

## Digital Twins in Control

***Citation for published version (APA):***

Classens, K. H. J., Oomen, T. A. E., Heemels, W. P. M. H., van de Wijdeven, J. J. M., van de Wal, M. M. J., & Aangenent, W. H. T. M. (2020). *Digital Twins in Control: From Fault Detection to Predictive Maintenance in Precision Mechatronics*. Abstract from 1st Euspen Special Interest Group Meeting on Precision Motion Systems & Control, Aachen, North Rhine-Westphalia, Germany. <https://www.euspen.eu/knowledge-base/PMC20128.pdf>

***Document status and date:***

Published: 18/11/2020

***Document Version:***

Accepted manuscript including changes made at the peer-review stage

***Please check the document version of this publication:***

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

***General rights***

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

[www.tue.nl/taverne](http://www.tue.nl/taverne)

***Take down policy***

If you believe that this document breaches copyright please contact us at:

[openaccess@tue.nl](mailto:openaccess@tue.nl)

providing details and we will investigate your claim.

## **Digital Twins in Control: From Fault Detection to Predictive Maintenance in Precision Mechatronics\***

Koen Classens<sup>1</sup>, Tom Oomen<sup>1</sup>, W.P.M.H. (Maurice) Heemels<sup>1</sup>, Jeroen van de Wijdeven<sup>2</sup>, Marc van de Wal<sup>2</sup>, Wouter Aangenent<sup>2</sup>

<sup>1</sup>Eindhoven University of Technology, The Netherlands

<sup>2</sup>ASML Research Mechatronics, The Netherlands

[K.H.J.Classens@tue.nl](mailto:K.H.J.Classens@tue.nl)

### **Abstract**

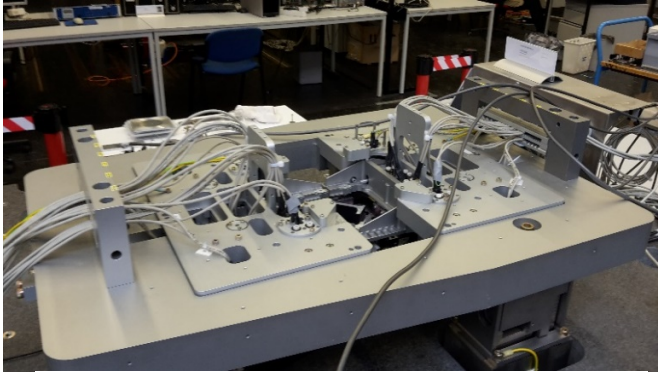
The economic value of high-tech production equipment is to a large extent determined by its productivity. In order to maximize productivity, it is essential to minimize unscheduled downtime. Equipment downtime can be minimized by means of predictive maintenance, which can be pursued via the process of predicting and detecting faults and simultaneously pinpointing its origin, which is called Fault Detection and Isolation (FDI).

Traditional FDI systems are either data-driven or based on physical models. As next generation FDI system, a physics-based model is envisaged that is learned from data to improve the predictive capability of the digital counterpart. Models of the system are often available prior to commissioning a machine, for instance, through Finite Element Modeling or identified models during system integration. After system integration and control design, the model is generally left unused. Evidently, this model is valuable and can be exploited in the form of a digital twin that is informed with real-time data through a large number of sensors and actuators. Comparison of this digital counterpart to the physical plant allows to monitor the ageing of critical components and allows to detect anomalies at an early stage. The underlying physics enable to isolate the origin of anomalous behaviour, which in turn allows for effective self-healing or specific hardware maintenance.

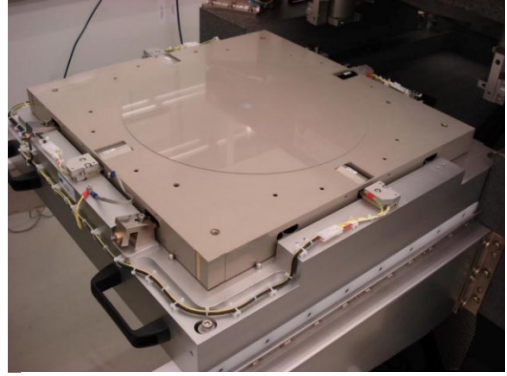
The envisioned approach involving data-enriched physics-based digital twins is general in nature and therefore likely to be applicable to a large range of systems, including production machines and scientific instruments. The proof-of concept will demonstrate that the envisioned approach can be applied to a broad industrial range of mechatronic systems far beyond wafer scanners. In this way, the present research project (2020-2024) focuses on bridging the gap between data-based and model-based FDI approaches, which are currently largely separated.

---

\*This work is supported by TKI and ASML Research



(a) Free floating reticle stage.



(b) Overactuated test rig.

Figure 1: Two experimental setups to illustrate predictive maintenance via digital twinning.