XLTRC2 Cyber-Physical system for real-time machine vibration visualization and diagnostics

Part 2: Mobile tool development using refined reduced-order models and cloud computing

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Introduction

Cyber-physical systems (CPS) and internet of things (IoT) have recently gained significant impetus due to their promise of enabling Industry 4.0, especially for real-time machine health monitoring, diagnostics, and troubleshooting. Two fundamental challenges in enabling CPS and IoT are:

1. Real-time transmission, processing, and analysis of machine data for extracting functional information pertaining to a given machine.
2. Real-time visualization of functional information derived from the machine data in order to help an industrial operator with quick sensemaking and decision-making tasks.

This project aims at addressing these challenges through a multi-year plan devoted to the integration of human-in-the-loop methodologies and real-time machine data processing and visualization in the context of rotordynamics, In the first year of this project, we developed a digital twin for generating a synthetic dataset based on unbalance fault in a rotordynamic system. The developed reduced-order models produced promising results in predicting the unbalance amount in a machine using measurements taken from a physical rotor kit. However, consolidating the performance of the models by continuously refining them using real-time data is essential for standardizing the efficacy of the system.

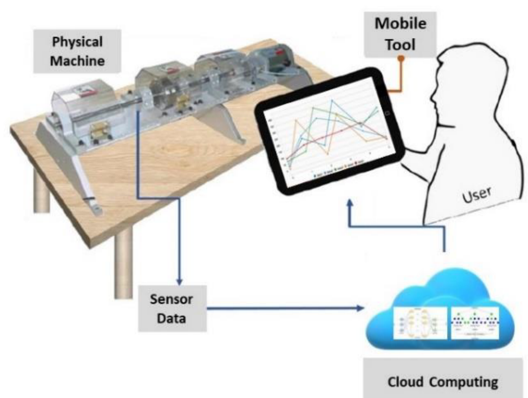

Figure 1: Mobile tool displaying functional information of the machine using raw sensor data

Continuous collection of data that represents the behavior of the machine under different conditions is critical for enabling efficient real-time health monitoring. Therefore, in the second year of work, our goal is to develop a mobile tool that can indicate functional information of the machine using reduced-order models stored in the cloud. Fig.1 shows an example of a mobile tool application where the operator is monitoring the health of the machine using the information shown by the tool. To achieve our objective, we plan to take the following approach:

1. We will develop a more comprehensive digital twin model by adding a variety of machine faults such as misalignment, bent shaft, and bearing failure. Using this enhanced data representation, we will refine our current digital twin to develop a multitude of reduced-order models using synthetic datasets.
2. We will refine the predictive performance of the reduced-order models by augmenting the synthetic datasets with real-time data collected directly from the machine (the rotor-kit in our case). Advanced machine learning and deep learning approaches will be implemented to assess their ability in understanding physics-based models produced by digital twin. The performance of the models will be enhanced by continuously validating their predictions with the physical machine data.
3. We will develop a simple mobile based data visualization framework wherein we will test the feasibility of a complete pipeline involving real-time cloud-based data transmission, prediction

of machine state, and visualization of the raw and processed sensor data on a mobile device (e.g., a tablet).

Proposed work

Second-year work for the development of cyber-physical system (see Figure 2) involves:

- Development of a multitude of reduced-order models through machine learning that can generate physically faithful analyses from raw sensor data.
    - Refining the developed reduced-order models using real-time data from machines to ameliorate their performance.
    - Incorporating more rotordynamic faults into the digital twin and generating synthetic datasets for training multiple machine learning models.
- Development and evaluation of communication protocol and sensor fusion from the machinery to the mobile tool in real-time.

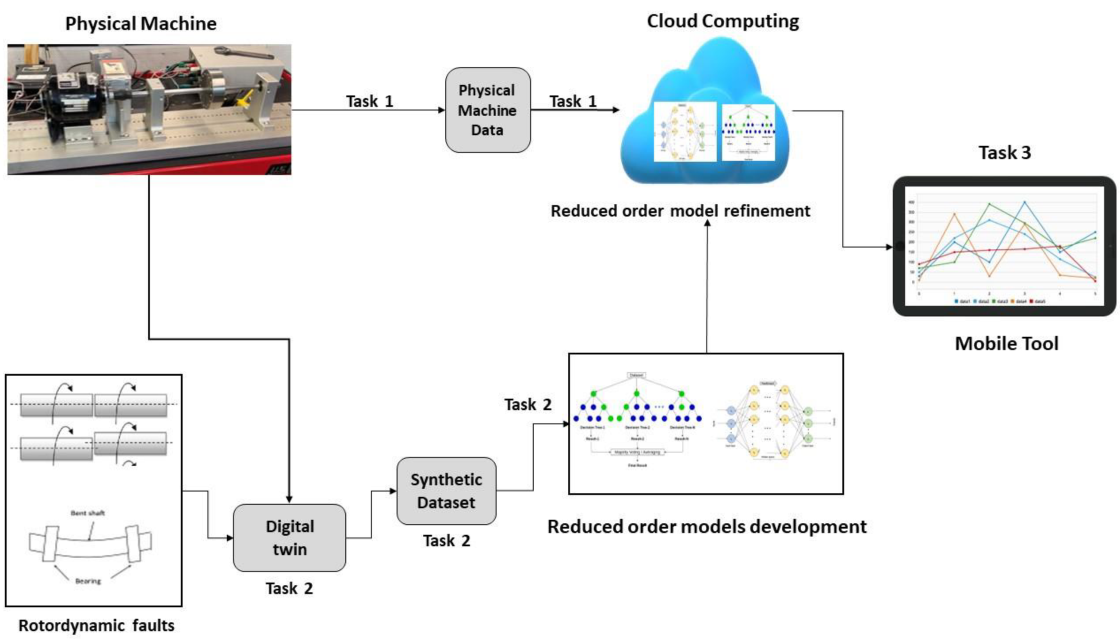

Figure 2: Flow chart of proposed tasks for year 2

Budget

Graduate Student Payroll, 12 months @ $2250/month	$ 27,000
Fringe benefits	$ 3,093
Tuition and fees	$ 17,349
Rotor kit and test supplies	$ 2,558
Total	$ 50,000