

**A Half Day Tutorial Proposal
On**

**Smart Predictive Maintenance (SPM) of Mechatronic Systems
based on Smart Big Data (SBD) and Digital Twins (DT)**

at

**The 9th IFAC Symposium on Mechatronic Systems (Mechatronics 2022)
The 16th International Conference on Motion and Vibration Control (MoViC 2022)
Jointly held at University of California, Los Angeles on September 7-9, 2022
<https://ifacms-movic2022.seas.ucla.edu/home/>**

1. Title of tutorial:

Smart Predictive Maintenance (SPM) based on Smart Big Data (SBD) and Digital Twins (DT)
<https://mechatronics.ucmerced.edu/spm>

2. Outline of the tutorial/workshop (topic and description): Workshop Abstract (why important and why timely and why good for audience): The field of health monitoring, fault diagnosis and predictive maintenance is expanding dramatically to maintain successful operation in many engineering applications. Experienced engineers and researchers agree that before designing a predictive maintenance program, we need to ask two questions 1) “What do we have/know?” and 2) “What do we want?” and after we have designed a systematic approach, we also need to ask two questions 1) “How optimal?” and 2) “How robust?”. With the emerging wave of “Digital Transformation” such as Industry 4.0, we promote asking the third question: “How smart?”. This workshop introduces a new frontier for engineers: Smart Predictive Maintenance (SPM), using Smart Big Data (SBD) and Digital Twins (DT) as the enabler technology combined with IAI (industrial artificial intelligence) and groundbreaking technologies like Deep Learning, AI, Data Analytics, Big Data, and edge computing.

For SPM, the concept of “smartness” follows the notion of the US NSF program on S&AS (smart and autonomous systems) based on the following attributes 1) Taskable; 2) Cognitive; 3) Reflective; 4) Ethical; 5) Knowledge-rich. It means that a smart predictive maintenance system can learn from past actions and induced errors (resilience), discover hidden patterns and anomalous behaviors at multiple time scales and reach the desired operation specifications. This workshop will present a case study to illustrate the SPM fundamentals enabled by SBD and DTs.

This tutorial workshop prepares our audience with

- *What is SPM: Smart Predictive Maintenance?*
- *Digital Twins (DT) concept, example DT platforms, and DT behavior matching algorithms, and usage for fault detection and RUL estimation*
- *SPM design based on SBD and DT*
- *Edge computing, embedded and industrial AI applications towards SPM. Mechatronics testbed for smart predictive maintenance and case studies. Rich future research opportunities in SPM and DT.*

Topics: Half day – 13:30-17:30

- 1) 13:30-13:40. Introduction to the Tutorial Workshop program (YangQuan Chen)
- 2) 13:40-14:30. What is SPM: Smart Predictive Maintenance? (Furkan Guc/ YangQuan Chen)
- 3) 14:30-15:20. Digital Twins: overview, construction and usage for fault detection and RUL estimation (Viola)
- 4) 15:20-15:40. Coffee break and free chats.
- 5) 15:40-16:10. Smart big data and complexity-aware advanced analytics (YangQuan Chen)
- 6) 16:10-16:40 Heavilytailedness-aware control system performance assessment and fault detection (Paweł D. Domański/Furkan Guc)
- 7) 16:40-17:10. Mechatronics testbed for smart predictive maintenance and case studies/ Implications in mechatronics education (Furkan Guc/Jing Wang)
- 8) 17:10-17:30 Discussions continue to group dinner time if needed.

More background information: Recent books from the presenters:

- Pawel D. Domański and YangQuan Chen and Maciej Ławryńczuk (2022). “**Outliers in Control Engineering – Fractional Calculus Perspective.**” March 2022. De Gruyter. Book Series on “**Fractional calculus and its applications in science and engineering**” <https://doi.org/10.1515/9783110729122>
- Pawel D. Domański (2020). **Control Performance Assessment: Theoretical Analyses and Industrial Practice**, Springer, <https://link.springer.com/book/10.1007/978-3-030-23593-2>
- Jing Wang, Jinglin Zhou, Xiaolu Chen (2022). **Data-Driven Fault Detection and Reasoning for Industrial Monitoring**, Springer, <https://link.springer.com/book/10.1007/978-981-16-8044-1>
- Jairo Viola, YangQuan Chen. (April 2022). "Digital Twin Enabled Smart Control Engineering - A Framework and Case Studies" New Springer Monograph

Recent papers from the presenters:

- Furkan Guc, and YangQuan Chen. "Fault Cause Assignment with Physics Informed Transfer Learning." IFAC-PapersOnLine 54.20 (2021): 53-58.
- Jairo Viola, Sina Dehghan, YangQuan Chen. “Embedded RIOTS - Model Predictive Control Towards Edge.” In Proceedings of the 2019 ASME IDETC, ASME/IEEE MESA, August 2019, Anaheim, CA, USA. IDETC2019-97046 (Best paper [award certificate](#))
- J Viola, YQ Chen, J Wang. **FaultFace: Deep Convolutional Generative Adversarial Network (DCGAN) based Ball-Bearing Failure Detection Method** Information Sciences (2020) <https://doi.org/10.1016/j.ins.2020.06.060>
- Jairo Viola and YangQuan Chen "Digital Twin Enabled Smart Control Engineering as an Industrial AI: A New Framework and A Case Study". Proc. of the Second International Conference on Industrial Artificial Intelligence (IAI20), Oct., 2020, Shenyang, China. Presented and published <https://arxiv.org/abs/2007.03677>
- Jairo Viola, Carlos Rodriguez, YangQuan Chen. "PHELP: Pixel Heating Experiment Learning Platform for Education and Research on IAI-based Smart Control Engineering". Proc. of the Second International Conference on Industrial Artificial Intelligence (IAI20), Oct., 2020, Shenyang, China. Presented and published. <https://arxiv.org/abs/2007.03048>

3. **Duration and sessions:** Half day, 13:30-17:30 (could be in the morning – flexible, perhaps preferred)

4. **Description of the intended audience and the expected learning outcomes:** Graduate students, postdocs, engineers, and faculty members dealing with complex process control, health monitoring, fault diagnosis and predictive maintenance tasks. **Expected learning outcomes:**

- 1) Basic knowledge on “being smart” of predictive maintenance and ways to achieve smart predictive maintenance (SPM)
- 2) Digital Twin basics, usage of DTs in fault detection and RUL estimation, example demo DTs.
- 3) Outliers, Heavytailedness, smart big data (SBD) and complexity-aware advanced analytics
- 4) Edge AI idea and its use in process monitoring using real time data analytics and fractional order signal processing.

5. **Desired prerequisite knowledge of the audience**

- 1) Basic knowledge of signals and systems, classical control system (Control-I).
- 2) PID control tuning, control system performance monitoring
- 3) (optional) edge computing, deep learning

6. **The tutorial speaker(s)**

- **Prof. YangQuan Chen**, University of California, Merced, CA 95343, USA, Emails: yqchen@ieee.org;
- **Dr Pawel D. Domański (PhD, DSc)**, Warsaw University of Technology, Email: p.domanski@ia.pw.edu.pl
- **Jairo Viola, Ph.D. student**, University of California, Merced, Emails: jviola@ucmerced.edu
- **Furkan Guc, Ph.D. student**, University of California, Merced, CA95343, USA, Emails: fguc@ucmerced.edu
- **Prof. Jing Wang**, North China Univ. of Technology (NCUT), Beijing, China, Email: jwang@ncut.edu.cn

7. **Brief biographies for each tutorial/workshop speaker (no more than 300 words per person)**

Details can be found in this link (workshop service webpage): <https://mechatronics.ucmerced.edu/spm>