advancing the frontiers of research with scientific machine learning, Mathematical Models and Methods in Applied Sciences, 2025, <https://doi.org/10.1142/S0218202525500125>



Carl Edward Rasmussen, Christopher K.I Williams: Gaussian processes for machine learning. Cambridge, MA: MIT press, 2006, <https://doi.org/10.7551/mitpress/3206.001.0001>

Real-Time Algorithms for Digital Twins

People



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Regression & Optimization

People to Follow



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YouTube: <https://www.youtube.com/@MachineLearningSimulation>

Regression & Optimization

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Data Driven Reduced Order Modelling

People to Follow



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1 References & People

2 Wrap Up

Real-Time Algorithms for Digital Twins

Wrap Up

- ▶ Introduction to Digital Twins
Motivation | Examples
- ▶ Classical / Analytical Reduced Order Modelling
Mode Displacement Method | Krylov Subspace Model Order Reduction
- ▶ Databased (Reduced Order) Modelling
SVD / POD | Operator Inference | Neural Networks
- ▶ Machine Learning for Dynamical Systems
Trajectory vs. Derivative Learning | Neural ODE | Optimization
- ▶ Advanced Topics / Outlook
Architectural Biases | Partial Observability | Hybrid Modelling | Non-linear Dimension Reduction | Uncertainty Quantification

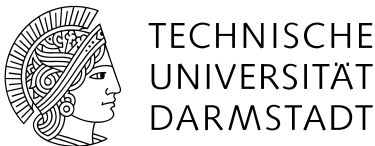
**It's exciting times
... however, without caution we will be lost**



Source: OpenAI - ChatGPT

One is sure, without caution and rigorous research we will be lost!

Overoptimism and weak baselines call for more rigor and clarity!



McGreivy, N., & Hakim, A. (2024). Weak baselines and reporting biases lead to overoptimism in machine learning for fluid-related partial differential equations. *Nature machine intelligence*, 6(10), 1256-1269.



K Vafa, PG Chang, A Rambachan, S Mullainathan (2025): What has a foundation model found? using inductive bias to probe for world models. arXiv preprint arXiv:2507.06952.



Y Choi, SW Cheung, Y Kim, PH Tsai, AN Diaz, I Zanardi, ... M Heinkenschloss (2025): Defining Foundation Models for Computational Science: A Call for Clarity and Rigor. *arXiv preprint arXiv:2505.22904*.



K Vafa, PG Chang, A Rambachan, S Mullainathan (2025): What has a foundation model found? using inductive bias to probe for world models. arXiv preprint arXiv:2507.06952.

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The Art of the Possible – Blog: <https://blogs.sw.siemens.com/art-of-the-possible>