Control at Ulster University

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Content

- Teaching
  - EEE316
  - EEE526
- Research
  - Fault Diagnosis with Volvo Car Corporation, Sweden
  - Digital Shadow of a Manufacturing System with Technische Hochschule Augsburg, Germany
  - Autonomous Drone System
  - Research Equipment at School of Engineering, Ulster University

Teaching

EEE316 (2nd Year, Before placement, Sem 2 Feb–Jun)

- Modelling a dynamic system (electrical and mechanical)
- Calculating output as function of time
- Quality of response of a system
- Steady-state errors
- Routh-Hurwitz stability criterion
- Frequency response (backgrounds and plotting)
- Controller design (concept of PID etc.)
- State space

EEE526 (3rd Year, After placement and before FYP, Sem 1 Sep–Dec)

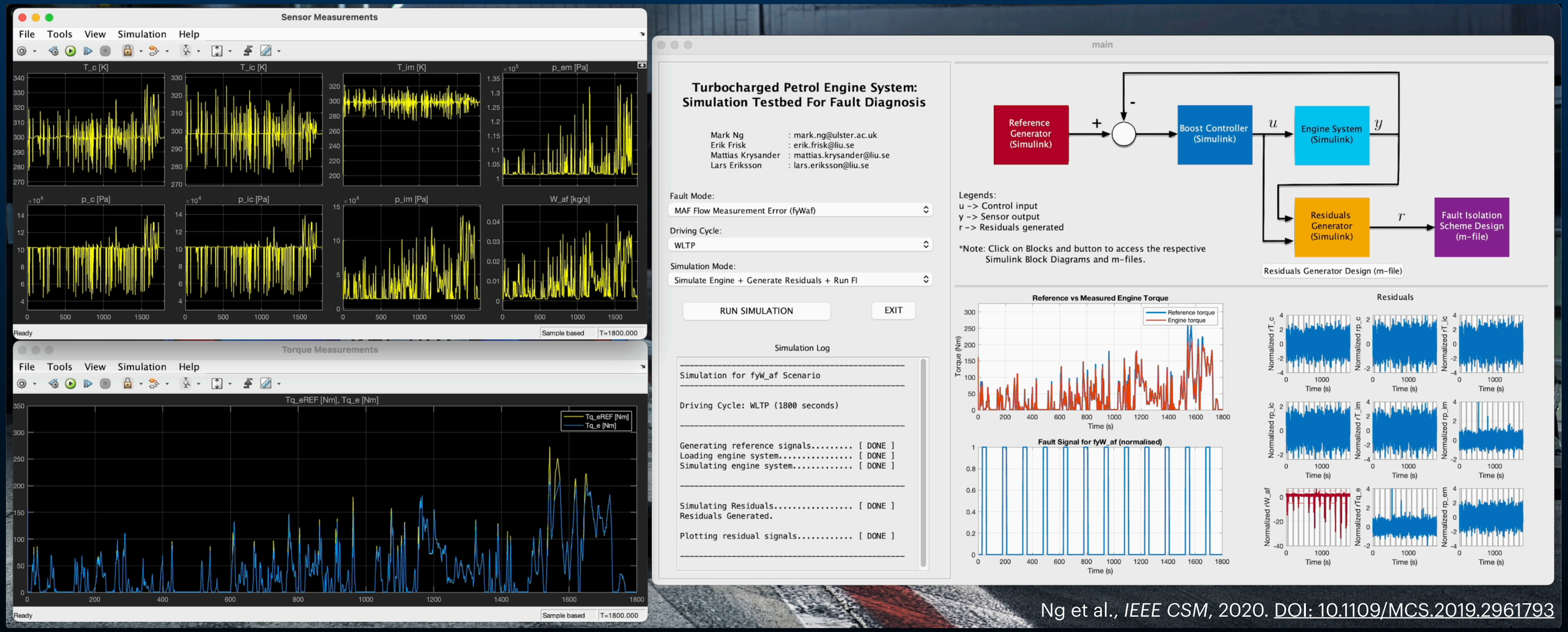
- Introducing mechatronics
- System models (adding hydraulic, pneumatic, and thermal)
- Dynamic responses of systems
- Frequency response (system identification from plots)
- Closed-loop controllers (circuitry design)
- Programmable logic controllers
- Sensors
- Actuation systems
- Fault finding

Research

Fault Diagnosis

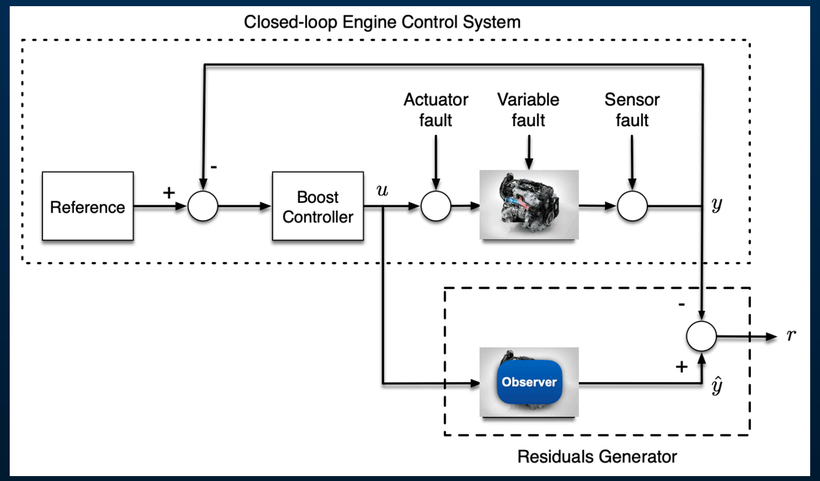
- PhD in fault diagnosis (FD) using Sliding Mode Observer
- 2014–2015
  - Postdoctoral researcher at the Division of Vehicular Systems (FS), Linköping University, Sweden
  - Worked with Volvo Car Corporation (VCC) on advanced FD schemes in engines using model-based and data-driven methods
  - Instrumental in developing a Digital Twin on Matlab/Simulink platform for realistic Model-In-The-Loop testing of residuals generation and FD methods for the following:
    - Realistic modelling and control of the engine
    - Injection and simulation of a variety of actuator, sensor, and variable faults in the engine
    - In-house designed algorithm for additional residuals selection
    - In-house designed algorithm for alarm generations, residuals monitoring, as well as Fault Isolation (FI)
    - Simulation and FI of system with intermittent residuals
- 2016 — Visiting researcher (invited back to FS to complete the project and final presentation at VCC R&D HQ in Göteborg)

Digital Twin of Engine System for Control and Fault Diagnosis Research

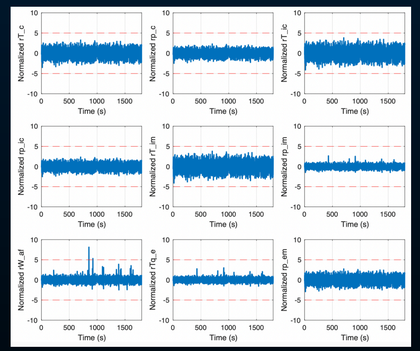


Ng et al., *IEEE CSM*, 2020. DOI: 10.1109/MCS.2019.2961793

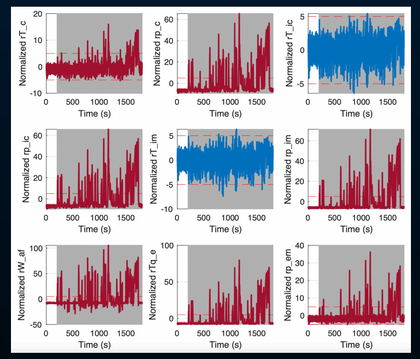
Fault Diagnosis Algorithms



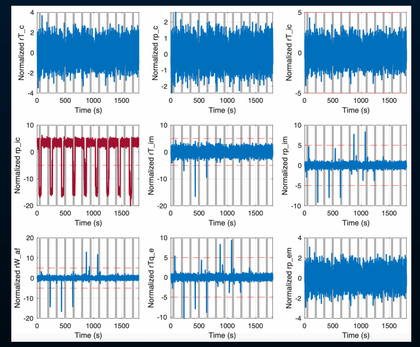
Closed-loop engine control system and the residuals generator



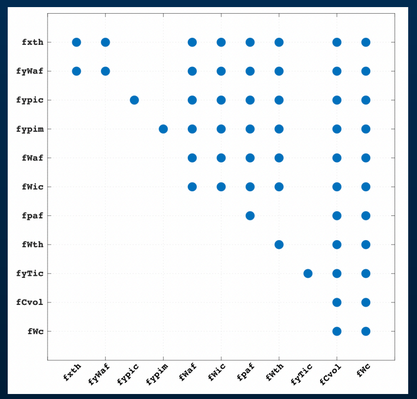
Nominal

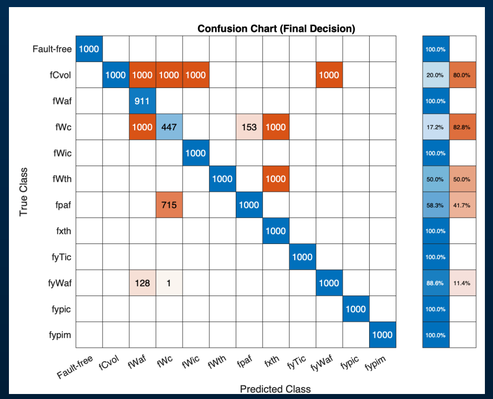


Pressure fault in air filter



Intercooler pressure sensor fault





Fault isolation analysis

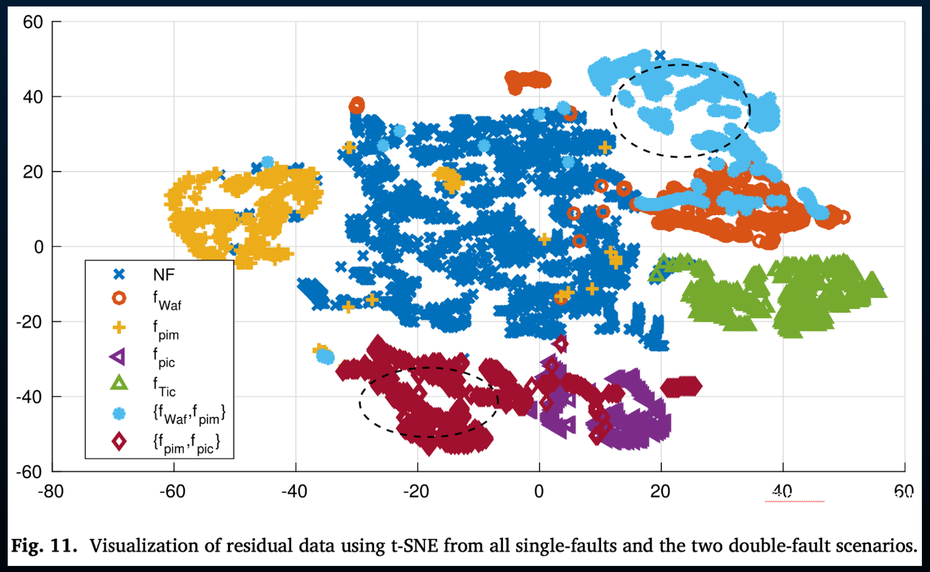
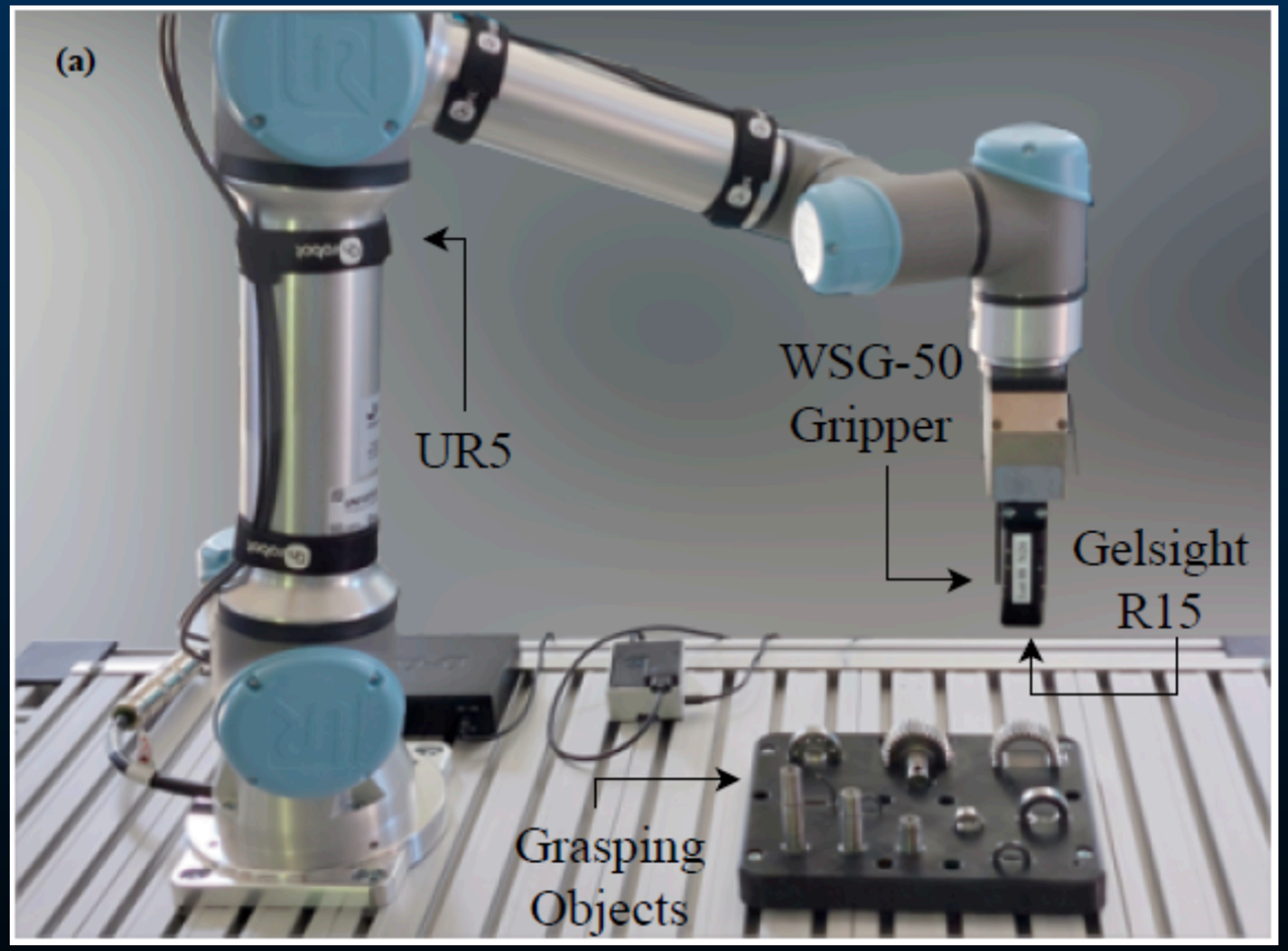


Fig. 11. Visualization of residual data using t-SNE from all single-faults and the two double-fault scenarios.

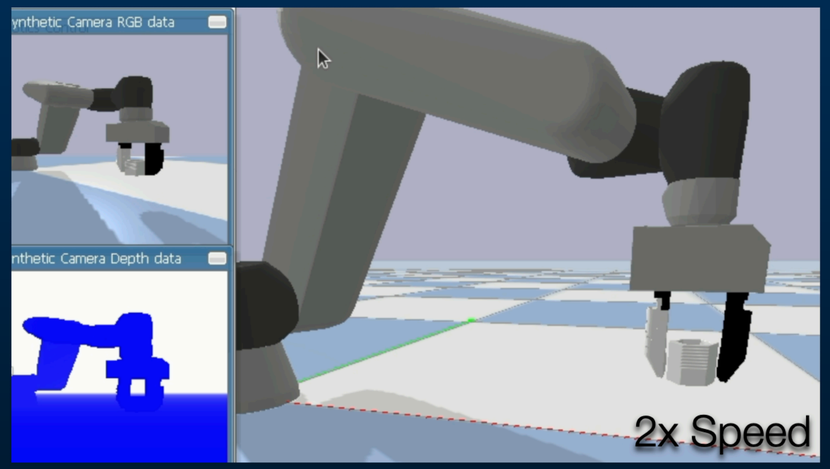
Visualising residual data using dimensional reduction technique

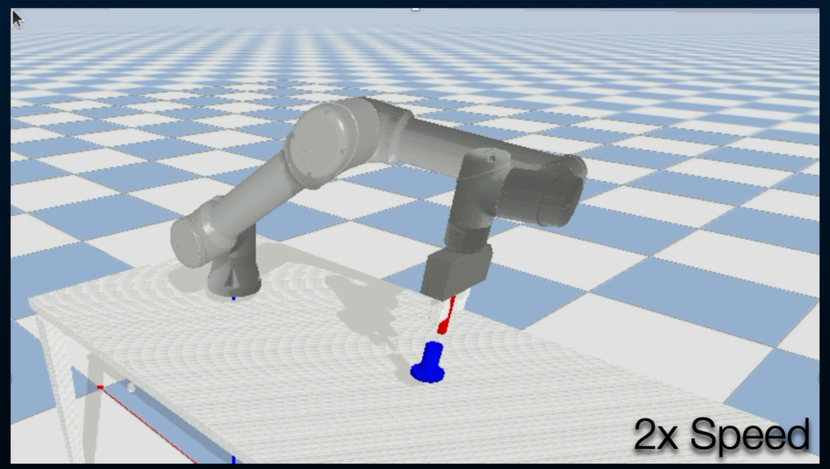
Ng *et al.*, *IEEE CSM,* 2020. DOI: 10.1109/MCS.2019.2961793
Jung *et al.*, *CEP,* 2018. DOI: 10.1016/j.conengprac.2018.08.013
Ng *et al.*, *IEEE CoDIT'20*, 2020. DOI: 10.1109/CoDIT49905.2020.9263792

Digital Shadow of a Manufacturing System



Actual physical system

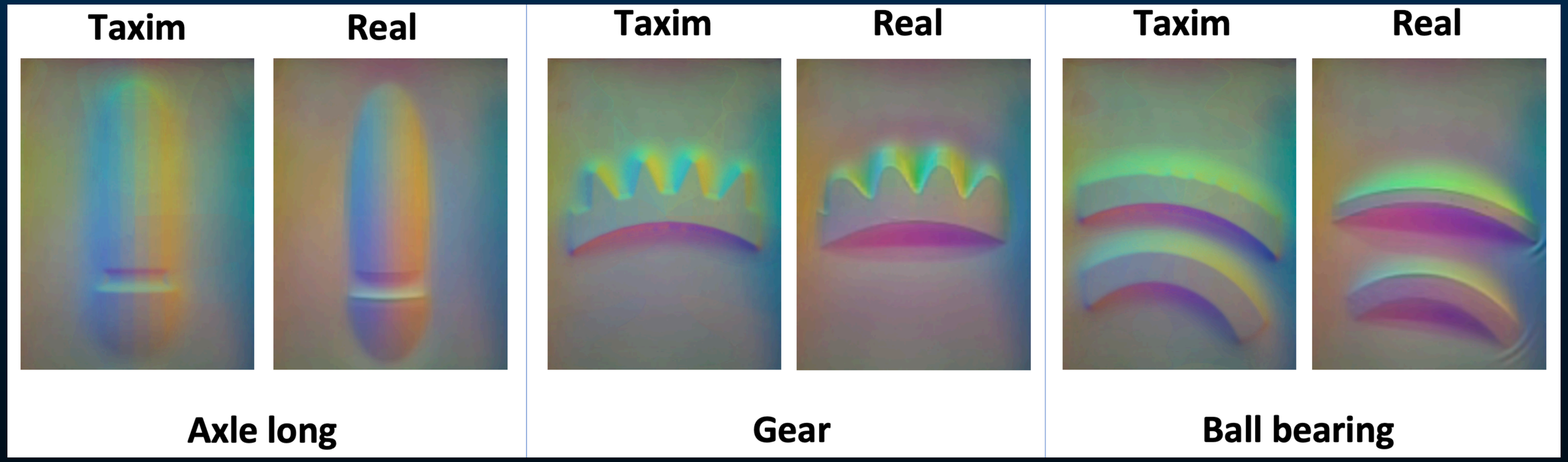




Digital shadow

Wucherer *et al.*, *arXiv*, 2023. DOI: 10.48550/arXiv.2302.03504

Digital Shadow of a Manufacturing System

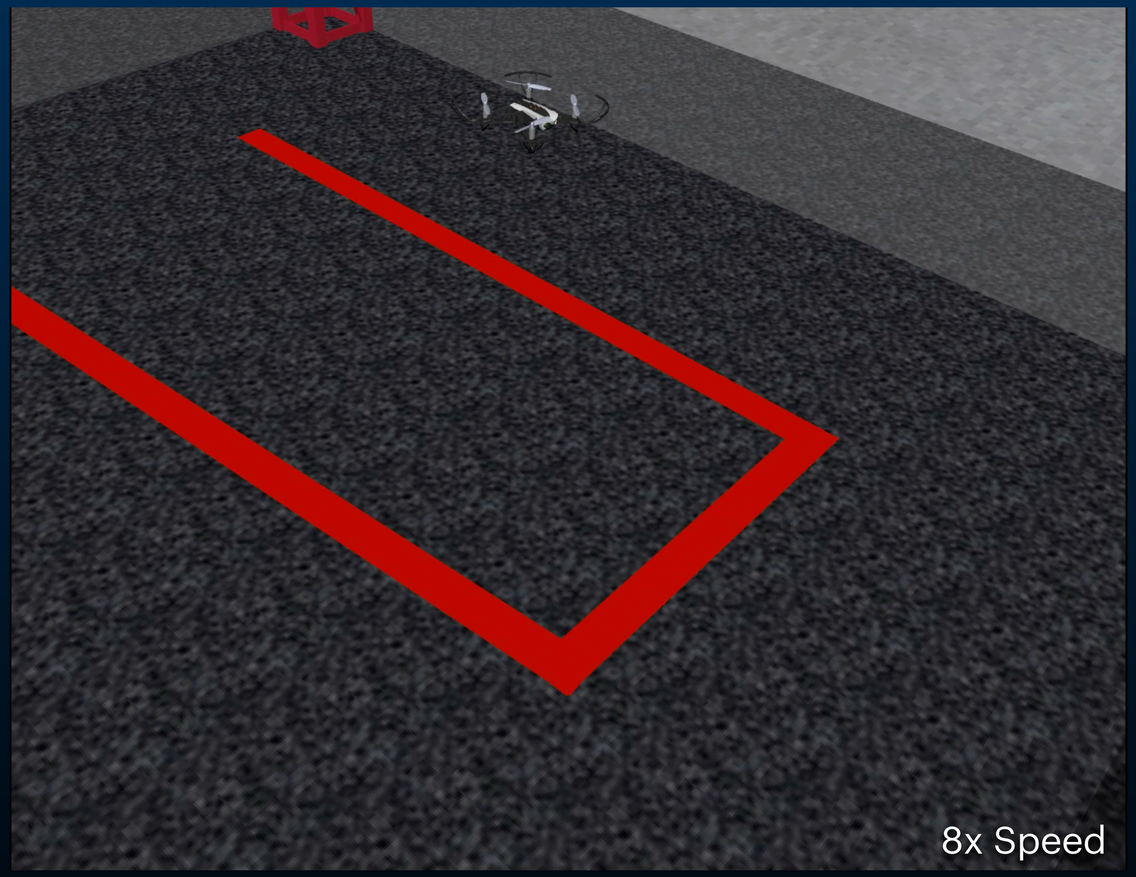


Synthetic vs Real Data

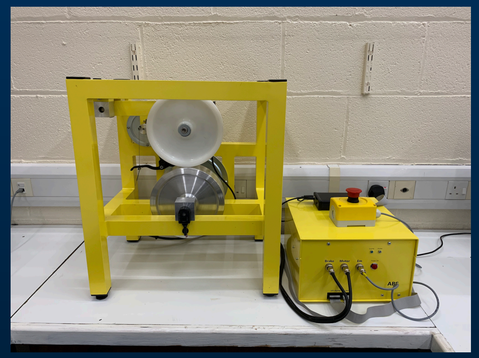
Wucherer *et al.*, *arXiv*, 2023. DOI: 10.48550/arXiv.2302.03504

Autonomous Drone System

- Participation in the annual Mathworks Minidrone Competition
- Team consists of mainly FYP students



Research Equipment at School of Engineering



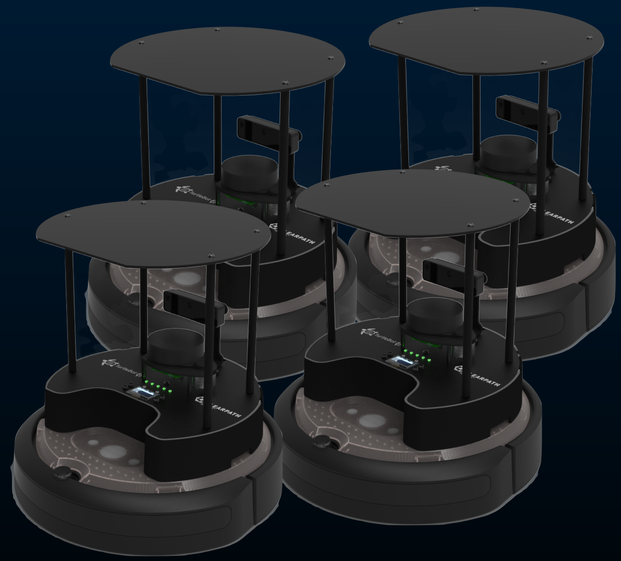
INTECO Antilock Braking (ABS) and Dual-Rotor Systems

Dell OneFS and PowerScale Digital Twin Solution

Festo Didactic Manufacturing and Assembly System with Robotino

Coming in 2024

Autonomous Mobile Cobot Systems



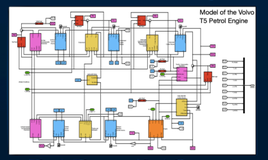
Turtlebots

Digital Twin @ School of Engineering

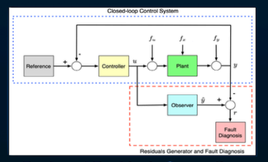
Physical Systems

Modelling and Parameterisation

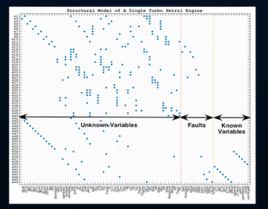

Mathematical Modelling



Block Diagram Modelling and Controller Design



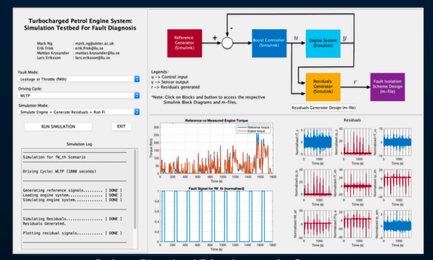
Design of Residuals Generation and Anomaly Detection/Fault Diagnosis Scheme



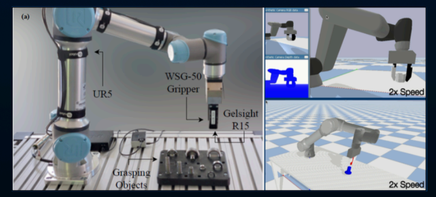
Structural Model

Digital Twin, Digital Shadow, and Simulation Testbed

Healthcare

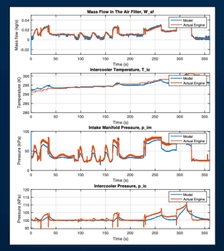


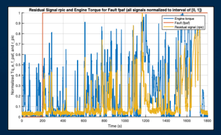
Cyber-Physical/Mechatronic System

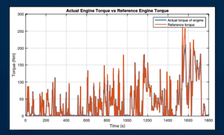


Manufacturing

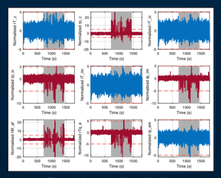
Prediction of Dynamics and Maintenance, Fault/Anomaly Diagnosis, Availability and Sustainability Analysis, Personalised Healthcare, Simulated Surgery, Improved Diagnosis, etc.

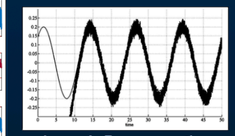

Digital Twin vs Physical Sensor Data

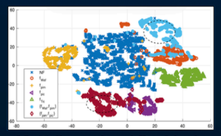

Effects of Anomaly/Fault onto System Dynamics

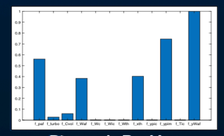

Verification of Controller Design

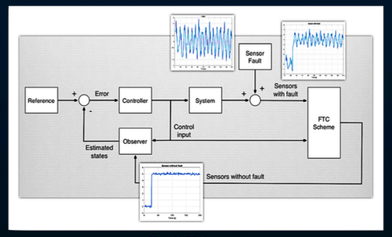

Anomaly Isolation Analysis


Residuals Analysis

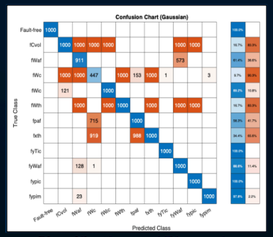

Anomaly Reconstruction


Multidimensional Residuals Analysis

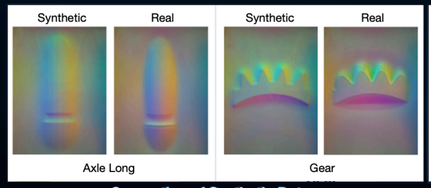

Diagnosis Ranking



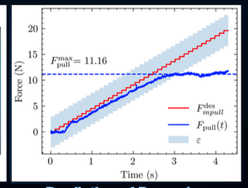
Fault Tolerant



Classification and Diagnosis



Generation of Synthetic Data



Prediction of Dynamics

References

1) K. Y. Ng, E. Frisk, M. Krysander, and L. Eriksson (2020), "A Realistic Simulation Testbed of A Turbocharged Spark Ignited Engine System: A Platform for the Evaluation of Fault Diagnosis Algorithms and Strategies", *IEEE Control Systems Magazine*. https://ieeexplore.ieee.org/document/9036118
2) K. Y. Ng, E. Frisk, and M. Krysander (2020), "Design and Selection of Additional Residuals To Enhance Fault Isolation of A Turbocharged Spark Ignited Engine System", *7th International Conference on Control, Decision and Information Technologies (CoDIT 2020)*. https://doi.org/10.1109/CoDIT49905.2020.9263792
3) D. Jung, K. Y. Ng, E. Frisk, and M. Krysander (2018), "Combining model-based diagnosis and data-driven anomaly classifiers for fault isolation", *Control Engineering Practice*. https://doi.org/10.1016/j.conengprac.2018.08.013
4) J. H. T. Ooi, C. P. Tan, S. Nurzaman, and K. Y. Ng (2017), "A Sliding Mode Observer for Infinitely Unobservable Descriptor Systems", *IEEE Transactions on Automatic Control*. https://doi.org/10.1109/TAC.2017.2655699
5) D. Jung, K. Y. Ng, E. Frisk, and M. Krysander (2016), "A combined diagnosis system design using model-based and data-driven methods", *IEEE 3rd Conference on Control and Fault-Tolerant Systems (SysTol)*, Barcelona, Spain. https://doi.org/10.1109/SYSTOL.2016.7739747
6) S. Wucherer, R. McMurray, K. Y. Ng, and F. Kerber (2023), Learning to Predict Grip Quality from Simulation: Establishing a Digital Twin to Generate Simulated Data for a Grip Stability Metric, *arXiv*. https://doi.org/10.48550/arXiv.2302.03504

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