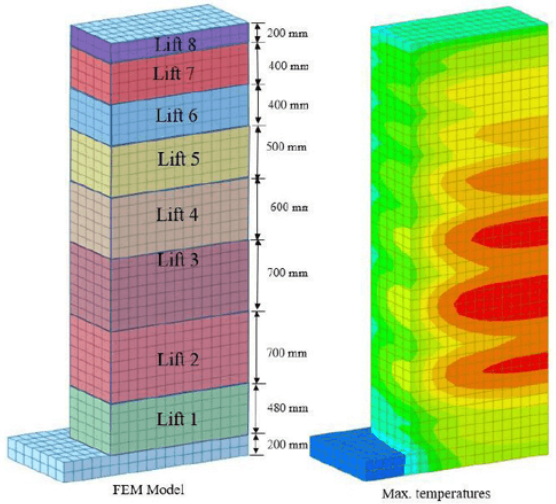
PROJECT: general (Artificial Intelligence for Digital-Twin and SHM)

Title: Coupled temperature and load estimation to improve anomaly detection techniques

RESEARCH BACKGROUND:
Fibre optics are the state of the art in strain sensing techniques and they are applied to many real-world structures. However, they are highly sensitive to temperature changes: reconstructing both temperature and external forces acting on the structure is a challenging task but of high practical value.



RESEARCH ACTIVITIES:

- Couple a force reconstruction model with a thermal model to a simple sample problem in a numerical environment
- Develop a more complex model/algorithm and test it on experimental data

METHODOLOGY: numerical – analytical

DURATION: 9 months

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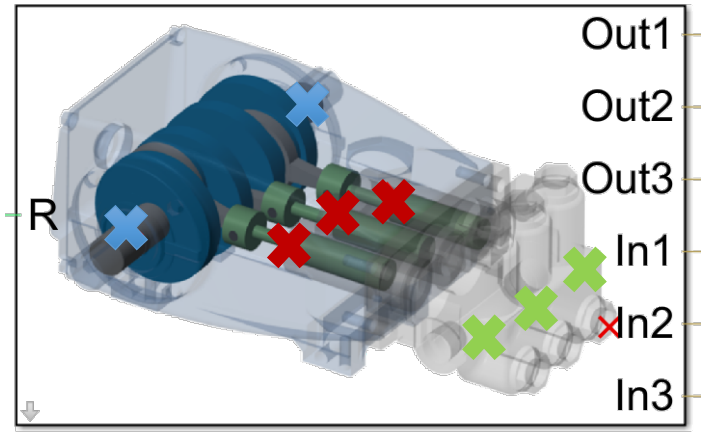
PROJECT: general (Artificial Intelligence for Digital-Twin and SHM)

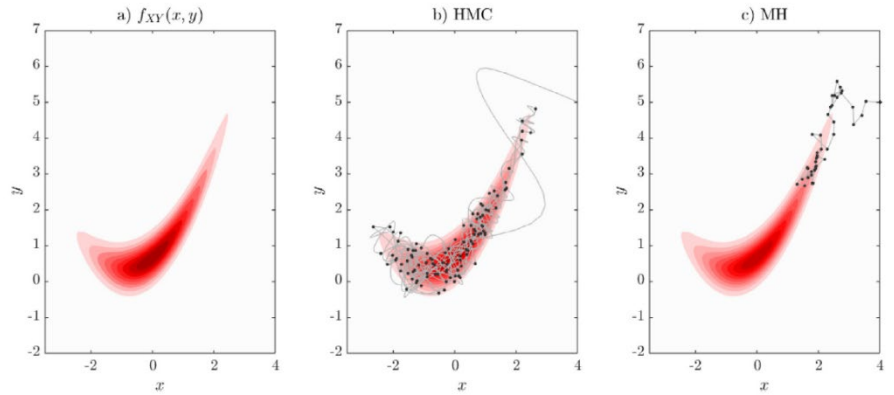
Title: Scalable Hamiltonian Monte Carlo via Surrogate Methods for Digital-Twins

RESEARCH BACKGROUND:
Hamiltonian Monte Carlo coupled with **surrogate modelling** and random bases may prove to be one of the leading algorithm for **uncertainty quantification** for models with a large number of parameters. However, so far its application has been limited to some sample problems: hence the need to prove its effectiveness with real-world probability distributions, such as the ones that may arise from a complex Digital-Twin.



Pump

RESEARCH ACTIVITIES:
- Application of Hamiltonian Monte Carlo to sample problems
- Application of HMC coupled with surrogate models to estimate complex multi-dimensional distributions with data generated from numerical Digital-Twin for damage estimation



METHODOLOGY: numerical – analytical

DURATION: 9 months

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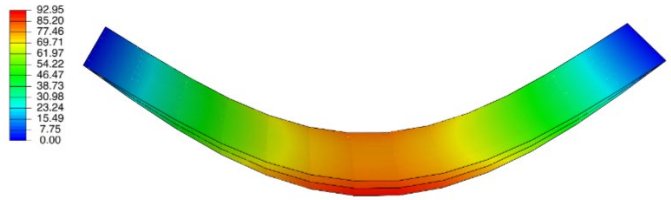
PROJECT: general (Artificial Intelligence for Digital-Twin and SHM)

Title: Constrained Gaussian Processes for Surrogate Modelling and Regression

RESEARCH BACKGROUND:
Gaussian Process are Machine Learning algorithms that have been used as non-parametric and probabilistic regression tools in a variety of contexts. Constrained Gaussian Process can be used to improve Surrogate Modelling techniques, Regression for Fatigue Life Estimation, and as pre-extrapolation tools to quantify uncertainty in the inverse Finite Element Method.



RESEARCH ACTIVITIES:

- Application of a physics-constrained multivariate Gaussian Processes extrapolate strains for uncertainty qunatification in iFEM
- Application of constrained Gaussian Processes to improve fatigue life models or to improve surrogate models

METHODOLOGY: numerical – analytical

DURATION: 9 months

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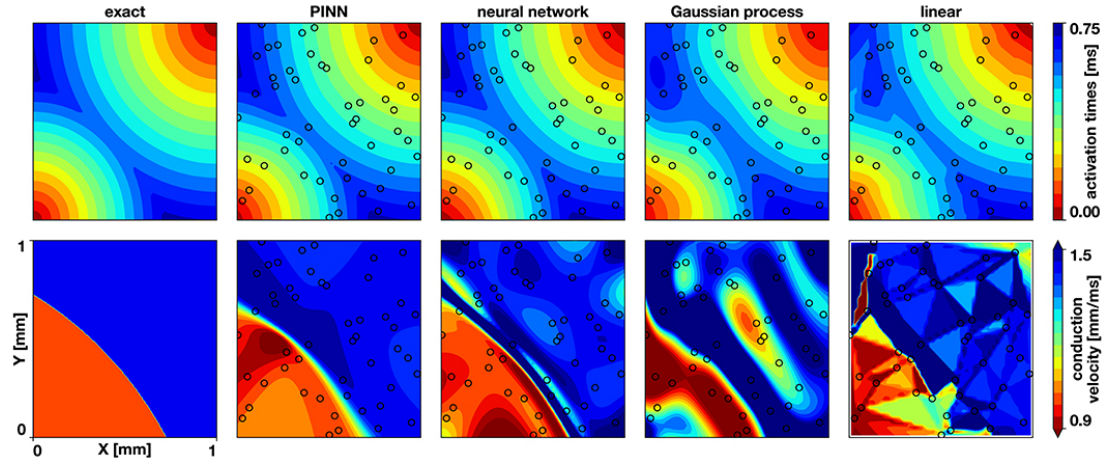
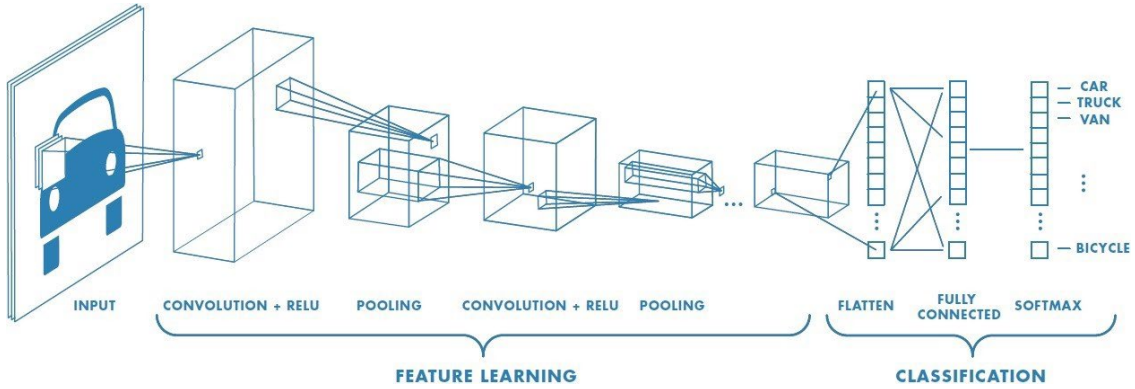


PROJECT: general (Artificial Intelligence for Digital-Twin and SHM)

Title: Manoeuver classification and clustering from experimental strain data using Convolutional Neural Networks and Wavelet Transforms

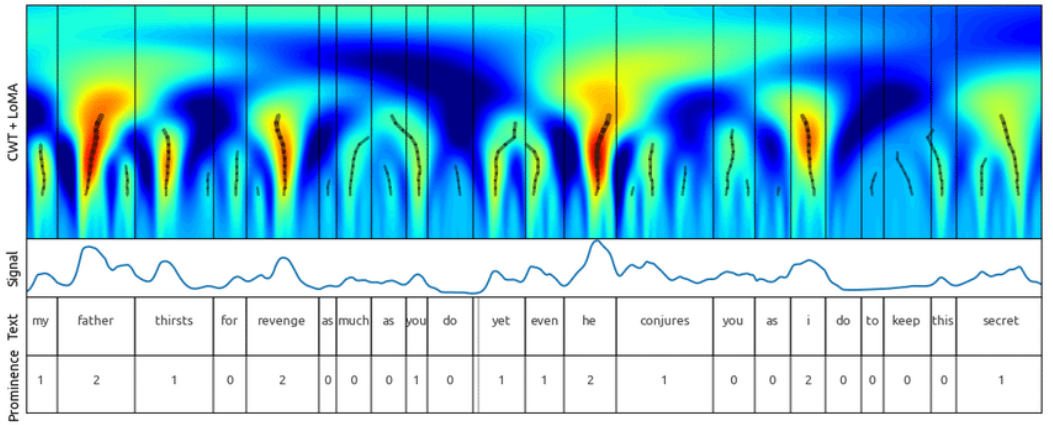
RESEARCH BACKGROUND:
Automatic maneuver classification in aircrafts from strain data is a little researched area which can be useful for classifying operational loads according to the maneuver type, improving the design phylosophy, and for limiting the flight envelope of a damaged aircraft on-line.



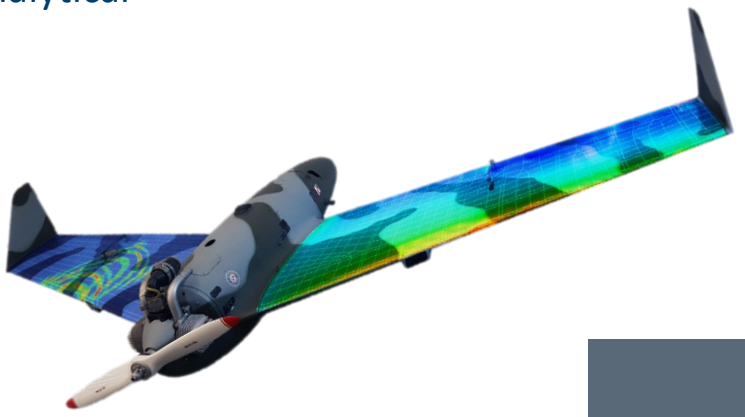
RESEARCH ACTIVITIES:

- Application of Wavelet Transforms to experimental strain data
- Application of a CNN to classify maneuver data

METHODOLOGY: numerical – analytical



DURATION: 9 months



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PROJECT: general (Artificial Intelligence for Digital-Twin and SHM)

Title: Domain Adaptation Assisted Particle Filter for the Damage Diagnosis and Prognosis of Helicopter Panel

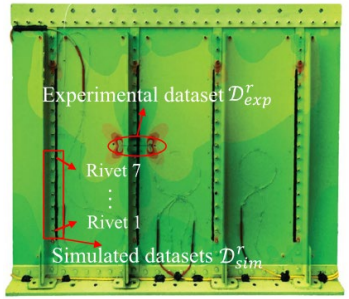
RESEARCH BACKGROUND:
The particle filter has found widespread application in the field of damage diagnosis and prognosis for aeronautical and mechanical structures. Through the utilization of state-parameter Bayesian estimation, the model parameters can be updated using observation data. However, when dealing with data-driven process or observation models developed through simulations or historical data, the performance of the model is significantly affected by the discrepancy in data distribution. This discrepancy poses challenges for updating the model due to the absence of explicit parameter representation. Domain adaptation techniques can be incorporated into the particle filter framework. This integration of domain adaptation within the particle filter can be validated through experimentation involving a helicopter panel, serving as a suitable testbed.

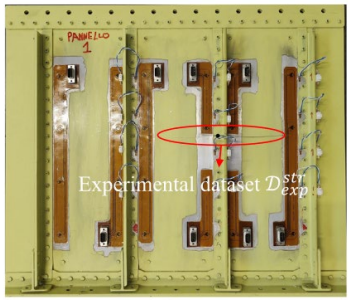
RESEARCH ACTIVITIES:

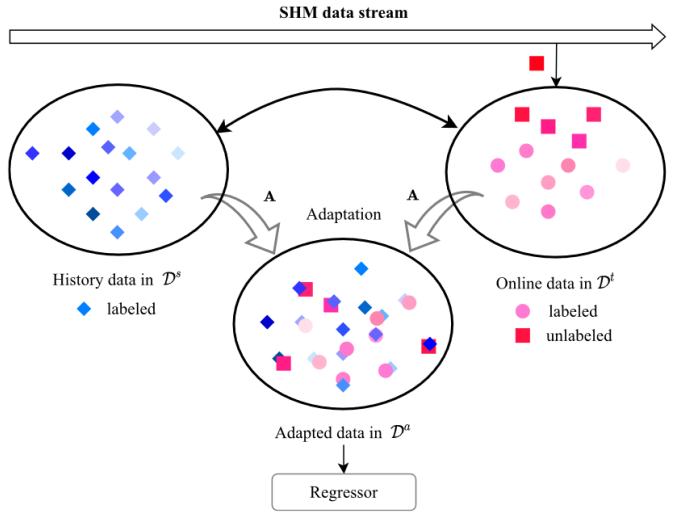
- Bilit the particle filter-based diagnosis and prognosis model of the helicopter panel
- Integrate the domain adaptation into the particle filter framework

METHODOLOGY: numerical – analytical

DURATION: 9 months







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PROJECT: general (Artificial Intelligence for Digital-Twin and SHM)

Title: Physics-aided cross-sensor domain adaptation for damage detection and quantification

RESEARCH BACKGROUND:
Domain adaptation has been employed in the damage detection and quantification to enhance diagnostic accuracy by leveraging historical data from simulations or similar structures. Nevertheless, it continues to pose a challenge when applied to similar structures that are equipped with different kind of sensors. Given the availability of physics models for structures, leveraging this model to bridge the gap between two different sensor domains and achieve cross-sensor domain adaptation is highly desirable. The developed method can subsequently be utilized for damage detection and quantification purposes.

RESEARCH ACTIVITIES:

- Construct multiple deep-learning based damage diagnosis model of the structure.
- Develp the domain adaptation approach for the models to achieve cross-sensor domain adaptation.

METHODOLOGY: numerical – analytical

DURATION: 9 months

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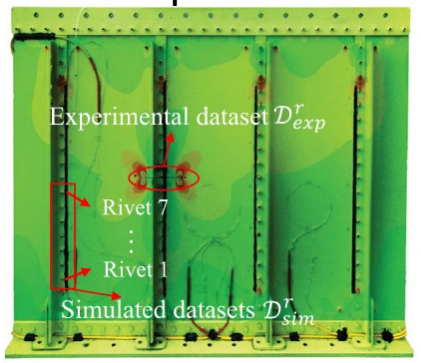
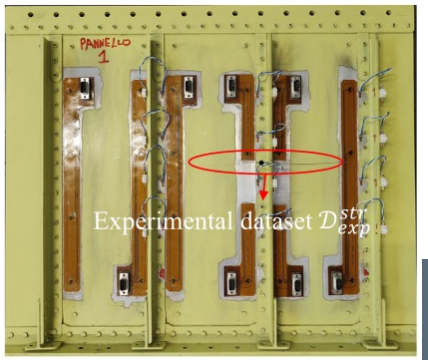
Fiber optic sensor



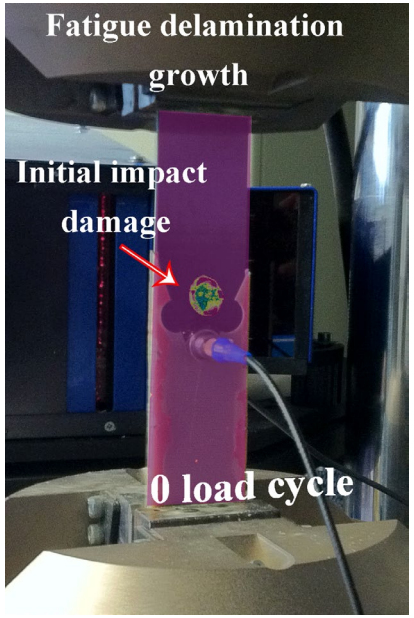
Lamb wave sensor



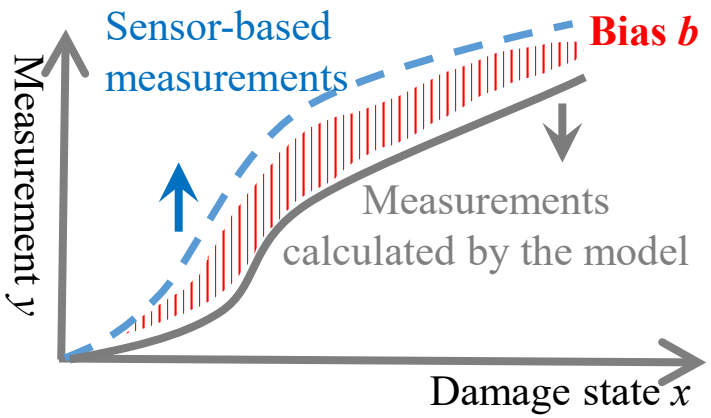
PROJECT: general (Artificial Intelligence for Digital-Twin and SHM)

Title: particle filter-based delamination shape prediction in composites using Lamb waves

Delamination shape prediction [1]



Uncertainties (or bias) [2]



Novelty: bias-based prognostic model

$$\begin{cases} \boldsymbol{z}_k = \begin{bmatrix} \boldsymbol{\theta}_k \\ x_k \\ b_k \end{bmatrix} = \begin{bmatrix} \boldsymbol{\theta}_{k-1} + \boldsymbol{\omega}_{\theta,k} \\ f(x_{k-1}, \boldsymbol{\theta}_k, \omega_k) \\ b_{k-1} + \omega_{b,k} \end{bmatrix} \\ y_k = h(x_k) + b_k + v_k \end{cases}$$

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METHODOLOGY: numerical – analytical - programming

DURATION: 9 months

Collaboration with researchers from Spain and China