Adaptive Simulation Modelling using the Digital Twin Paradigm

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Introduction

A fundamental aspect of Structural Health Management (SHM) involves using a simulation model to predict the response of a structure/system to disturbances. In general engineering practice, due to the complexity of fully specifying a structure/system, a parametric high-fidelity simulation model (simulator) that sufficiently represents the phenomenon of interest is implemented (fig 1).

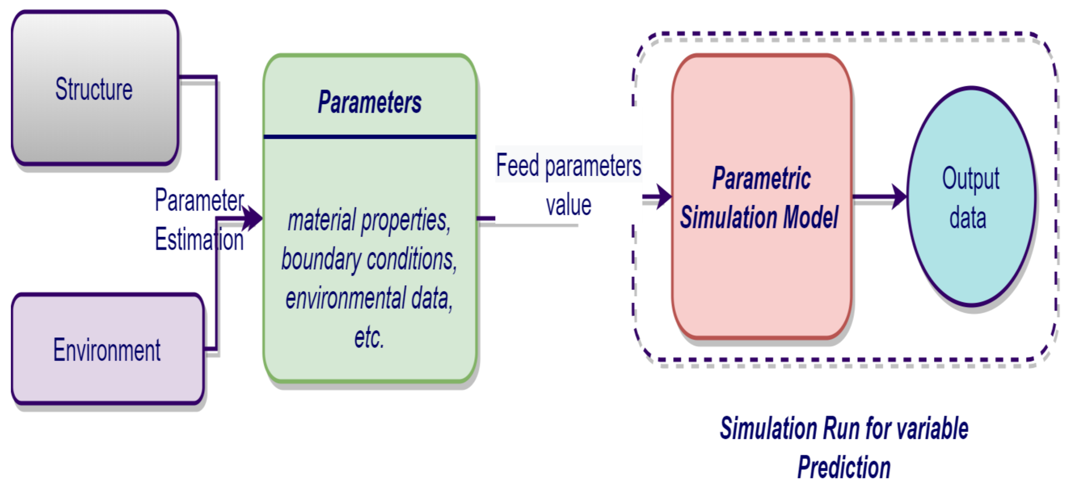

Fig 1: simulation execution with parameter feed into Parametric Simulation Model to make prediction

An important step in developing a simulation model (fig:2) is determining the best set of input parameters that correlate the model output (i.e. prediction made by the model) to the available structural data (Oliveira 2019). When the threshold of fitness is achieved, the model is ready to be used for its predictive task.

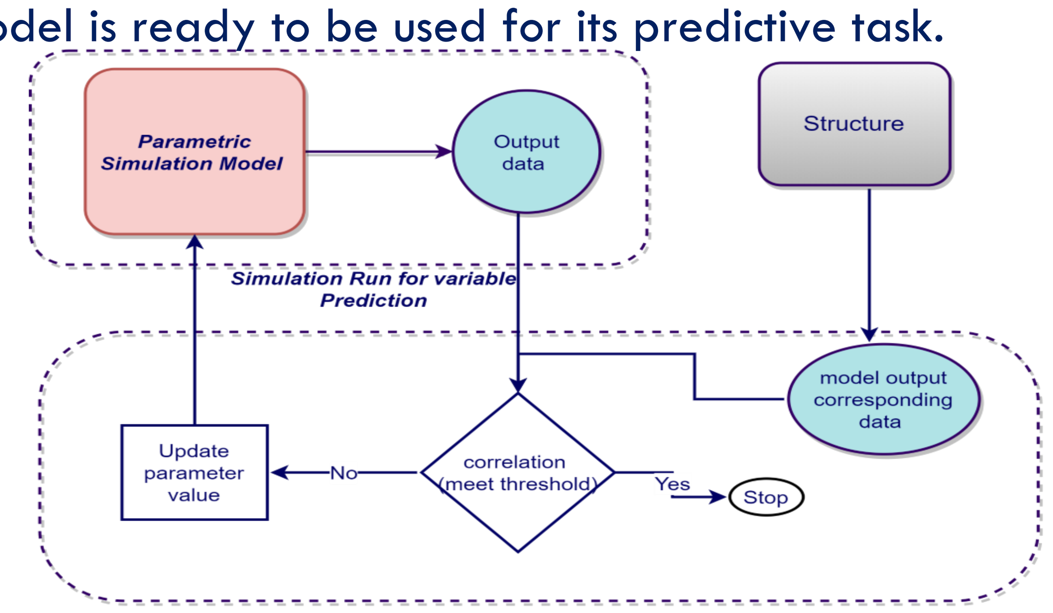

Fig 2: model calibration with parameter updating with model output and structural data comparison.

However, in spite of the accuracy of the calibration of the parametric model, it tends to drift from the actual behaviour of the asset over time (fig. 3). This tends to mainly be due to the complexity and non-uniformity of the change in material properties of the structure in response to the environmental factors (Sehgal, 2016).

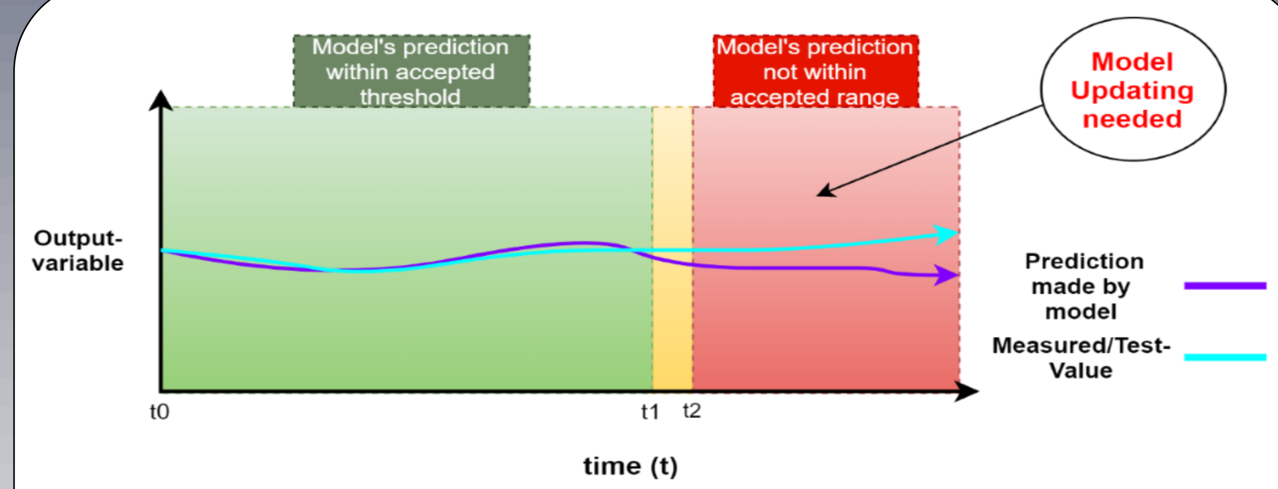

Fig 3: Performance drift in model working (prediction) capacity with time, due to the uncertainties in the input parameter(s) with time

There is therefore a need for more comprehensive simulation model which accurately represents the structure's material properties as well as its evolving surroundings over time (Gabor, 2016).

Aim of Research

The project "Adaptive Simulation Modelling using the Digital Twin Paradigm" aims to investigate simulation modelling within Digital Twinning (DT) as an approach for addressing the time-consuming problem of model calibration task and predictions not being within the threshold to the response from the structure with time.

Research Questions?

The project will explore the following research questions:

1. "How can the model operational validation task be supported with DT concept?"
2. "How can adaptation of Simulation Model be supported and assessed with DT concept?"

Research Methodology

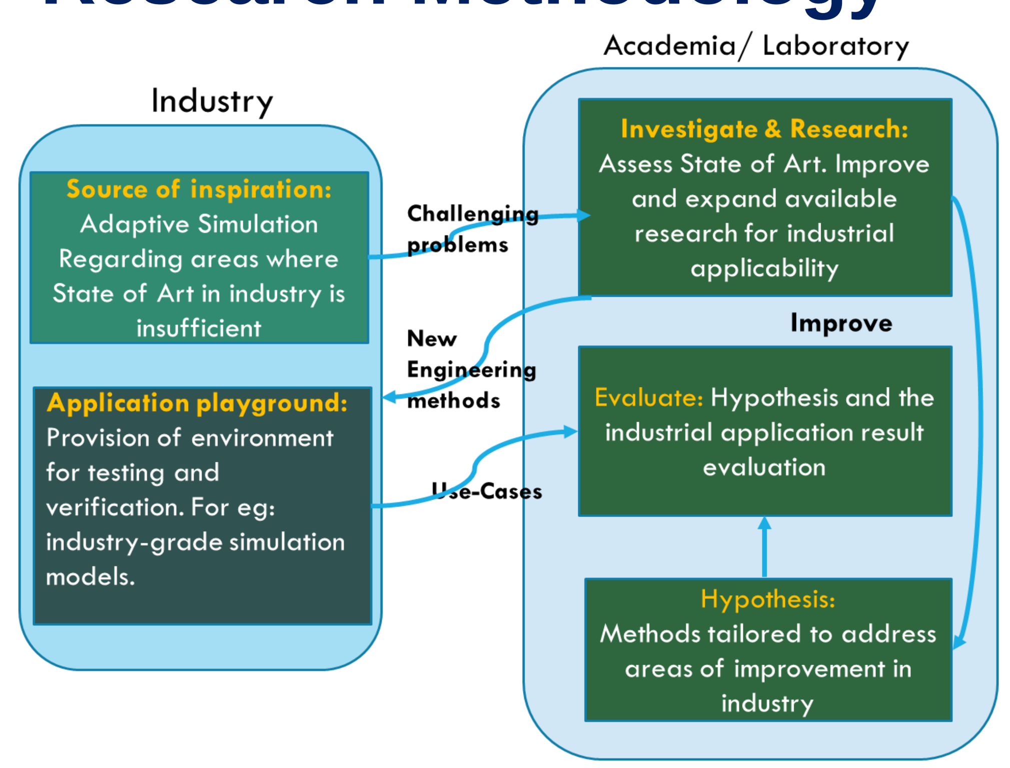

Fig 4: Industry-as-laboratory methodology

The project will use the industry-as-laboratory methodology (fig. 4) which has been successfully utilized by many researchers including Potts(1993) and (Hällqvist 2019) .

Research Challenges

- There are varied definitions of Digital Twin due to the absence of an international standard for Digital Twin, with ISO\CD 23247-1 only now under development.
- There is a need for a framework for continuous improvement of the digital twin by adapting every single digital twin to possible changes occurring in its environment or its own main system (Gabor, 2016).
- Aivaliotis (2019) also suggests a requirement of an enhanced and online tuning mechanism with more efficient algorithms to tune the modelling parameters during physics-based DT creation and enabling.
- Gathering timely runtime data (a DT's anticipated feature) also remains a challenge in model calibration when the data are obtained from survey and available in unstructured survey report.

Proposed Artefact & Objective

This project proposes a continuous, automatic model validating & updating artefact/module within a DT, which offers to reduce the computational (parametric) uncertainties of the model (fig. 5).

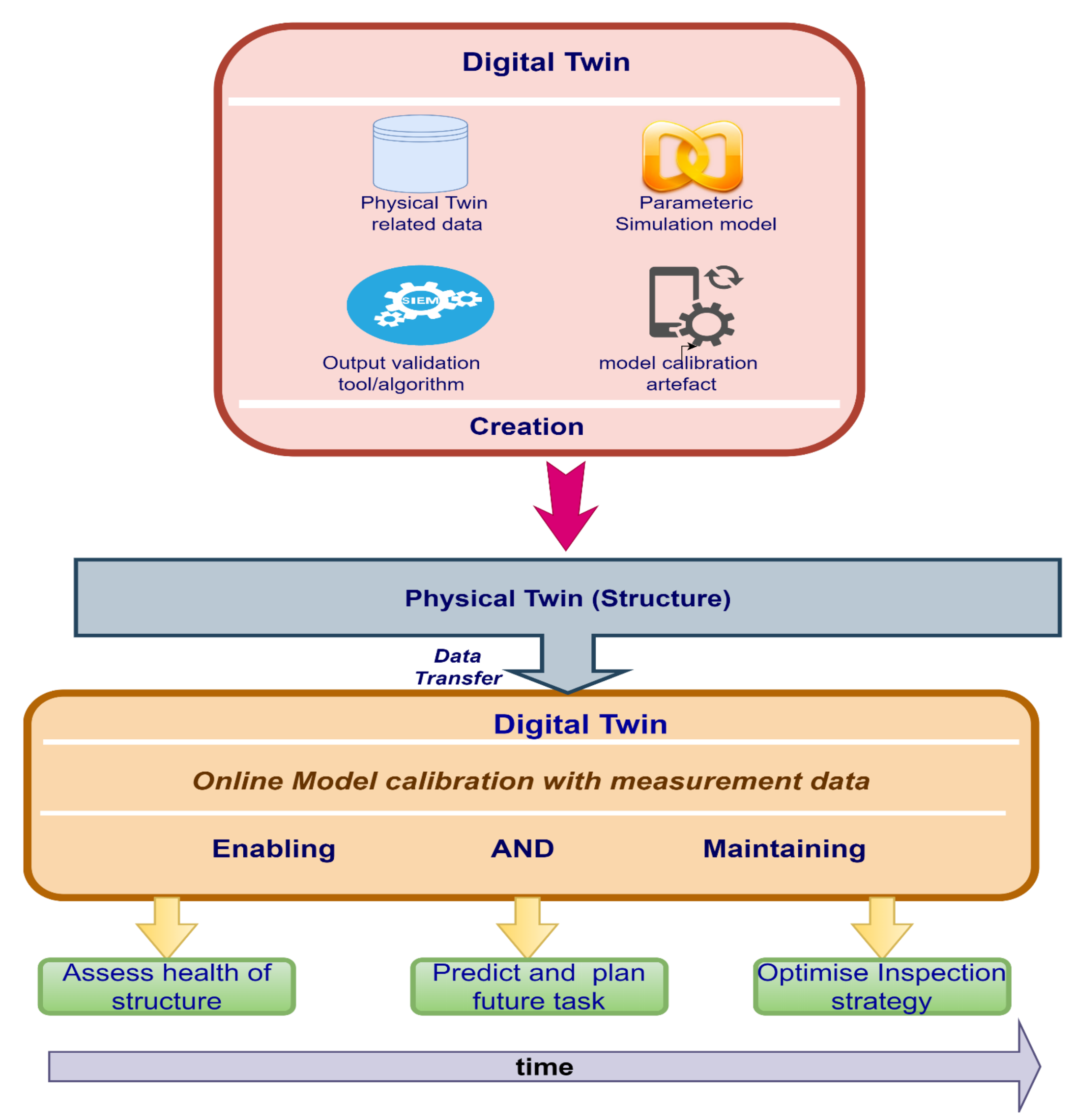

Fig 5: DT creating, enabling and maintaining process with model validation and adaptation/calibration artefact.

The project aims to investigate the integration of an online validation and adaptation artefact within the digital twin paradigm. The different approaches and techniques for undertaking such an integration will be investigated with the goal of highlighting improvements the integration provides.

Contribution to Field

The solver (artefact/algorithm/framework) will be developed and tested using real-world data. Its application in addressing real world problems such as cathodic-protection simulation will also be explored.

The findings and results from the project will be published in high impact conferences and journals. The project will make the following key contributions to the field of DT:

1. Online model validation within the DT paradigm.
2. Data integration to the DT model, with the unstructured survey data extraction.
3. Online model calibration/adaptation within the DT paradigm.

Bibliography

Aivaliotis, P., Georgoulias, K., Arkouli, Z., & Makris, S. (2019). Methodology for enabling Digital Twin using advanced physics-based modelling in predictive maintenance Procedia CIRP, 81(July), 417–422. https://doi.org/10.1016/j.procir.2019.03.072

Gabor, T., Belzner, L., Kiermeier, M., Beck, M. T., & Neitz, A. (2016). A simulation-based architecture for smart cyber-physical systems. Proceedings - 2016 IEEE International Conference on Autonomic Computing, ICAC 2016, 374–379. https://doi.org/10.1109/ICAC.2016.29

Hällqvist, R. (2019). On Standardized Model Integration Automated Validation in Aircraft.

Oliveira, H. L., & Leonel, E. D. (2019). Constitutive relation error formalism applied to the solution of inverse problems using the BEM. Engineering Analysis with Boundary Elements, 108(July), 30–40. https://doi.org/10.1016/j.enganabound.2019.07.023

Potts, C. (1993). Software-engineering research revisited, 19–28

Schleich, B., Anwer, N., Mathieu, L., & Wartzack, S. (2017). Shaping the digital twin for design and production engineering. CIRP Annals - Manufacturing Technology, 66(1), 141–144. https://doi.org/10.1016/j.cirp.2017.04.040

Sehgal, S., & Kumar, H. (2016). Structural Dynamic Model Updating Techniques: A State of the Art Review. Archives of Computational Methods in Engineering, 23(3), 515–533. https://doi.org/10.1007/s11831-015-9150-3