XLTRC2 Cyber-Physical System for Real-time Machine Vibration Visualization & Diagnostics Part 1: Digital Twin Generation and Evaluation

NEW PROPOSAL

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June 2021

Introduction

As part of the fourth industrial revolution (Industry 4.0) [1], the development of digital twins and the internet of things have become focal points for the next generation of machine health monitoring, troubleshooting and optimization of adaptable maintenance cycles. While there are many challenges associated with the implementation of the Industry 4.0, one of the aspects often overlooked is the development of physics-based models to assemble meta-models with different level of fidelity. The turbomachinery Laboratory has a vast compilation of benchmarked models to predict the static and dynamic performance of turbomachinery components and systems. These resources will be leveraged to produce the required reduced-order models for developing real-time monitoring and diagnosis tools.

The ultimate long-term goal of this project is to develop a cyber-physical system for real-time monitoring and diagnostics of machine health from data streamed from multiple sensors attached to the machinery. This cyber-physical system will be materialized as a mobile augmented reality (MAR) application that will render visualization of machine health potentially including raw or partially processed sensor data combined with reduced order mechanical analyses (for example stress plot on the shaft, etc.) overlain on the machine itself. Figure 1 shows a notional example of the app being used to monitor the operation of a rotor kit. 1. Figure 2 shows a high-level flowchart of the proposed vibration diagnosis tool. This is a significant multi-year undertaking that will involve:

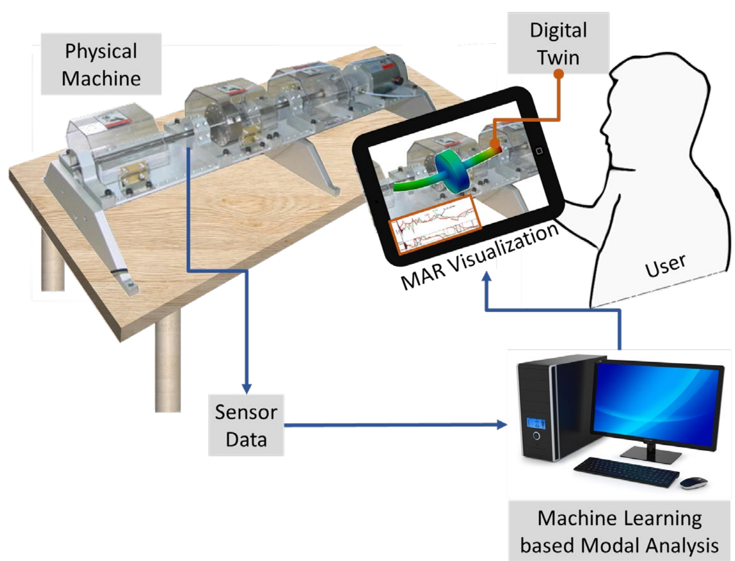

Figure 1 Simulated example of mobile app displaying operating conditions extracted from vibration data for a rotor kit.

1. Development and evaluation of a digital twin model that can simulate both the sensor data generation as well as detailed vibrational analyses close to actual machine performance under a variety of real-world physical conditions.
2. Development of a multitude of reduced order models through machine learning that can generate physically faithful analyses from raw sensor data.
3. Development and evaluation of communication protocol and sensor fusion from the machinery to the mobile device in real-time,
4. Development and evaluation (through actual user testing) of the human-computer interaction and visualization protocols that enable the intuitive and efficient understanding of the visualized data for real diagnostics and health monitoring tasks.

Proposed work

The first phase (year 1) of the project will focus on three tasks:

1. First, we will create a roadmap for the development of the tool including scope, milestones and schedule.
2. We will development of the basic framework for creating a simple digital twin for a rotor kit. This digital twin will be used to create a synthetic dataset based on simulations user several running conditions (for example: wear and tear, etc.)
3. We will train a machine learning model that will learn the relationship between the input sensor data (as generated by the digital twin) to a reduced order simulation model. We will initially test the feasibility of neural networks (NN) as well as classical regression models (such as logistic regression) and investigate their ability to learn the sensor-to-analysis relationship.

The deliverables will include a multi-year plan for developing the cyber-physical system, a feasibility analysis of the NN and regression algorithms and guidelines, and enhanced training for a basic digital twin of a rotor kit.

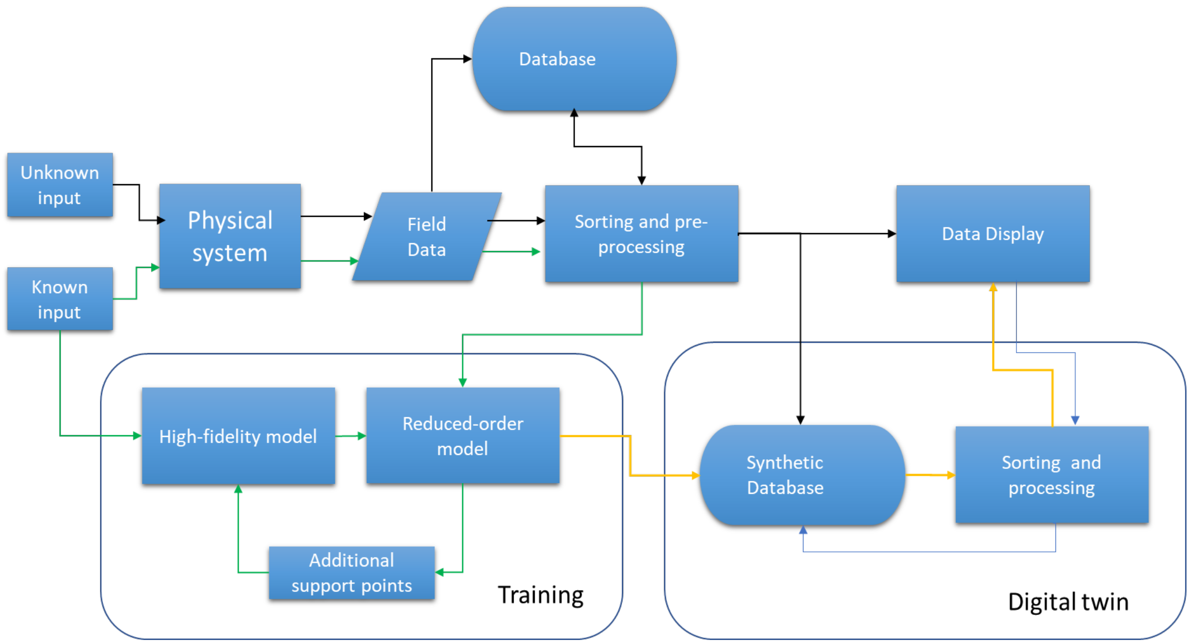

Figure 2. Flowchart of proposed vibration diagnose tool

Budget

Graduate Student Payroll, 12 months @ $2200/month	$ 26,400
Fringe Benefits	$ 5,755
Tuition and fees	$ 13,275
Computer and software	$ 4,570
Total	$ 50,000

References

[1] Jacoby, M., and Usländer, T., 2020, "Digital Twin and Internet of Things-Current Standards Landscape," Appl. Sci., **10**(18), p. 6519.