UDT
Undersea Defence Technology
13-15 May 2019
Stockholmsmässan, Sweden

Machine Learning for monitoring the condition of critical systems

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#UDT2019

Stand: A19

Project Outline

- Industry & Academic partnership project
- Assessing the potential for use of Condition Monitoring (CM) data to improve asset performance
- Provide decision support in the form of fault prediction and assessment tools
- Primarily hydraulic assets and equipment

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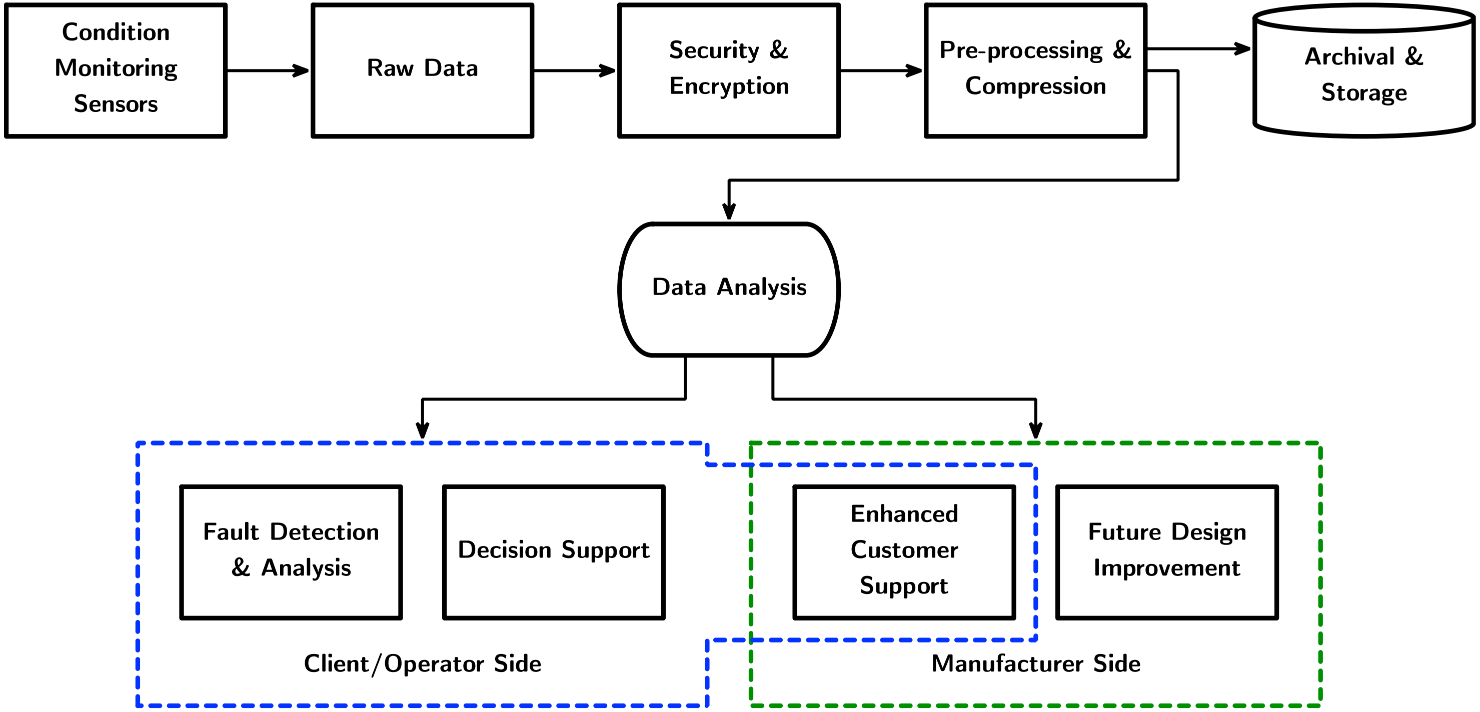
Aims & Motivations

- Increase asset reliability & availability
- Improve understanding of *“real-world”* asset usage
- Improve information available for decision support
- Improve quality of servicing and product support
- Improve future designs

PROCESS

Process Outline



Learning Cases

- **Supervised learning** requires historic data on fault and failures to learn data characteristics (data is *labelled* i.e. fault/no fault)
- **Unsupervised learning** directly learns patterns in the data without apriori labelling
- **Anomaly Detection** learning what is *normal* to provide information on deviation from the *normal.*

Learning Cases

- In fault analysis the two cases are analogous to two broad cases in engineered equipment:
    1. Low cost cheaply replaceable components/equipment can easily provide an extensive *training set* often through accelerated lifecycle testing or analytical modelling
    2. Robust expensive equipment lacks fault/failure data due to costs in obtaining data and strict maintenance regimes mitigating faults

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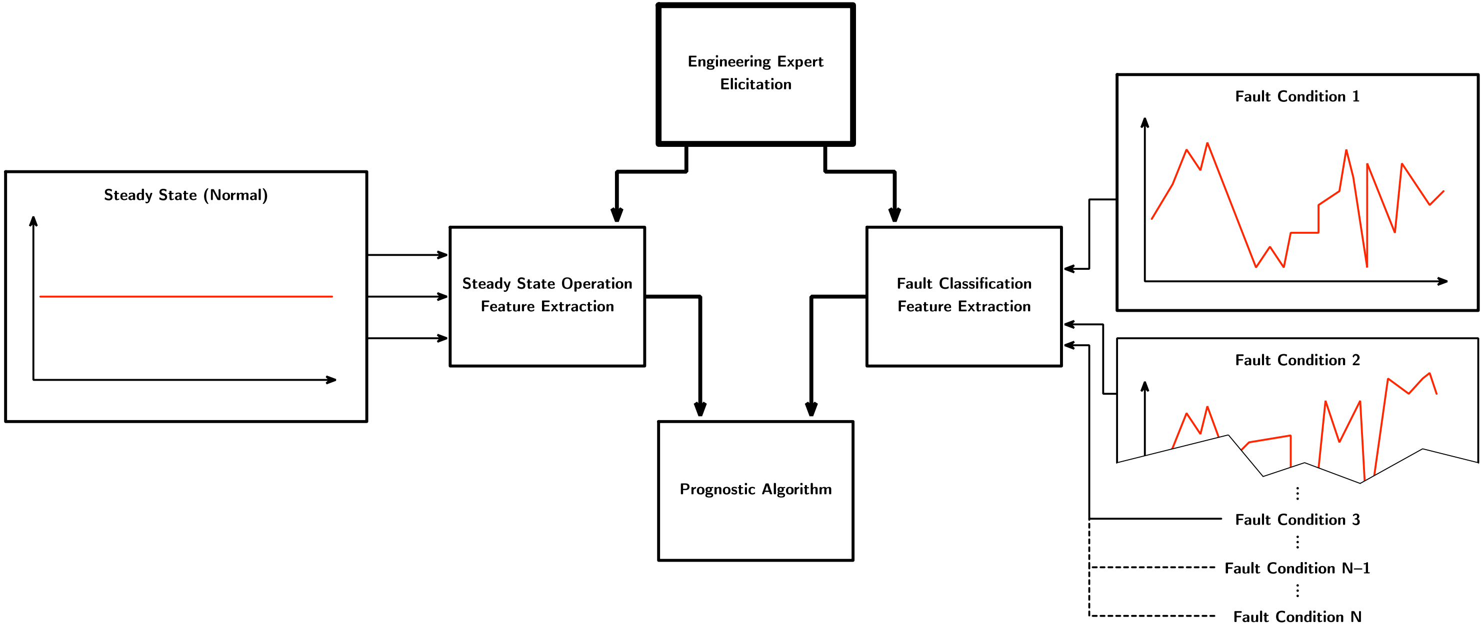
Learning from a Fault Dataset



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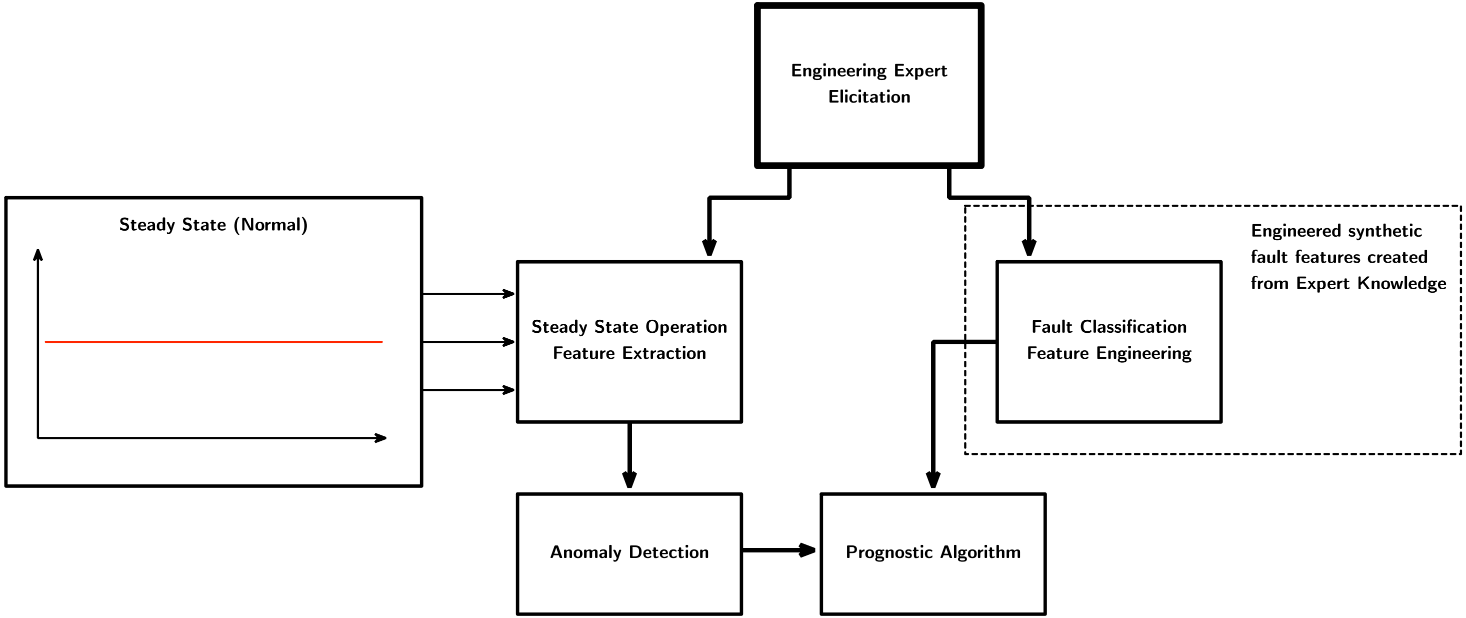
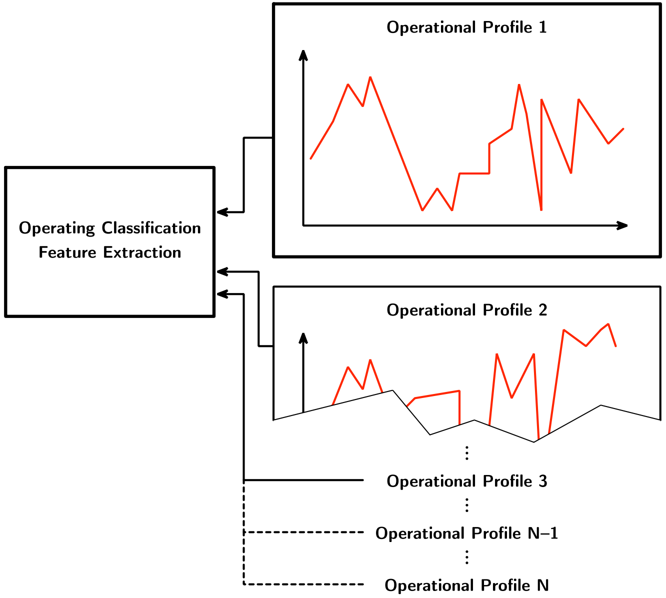
Learning in Absence of Fault Dataset



Anomaly Detection

- Identify common/ expected operational parameters
- Extract data features from profiles using Expert Elicitation or Empirical Operating data
- Anomaly detection uncovers deviations outside the expected operational *space*
- Inclusion of classification also makes estimates of fault mode and/or mechanism

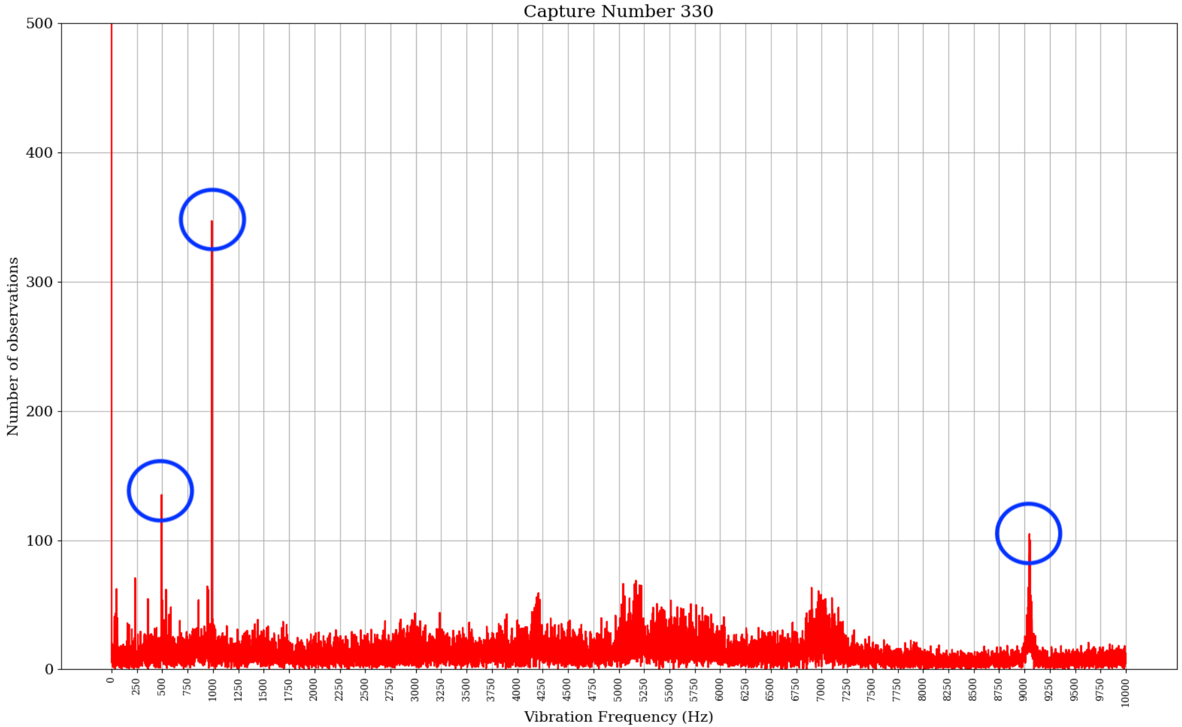


APPLICATION

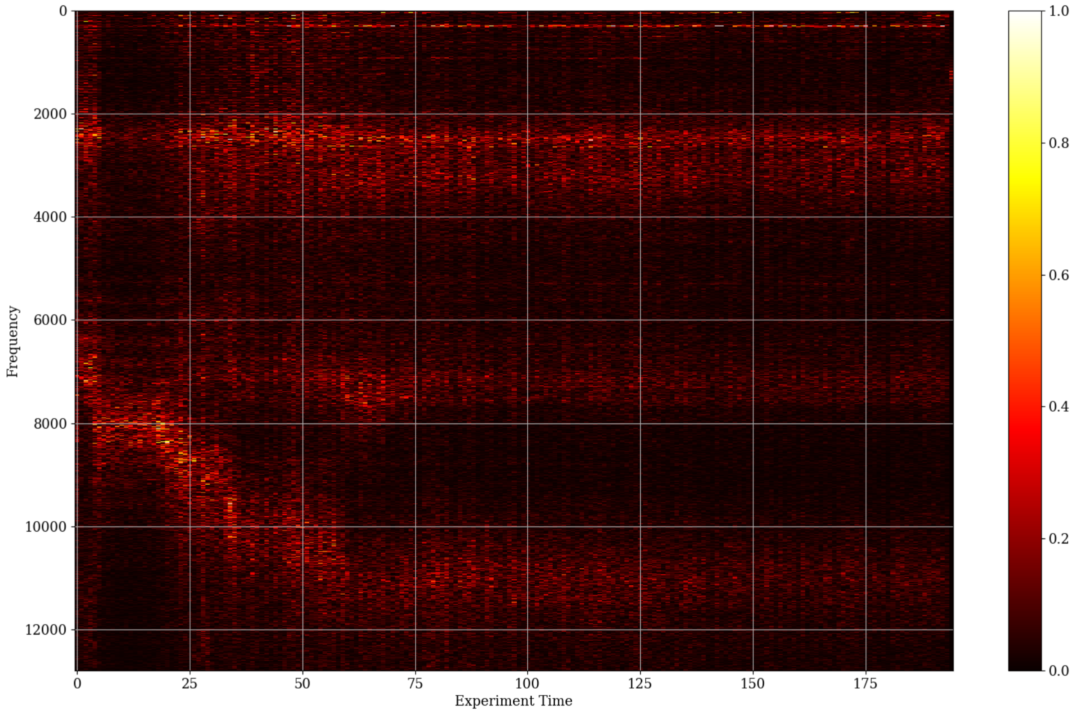
Application to Machinery Vibration

- Perform signal processing techniques Fast Fourier Transforms, Wavelets etc.
- Monitor spectra across history of equipment
- Automatically detect fault conditions
- Improve historical record for specific asset to improve fault detection and diagnosis

Application to Machinery Vibration



Application to Machinery Vibration



Application to Machinery Vibration

- Passively assess internal workings of machinery
- Can be performed using relatively low cost accelerometers
- Suited for regression, classification and anomaly detection
- Central assumption increased vibration = decreased equipment quality

Application to Machinery Vibration

Future Challenges

- Adapt algorithm to account for operating conditions (*avoidance of false positives*)
- Incorporation of advanced signal processing techniques for increased contextual inference (Wavelet transforms etc.)
- Ensure robustness of algorithms to noise

BENEFITS

Operational Benefits

- Live high resolution understanding of asset operation including reports of impending faults **improves situational awareness**
  - Leads to improved maintenance logistics by ***increasing maintenance horizon.***
  - Improvements in operational planning based upon system state i.e. mission requirements can be compared with asset predicted capability
  - Reduction in manned maintenance inspections
  - Increased equipment availability

Operational Benefits

- Increased *"Mission Reliability"*
  - Use of past data to understand how different scenarios affect reliability of assets
  - Use of data to model asset future operating scenarios
- Safety improvements
  - Knowledge of impending faults impedes the development of safety critical failure situations
  - Provides visibility to **hidden failures** outside of routine inspection intervals

Manufacturer & Customer Benefits

- High quality system state estimations enable improved contract and product support
  - Enhanced product support via asset data analysis
  - Improved product development and design driven by *real world* usage profiles and duty cycles
  - Enabling technology for Contracts for Availability (CfA)

Future Technical Benefits

- Access to high resolution data history of equipment
- Improved understanding of asset operational profiles i.e. system stresses under different operating modes
- Incorporation with **Integrated Platform Management Systems (IPMS)** and **Digital Twin** technology
- Use within **automated & autonomous control systems** to providing **self-awareness** element of mission planning/execution

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Recapitulation

- Many techniques exist to make use of large existing and potential datasets (sensor streams etc.)
- Accessibility of techniques constantly improving.
- Mission critical assets requires expert elicitation we cannot blindly trust "black-box" style prediction systems i.e. breaking down the walls of the black box.

Funding and Stakeholders

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Questions?