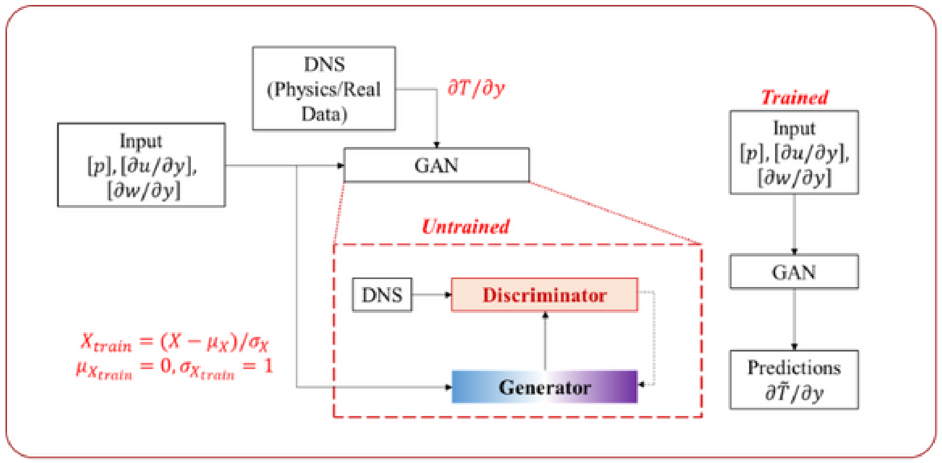
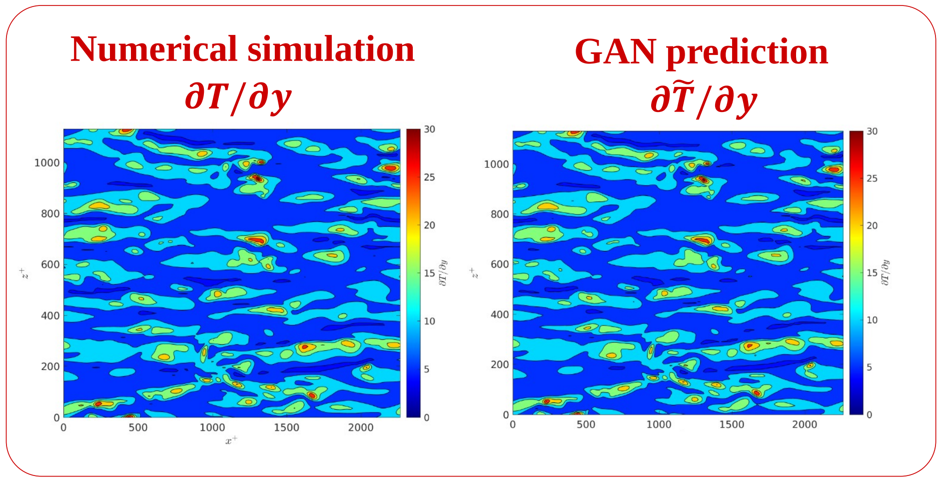
Unsupervised Deep Learning of Turbulent Heat Transfer via Generative Adversarial Networks

Nicholas J. Ward^1, Stephen Ekwaro-Osire^1



Methodology



Training results

Introduction

- Extensive importance of fluids simulations
  - Atmospheric flows, heat exchangers
  - Current methods are costly
- Correlation between temperature and velocity
- Machine learning for fluid dynamics [3]
  - Deep learning
  - Generative adversarial networks (GANs)
- Application of machine learning for studying turbulence

Motivation

- Previous works provided insight on modeling turbulence
  - Fluids modeling: direct numerical simulation (DNS), near-wall physics
  - Artificial intelligence: data-driven models, supervised/unsupervised learning
- Simulate at reduced computational expense
- Improve data-driven models in turbulence research
- Apply deep learning for predicting turbulent heat transfer

Research question

Can turbulent heat transfer be efficiently predicted with wall variables?

- Predict heat transfer from wall variables
- Extrapolate temperature gradients to higher Reynolds numbers

Prognostics and Health Management of Wind Energy Infrastructure Systems

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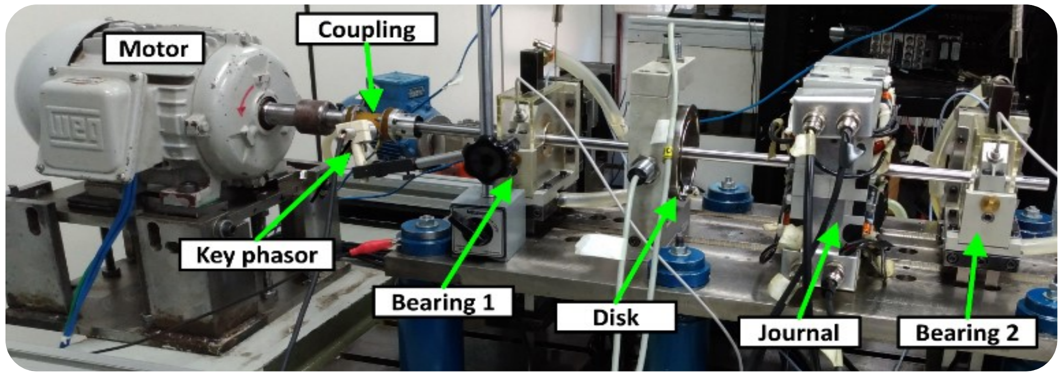
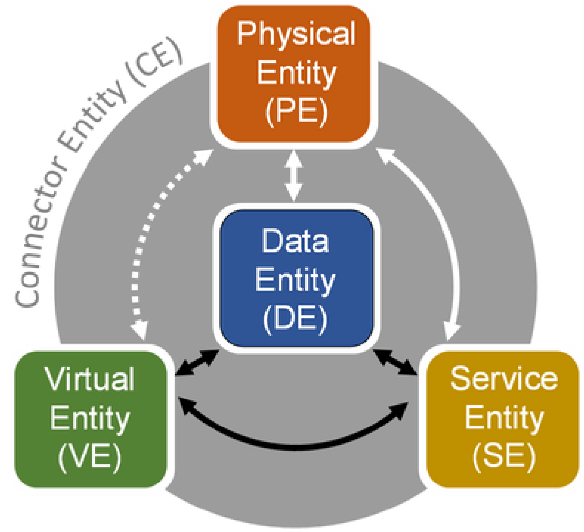


Rotary machinery experimental setup configuration



5-dimension DT model

Introduction

- A digital twin (DT) is a combination of integrated multi-physics, multi-scale, probabilistic simulation of a complex product
- Verification and validation (V&V) is the method of determining if the criteria for a part or a system are accurate and complete
- Applications; aerospace, manufacturing, construction, healthcare, automobile, city, agriculture, electricity

Motivation

- Implementing V&V of a single component instead of a full system in DT
- Enhancing the model's credibility which is carried out by V&V as an essential initial service in DT
- Providing quick access to asset data or information and a reduction in manual data transfer effort

Research question

Does implementing V&V using DT improve access to data and reduce the effort of data exchange?

- To conduct a code and calculation verification
- To validate simulations against experiments
- To demonstrate easy access to asset information or data

Prediction of the remaining useful life of a battery with limited data and no temporal identifier

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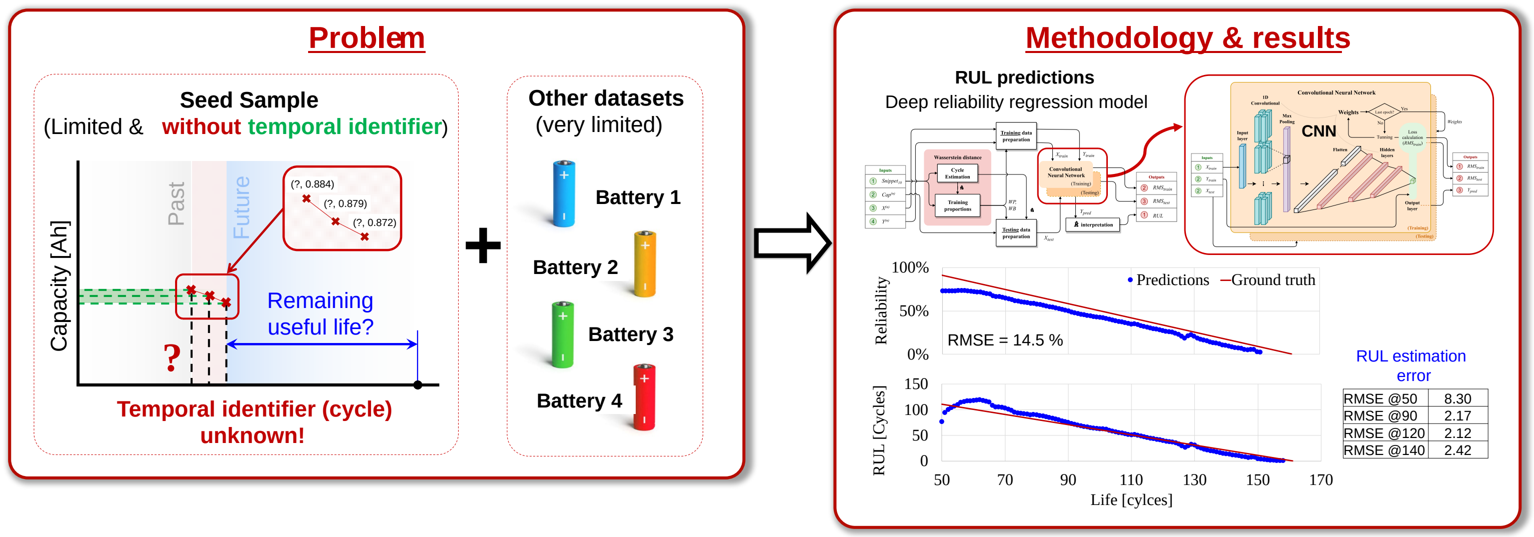

Battery RUL prediction framework

Introduction

- Li-ion batteries are ubiquitous
- Unavailability of battery data makes it difficult to perform prognostics (deep learning)
- Is it possible to predict the remaining useful life (RUL) of batteries having only three data points without a temporal identifier?

Motivation

- High unpredictability of battery state of health parameters and experimental data unavailability
- Learning methods can handle complex regression tasks but they require large amounts of high-quality data
- There is a literature gap on predicting the RUL of batteries without temporal information
- By estimating RUL of batteries on an ongoing basis, adaptative actions can be made during the mission to extend the maintenance-free operation window

Research question

Can the remaining useful life (RUL) of a battery be predicted with no temporal identifier?

Can entropy be used to predict the incipient failure of systems?

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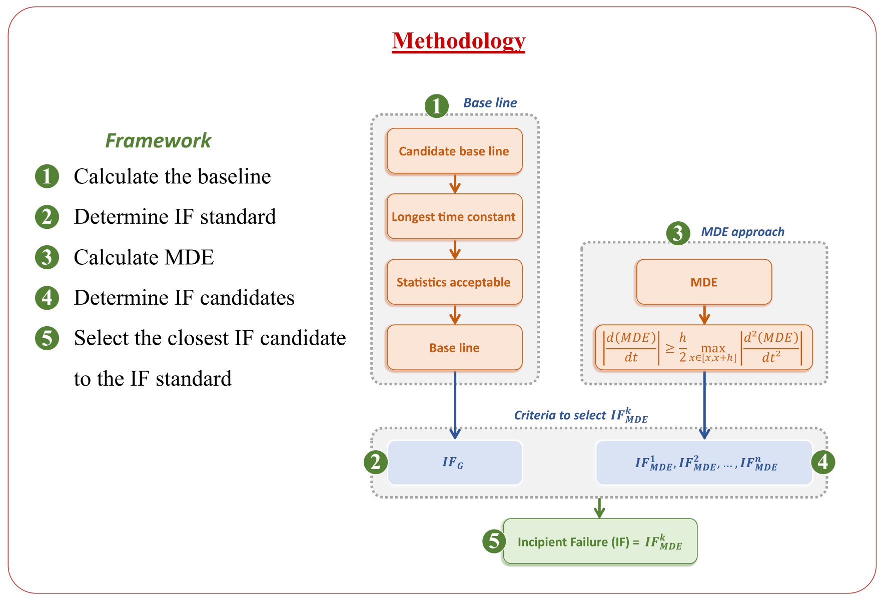
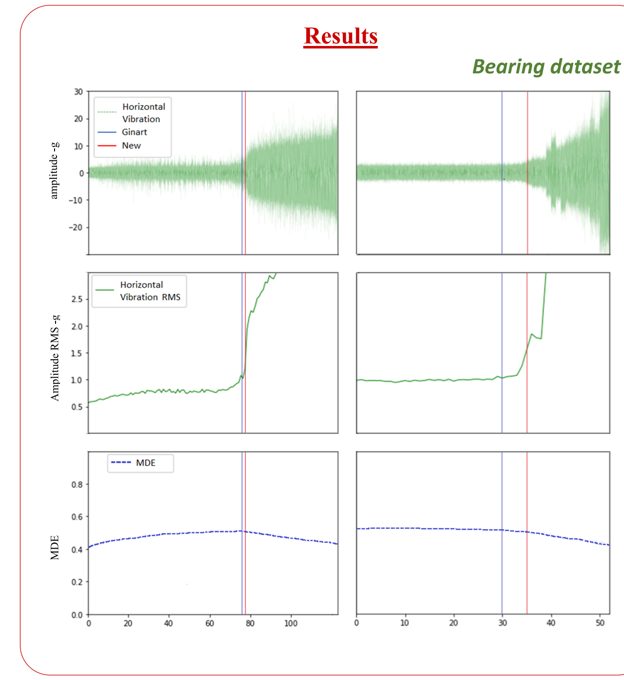


Incipient failure (IF) point prediction framework



IF point prediction results for bearing vibration dataset

Motivation

- Entropy is used to quantify dynamic complexity from an arbitrary time series
- Incipient failure (IF) is an imperfection in the condition of an item from which a degraded or critical failure can be expected to result if corrective action is not taken
- Remaining useful life (RUL) is an estimate of the amount of time that an item is estimated to be able to function before replacement
- Data can be used to better predict IF and RUL
- Avoid catastrophic failure

Research question

Can Multi-scale Divesirty Entropy be used to develop a framework to predict the IF of a system?

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