

Theme 2: Support the Engineer

The nature of failure data sets poses particular challenges to modellers. Failures, particularly of critical equipment, are rare. Lots of equipment are replaced in whole or in part before end of life. As a result failure data-sets are unbalanced and sparse. Failures are seldom labelled accurately, and there is often no ground truth for validation.

Condition monitoring data, when available, is often collected at different time intervals. Poor quality data results in greater model complexity that at best muddies inference, and at worst misleads inference and produces persistent prediction bias. These contextual issues, if not dealt with rigorously in model selection and validation practice, leads to poor model performance and a loss of trust by decision makers. To manage these risks, this theme is explicitly cross-disciplinary combining the Bayesian statistics, engineering, nonlinear system identification, machine learning and deep learning.

Initial project areas for Theme 2 include:

1

Dynamic modelling and nonlinear time series

Early signs of asset failure result in nonlinear changes in system dynamics of complex systems. That is, many assets consist of complex interacting part, and are a non-autonomous component in a larger system. Failure of each component will result in subtle changes in the dynamical behaviour of that system and these changes are best detected with a suite of new nonlinear signal processing tools. The ability to detect these would provide an earlier indication than traditional linear condition monitoring techniques. The aim of this project is to develop and to apply a range of nonlinear time series analysis methodologies – including state-space based dynamical reconstruction, frequency domain characterization, and novel machine learning paradigms – to provide a new and improved indicator of asset failure. Condition monitoring data is collected across a range of assets across all our industry partners – this may include chemical reaction and mixing processes, pump vibration time series data, multi-modal condition monitoring of heavy equipment or process throughput control. In all cases this time varying condition data provides a proxy for the system health, which is imperfectly understood. The aim of this project is to develop the tools to better characterize and understand conditions of these systems across operations. The project will produce real-time diagnostic algorithms which can be deploy and embedded within current operations.

2

Bayesian models for failure prediction and remaining useful life estimation

This project aims to deliver improved predictability of failure (with uncertainty estimates) for individual assets (rather than a population of assets) from longitudinal data. Remaining useful life (RUL) estimation provides a probabilistic maximum likelihood estimate of the expected time to failure. This is naturally a stochastic quantity. The aim of this project is to apply Bayesian methodologies in conjunction with other data driven modelling paradigms to optimally estimate expected failure. This will include an estimate not only of the RUL, but also the uncertainty of this estimate. Combined, these quantities can then be drawn upon for optimal maintenance scheduling and planning and for empirical expected-value based planning of asset replacement and retirement.

Publications

- [A Novel Approach to Time Series Complexity via Reservoir Computing \(...\)](#) —

Conference Publishing

[Braden Thorne](#)

Authors: Braden Thorne, Thomas Jüngling , Michael Small , Debora Correa , and Ayham Zaitouny

2022-12-07

- [Constrained Markov Order Surrogates \(...\)](#) —

Journal Article

[Dr Debora Correa](#)

Authors: Corrêa, D. C., Moore, J. M., Jüngling, T., & Small, M.

2020-02-28

- [Data-Driven Approach for Labelling Process Plant Event Data \(...\)](#) —

Journal Article

[Dr Debora Correa](#)

Authors: Débora Corrêa, Adriano Polpo, Michael Small, Shreyas Srikanth, Kylie Hollins, Melinda Hodkiewicz

2022-01-24

- [Deforestation-induced surface warming is influenced by the fragmentation and spatial extent of forest loss in Maritime Southeast Asia \(...\)](#) —

Journal Article

[Dr Debora Correa](#)

3

Fault diagnosis and prediction through advanced spectral analysis techniques

In addition to time series data (the subject of the preceding two projects, and probably a good justification to seek progress on them first), asset health is often monitored with multi-modal data. By combining that data from different modalities (video, spectral, time series) the objective of this project is to improve fault diagnosis. The primary research question here is two levelled – first, how is that data best understood individually; and, second, how can one best integrate data from different modalities for optimal prediction?

Additional information concerning corrosion, contamination, degradation, congestion and failure can be obtained from video and image data (in addition to time series and audio). The combination of 2D (image) and 3D (video) data with techniques honed for 1D (time series/audio) data requires both novel mathematics and new computation algorithms. The objective of this project is to develop the algorithmic techniques to allow for integration of multi-channel multi-modal and multi-dimensional data from multiple sources for better predictions. Applications will include proves monitoring and overall system health across a range of industrial processes in mining, oil and gas and processing.

4

Optimise maintenance management work flow

Equipment maintenance typically involves many different individuals with different duties within an organisation interacting with the equipment. Each transaction (work request, routine maintenance, replacement, service, etc.) is recorded in a Maintenance Work Management System (typically SAP or equivalent systems) and provides a rich quantitative data set of records of interaction and interdependence among individuals and equipment. Whereas the other projects in Theme 2 view the physical assets as a complex system, here we treat the maintenance workforce as a virtual complex system of human capital. The topology of this system, and how it interacts with the maintenance objects defines a set of complicated interdependencies which lead to redundancy (and hence reliability) or leanness (and hence fragility) in the maintenance system. The object of this project is to describe and optimize that system, identify bottlenecks and inefficiencies in across the entire maintenance process.

Authors: Crompton, O., Corrêa, D., Duncan, J. and Thompson, S.,
2021-09-03

- [Detecting Asset Cascading Failures Using Complex Network Analysis \(...\)](#) —

Journal Article

[Dr Ayham Zaitouny](#)

Authors: Jaymin Moffatt; Ayham Zaitouny; Melinda Hodkiewicz; Michael Small
2021-08-27

- [Developing and evaluating predictive conveyor belt wear models \(...\)](#) —

Journal Article

[Prof Melinda Hodkiewicz](#)

Authors: Callum Webb, Joanna Sikorska, Ramzan Nazim Khan, Melinda Hodkiewicz
2020-06-18

- [Evaluating the Accuracy of Bluetooth-Based Travel Time on Arterial Roads: A Case Study of Perth, Western Australia \(...\)](#) —

Journal Article

[Dr Aloke Phatak](#)

Authors: Liu, Y., Xia, J., & Phatak, A.
2020-02-21

- [Fast automatic detection of geological boundaries from multivariate log data using recurrence \(...\)](#) —

Journal Article

[Dr Ayham Zaitouny](#)

Authors: Michael Small; June Hill; Irina Emelyanova; Michael Ben Clennell
2019-11-12

- [Fast automatic detection of geological boundaries from multivariate log data using recurrence. \(...\) —](#)

Journal Article

[Dr Ayham Zaitouny](#)

Authors: Zaitouny, A., Small, M., Hill, J., Emelyanova, I. and Clennell, M.B., 2020. Fast automatic detection of geological boundaries from multivariate log data using recurrence. Computers & Geosciences, 135, p. 104362.

2019-11-12

- [Grading your models: Assessing dynamics learning of models using persistent homology \(...\) —](#)

Journal Article

[Dr Debora Correa](#)

Authors: Eugene Tan, Débora Corrêa, Thomas Stemler, Michael Small

2021-12-01

- [Informative Bayesian Survival Analysis to Handle Heavy Censoring in Lifetime Data \(...\) —](#)

Conference Publishing

[Ryan Leadbetter](#)

Authors: Ryan Leadbetter; Aloke Phatak; Adriano Polpo; Melinda Hodkiewicz

2021-12-15

- [Interpretable Survival Models for Predictive Maintenance \(...\) —](#)

Conference Publishing

[A/Prof Adriano Polpo](#)

Authors: Paul Castle, Janet Ham, Melinda Hodkiewicz, Adriano Polpo

2020-11-01

- [Managing streamed sensor data for mobile equipment prognostics. \(...\) —](#)

Journal Article

[Dr Debora Correa](#)

Authors: Griffiths, T., Corrêa, D., Hodkiewicz, M., & Polpo, A. (2022). Managing streamed sensor data for mobile equipment prognostics. Data-Centric Engineering, 3, E11. doi:10.1017/dce.2022.4

2022-04-07

- [Modeling Failure Risks in Load-Sharing Systems With Heterogeneous Components \(. ..\) —](#)

Journal Article

[Tim Pesch](#)

Authors: Tim Michael Pesch , Erhard Cramer , Edward Cripps , and Adriano Polpo , Senior Member, IEEE

2024-02-21

- [Modelling failure risks in load sharing systems with heterogeneous components \(...\) —](#)

Journal Article

[Tim Pesch](#)

Authors: Tim Pesch, Erhard

Cramer, Edward
Cripps, Adriano
Polpo

2023-07-20

- [Objective Domain Boundaries Detection in New Caledonian Nickel Laterite from Spectra Using Quadrant Scan \(...\)](#) —

Journal Article

[Dr Ayham Zaitouny](#)

Authors: Zaitouny
A, Ramanaidou E,
Hill J, Walker DM,
Small M

2022-01-01

- [On detecting dynamical regime change using a transformation cost metric between persistent homology diagrams. \(...\)](#) —

Journal Article

[Dr Debora Correa](#)

Authors: Dee Algar,
S., Corrêa, D.C. and
Walker, D.M

2021-12-17

- [On using the modularity of recurrence network communities to detect change-point behaviour \(...\)](#) —

Journal Article

[Dr Ayham Zaitouny](#)

Authors: David M.
Walker, Ayham
Zaitouny, Debora C.
Correa*

2021-03-01

- [Optimal Thresholding of Predictors in Mineral Prospectivity Analysis \(...\)](#) —

Journal Article

[Dr Aloke Phatak](#)

Authors: Adrian
Baddeley, Warick
Brown, Robin K.
Milne, Gopalan Nair,
Suman Rakshit,
Tom Lawrence,
Aloke Phatak, and
Shih Ching Fu

2020-11-11

- [Parameter extraction with reservoir computing: Nonlinear time series analysis and application to industrial maintenance \(...\)](#) —

Journal Article

[Braden Thorne](#)

Authors: Thorne, B., Jüngling, T., Small, M., & Hodkiewicz, M. (2021).

2021-03-01

- [Quadrant scan for multi-scale transition detection \(...\)](#) —

Journal Article

[Dr Ayham Zaitouny](#)

Authors: Zaitouny, A., Walker, D.M. and Small, M., 2019.

2019-10-08

- [Quantifying the generalization capacity of Markov models for melody prediction \(...\)](#) —

Journal Article

[Dr Debora Correa](#)

Authors: Corrêa, D. C., Jüngling, T., & Small, M.,

2020-02-17

- [Reconstruction of Complex Dynamical Systems from Time Series using Reservoir Computing \(...\)](#) —

Journal Article

[Prof Michael Small](#)

Authors: Jüngling, T., Lymburn, T., Stemler, T., Corrêa, D., Walker, D. & Small, M.,

2019-05-01

- [Recurrence-based reconstruction of dynamic pricing attractors \(...\)](#) —

Journal Article

[Dr Shuixiu Lu](#)

Authors: Shuixiu Lu - Sebastian Oberst

2023-06-13

- [Reliability inference with extended sequential order statistics \(...\) —](#)

Journal Article

[Tim Pesch](#)

**Authors: Tim
Pesch, Adriano
Polpo, Edward
Cripps, Erhard
Cramer**

2023-04-11

- [Reservoir time series analysis: Using the response of complex dynamical systems as a universal indicator of change \(...\) —](#)

Journal Article

[Braden Thorne](#)

**Authors: Thorne,
Braden Jüngling,
Thomas Small,
Michael Corrêa,
Débora Zaitouny,
Ayham**

2022-02-10

- [Selecting embedding delays: An overview of embedding techniques and a new method using persistent homology \(...\) —](#)

Journal Article

[Dr Debora Correa](#)

**Authors: Eugene
Tan, Shannon Alga,
Débora Corrêa,
Michael Small,
Thomas Stemler
and David Walker¹**

2023-03-01

- [Sensitization to immune checkpoint blockade through activation of a STAT1/NK axis in the tumor microenvironment \(...\) —](#)

Journal Article

[Dr Ayham Zaitouny](#)

**Authors: Rachael M.
Zemek, Emma De
Jong, Wee Loong
Chin, Iona S.
Schuster, Vanessa**

S. Fear, Thomas H. Casey, Cath Forbes, Sarah J. Dart, Connall Leslie, Ayham Zaitouny, Michael Small, Louis Boon, Alistair R. R. Forrest, Daithi O. Muiri, Mariapia A. Degli-Esposti

2019-07-17

- [Stillbirth risk prediction using machine learning for a large cohort of births from Western Australia, 1980–2015 \(...\)](#) —

Journal Article

[Dr Aloke Phatak](#)

Authors: Malacova, E., Tippaya, S., Bailey, H.D. et al.

2020-03-24

- [Variable Selection for Conveyor-Belt Mean Wear Rate Prediction \(...\)](#) —

Journal Article

[Prof Melinda Hodkiewicz](#)

Authors: Joanna Z Sikorska*, Callum Webb, Nazim Khan and Melinda Hodkiewicz

2021-02-26

Presentations

- [A Computer Vision Based Approach to Measuring Remaining Useful Life of Sizer Barrels \(...\)](#) —



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Braden Thorne

PhD Student

Theme 2

2022-05-06

- [A Novel Approach to Time Series Complexity via Reservoir Computing - AJCAI 2022 \(...\)](#) —



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Braden Thorne

PhD Student

Theme 2

2022-12-07

- [Advances in Time Series Analysis With Reservoir Computing \(...\)](#) —



Braden Thorne

PhD Student

Theme 2

2023-08-22

- [An alternative approach to conventional methods of belt wear modelling and forecasting \(...\)](#) —



Ryan Leadbetter

PhD Student

Theme 2

2022-05-06

- [An Introduction to Time Series Analysis with Reservoir Computing \(...\)](#) —



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Braden Thorne

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Theme 2

2021-09-10

- [Applied Mathematics and Complex Systems Seminars \(..\)](#) —



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[Dr Debora Correa](#)

Chief Investigator

Theme 2

2020-08-13

- [Conveyor Belt Wear Forecasting through a Bayesian Hierarchical Modeling Framework using Functional Data Analysis and Gamma Processes by Ryan Leadbetter \(...\)](#) —



Ryan Leadbetter

PhD Student

Theme 2

2023-02-21

- Conveyor belt wear forecasting through a Bayesian Hierarchical Modeling framework using functional data analysis and gamma processes. (...) —



Ryan Leadbetter

PhD Student

Theme 2

2022-09-29

- [Critical Transitions in Complex Systems \(...\) —](#)



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Prof Michael Small

Theme Lead

Theme 2

2023-05-29

- [DARE presentation - Conveyor Belt Wear Forecasting through a Bayesian Hierarchical Modeling Framework using Functional Data Analysis and Gamma Processes by Ryan Leadbetter \(...\) —](#)



Ryan Leadbetter

PhD Student

Theme 2

2023-02-21

- [Decision Support for Prognostics of Complex Systems: A Practical Approach Using Bayesian Networks \(...\)](#) —



Ryan Leadbetter

PhD Student

Theme 2

2020-10-09

- [Degradation modelling in mining and mineral processing equipment: a comparison of two statistical approaches \(...\)](#)
—



[Gabriel Jesus Gonzalez](#)

PhD Student

Theme 2

2022-07-01

- [Detecting transitions in dynamical and industrial systems \(...\)](#) —



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Prof Michael Small

Theme Lead

Theme 2

2023-09-02

- Dynamical System
Approaches to Online Fault
Detection (...) —



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Braden Thorne

PhD Student

Theme 2

2023-07-21

- [ESREL 2020 PSAM 15 - The 30th European Safety and Reliability Conference \(...\)](#) —



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A/Prof Adriano
Polpo

Chief Investigator

Theme 2

2020-11-05

- [Estimating the remaining useful life of process piping using Bayesian methods \(...\)](#) —



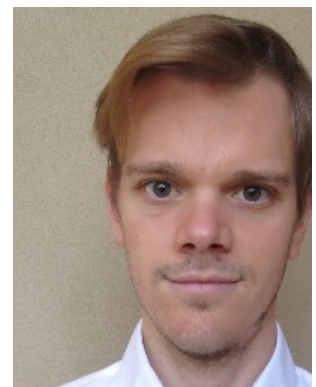
Gabriel Jesus
Gonzalez

PhD Student

Theme 2

2021-08-27

- Estimation and Testing with Extended Sequential Order Statistics (...) —



Tim Pesch

PhD Student

Theme 2

2023-08-18

- [Estimation with ESOS \(...\)](#) —



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Tim Pesch

PhD Student

Theme 2

2023-05-09

- [Estimation with Extended Single Order Statistics \(...\)](#) —



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Tim Pesch

PhD Student

Theme 2

2023-05-09

- [Forecasting Conveyor Belt Wear using Bayesian Hierarchical Modelling \(...\)](#) —



Ryan Leadbetter

PhD Student

Theme 2

2022-11-17

- [Get the most out of condition monitoring data: Improving conveyor belt wear forecasts to make better maintenance decisions \(...\)](#) —



[Ryan Leadbetter](#)

PhD Student

Theme 2

2023-06-27

- [Get the most out of condition monitoring data: Improving conveyor belt wear forecasts to make better maintenance decisions. \(...\)](#) —



Ryan Leadbetter

PhD Student

Theme 2

2023-06-16

- [ICIAM, 2019, \(...\) —](#)



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Prof Michael Small

Theme Lead

Theme 2

2019-07-15

- [ICMIAM Estimating the remaining useful life of process piping using Bayesian methods \(...\)](#) —



[Gabriel Jesus Gonzalez](#)

PhD Student

Theme 2

2021-12-14

- [ICMIAM Informative Bayesian Survival Methods to Handle Heavy Censoring in Lifetime Data \(...\)](#) —



Ryan Leadbetter

PhD Student

Theme 2

2021-12-14

- [Intelligent Maintenance Conference 2020 \(...\)](#) —



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Dr Debora Correa

Chief Investigator

Theme 2

2020-09-08

- [International Workshop on Complex Systems and Networks \(...\)](#) —



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[Prof Michael Small](#)

Theme Lead

Theme 2

2019-09-24

- [Learning the dynamics: from radial basis functions to reservoir computers. \(...\)](#) —



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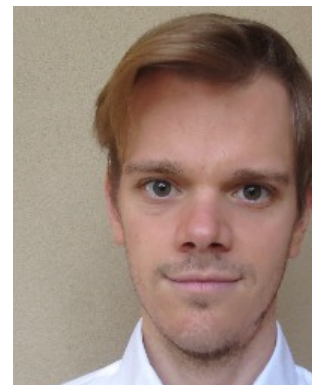
Prof Michael Small

Theme Lead

Theme 2

2021-11-04

- Lifetime Prediction for Systems with heterogeneous Components (...) —



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Tim Pesch

PhD Student

Theme 2

2022-08-12

- [Managing Streamed Sensor Data for Mobile Equipment Failure Prediction \(...\)](#) —



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[Dr Debora Correa](#)

Chief Investigator

Theme 2

2020-09-08

- [Master Class - Complex Time Series Modelling \(...\)](#) —



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Dr Debora Correa

Chief Investigator

Theme 2

2021-04-15

- Master Class - Deterministic Dynamics, Machine Learning & Tipping Points (...) —



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Prof Michael Small

Theme Lead

Theme 2

2021-03-04

- Master Class - Pattern Recognition and Change Point Detection (...) —



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Dr Ayham Zaitouny

Research Fellow

Theme 2

2021-03-04

- Nonlinear time series analysis of industrial data with uncertainty (...) —



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Dr Shuixiu Lu

Research Fellow

Theme 2

2023-08-18

- [Raising the Bar \(...\)](#) —



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Prof Michael Small

Theme Lead

Theme 2

2019-11-22

- [Reservoir Computing Approaches to Parameter Extraction with Applications \(...\)](#)
-



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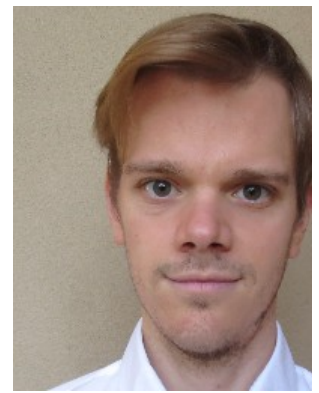
Braden Thorne

PhD Student

Theme 2

2021-06-11

- [Sequential Order Statistics for Non-identical Component Lifetimes \(...\)](#) —



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Tim Pesch

PhD Student

Theme 2

2021-10-26

- [SIAM 2019](#) (...) —



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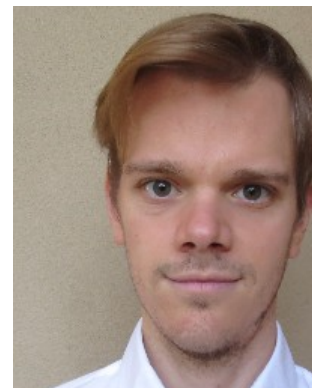
Prof Michael Small

Theme Lead

Theme 2

2019-05-20

- [SOS for non-id components \(...\)](#)



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Tim Pesch

PhD Student

Theme 2

2021-10-26

- [Sydney dynamics group workshop \(...\)](#) —



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Dr Ayham Zaitouny

Research Fellow

Theme 2

2019-11-05

- [The Benefits of Reservoir Computing Embedding for Recurrence Analysis \(...\)](#) —



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Braden Thorne

PhD Student

Theme 2

2023-08-28

- [The International Conference on Smart Computing & Communications \(ICSCC 2019\) \(...\)](#) —



Prof Andrew Rohl

Training Centre
Director

Directorate

2019-06-29

- What does the Data Say or
Why I don't like analogies? (...)



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Prof Michael Small

Theme Lead

Theme 2
2022-12-08

- WMC Presentation - Get the most out of condition monitoring data: Improving conveyor belt wear forecasts to make better maintenance decisions (...) —

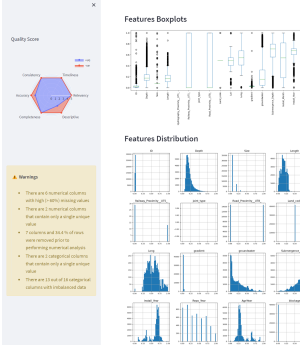


Ryan Leadbetter
PhD Student

Theme 2
2023-06-27

Tools

- IDEA Tool (...) —



2022-07-06

Evaluate the appropriateness of data for the purposes of maintenance predictive analytics

[Theme 2](#) [Theme 5](#)

The Team

Lead

- [Prof Michael Small](#) (...) —



[Prof Michael Small](#)

Theme Lead

[Theme 2](#)

Chief Investigators

- [Dr Debora Correa](#) (...) —



[Dr Debora Correa](#)

Chief Investigator

Theme 2

- [Dr Edward Cripps](#) (...) —



[Dr Edward Cripps](#)

Chief Investigator

Theme 2

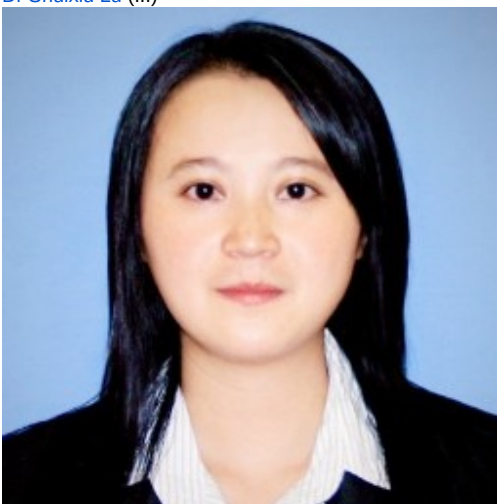
Partner Investigators

Content by label

There is no content with the specified labels

Research Fellows

- [Dr Shuixiu Lu](#) (...) —



[Dr Shuixiu Lu](#)

Research Fellow

Theme 2

PhD Students

- [Braden Thorne](#) (...) —



[Braden Thorne](#)

PhD Student

Theme 2

- [Gabriel Jesus Gonzalez](#) (...) —



[Gabriel Jesus Gonzalez](#)

PhD Student

Theme 2

- [Ryan Leadbetter](#) (...) —



[Ryan Leadbetter](#)

PhD Student

Theme 2

- [Tim Pesch \(...\)](#) —



[Tim Pesch](#)

PhD Student

Theme 2