

Digitilisation in Nuclear - Harnessing Data Science for Enhanced Through Life Management of Nuclear Plants

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Industry Requirements

- Lifetime extension of reactors, plant and equipment
 - Understanding of current condition
 - Prediction of likely degradation
- Reduced unplanned outages
 - Improved anomaly detection
 - Fault diagnosis
 - Prediction of likely degradation and failure timescales
- Increased periods between inspections
 - Improved knowledge of condition
 - Prediction of expected degradation
- Optimisation of maintenance
 - Understanding of current condition
 - Prediction of likely degradation







Bayesian Belief Networks Data Science Unsupervised Learning Data Mining **Big Data Knowledge Engineering Sentiment Analysis** Genetic Algorithms Machine Learning Supervised learning **Deep Neural Networks Cognitive Science Expert Systems** Exploratory Data Analysis Artificial Intelligence Natural Language Processing

Drivers & Enablers

- Social Media and eBusiness
- Large academic initiatives
 - DNA Sequencing
 - Astronomy & Cosmology
- Search (text and images)
- Games
 - Chess (IBM Deep Blue)
 - Jeopardy (IBM Watson)
 - Go (Google AlphaGo)
- Interaction
 - Handwriting recognition
 - Speech recognition
 - Image recognition
 - Natural Language Processing



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What Does the Industry Need? Decision Support through "Agile" Analytics





value in a standard platform

Link analytics and data from sprints

EDF Energy Data Analytics

Control Rod Monitoring

ASIST: Automated Stitching of TV Inspection images

Rotating Plant: Steam Turbines and Gas Circulators BETA: Automated Analysis of FGLT

IMAPS: Intelligent Monitoring Assessment Panel System

> CESL Nuclear Engineering Wallchart http://econtent.unm.edu/cdm4/browse.php?CISOROOT=/nuceng&CISOSTART=1,1

The Agile "Journey"



- Exploration
 - Often include visualisation
 - Provides a better understanding of the data and therefore the subject of the data
- Supporting humans to make decisions
 - Faster
 - More reliably
 - Repeatably
- Anomaly Detection → Fault Classification → Diagnostics → Prognostics
- Often includes domain expertise

Data Analysis Techniques



- K-means Clustering
- DBScan Clustering
- Dendrograms
- Sammon Mapping

Structure from Motion

 Kernal Density Estimation

- Artificial Neural Networks
- Decision Trees
- Support Vector Machines
- Bayesian Linear Regression
- Label propagation

...but don't forget engineering knowledge



Agile delivery journey...







AGR - Graphite Inspection

- ASIST Software automatically creates CHANORAMA images from inspection videos
- Used for every fuel channel inspection at all 7 stations



Manual Method: Full working day to produce 3-4% of full channel image



Automatic Method: 20 minutes to produce 100% of 8 layers







Decision support



AC Ch 6: LPA Rotor Rear Bearing ALARM



Automated Sizing & Classification of Pressure Tube Defects

- During outages selected channels are ultrasonically inspected
- Data manually assessed by two independent analysts
 - Defects sized and classified
- Developing intelligent system algorithms for automated assessment of flagged indications
 - Time sensitive critical outage path
 - Limited pool of analysts
- Robust, Repeatable, Rapid





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Automated Sizing & Classification of Pressure Tube Defects

- Automated end-to-end analysis of pressure tube data
 - Defect identification
 - Defect characterisation
 - Defect classification

Features found for Lower Rolled Joint

2360

2370

2380

IEIXY 2420

2430

2440

2450

0

50

100

150

200

Roll Joint, End of Tube and

Burnish Mark detection

• Proposed deployment via existing software

Burnish Marl

End of Tube

Rolled Joints

350

300

Knowledge-based vs data driven

250



Automated sizing of defects







Transformer analytics









Bayesian Combined Model







Aside: Labelling data





Are you a robot?

 To learn, the machine needs to be told whether it is right or wrong

Active learning



- Data analytics techniques can be applied in a "one off" to:
 - Better understand the data
 - Train a classifier
 - Time stamped (and validated)
- What happens if data is changing over time?
 - New observations, new classes
 - Incremental machine learning
 - Reinforcement learning
- Question of where the human is in the loop

Is nuclear data "Big Data"?

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£7.1M portfolio of projects £5M currently being defined

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Tier 1 & 2 Partners



Innovation at wor













Nuclear transmitterion transfitting of Australians



UNE N University Network of Excellence in Nuclear Engineering





Industrial Informatics – Delivering Value from Data

As projects are added, new data sources and capabilities become available

and the system architecture is developed based on need







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