Sniffing Wear Patterns: AE signals as a diagnostic tool for joint wear

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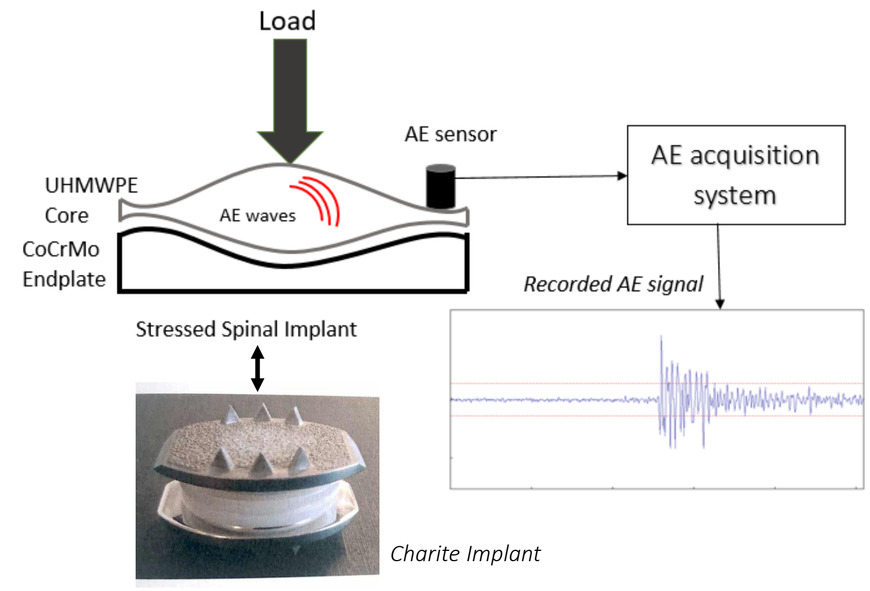
Background

- Acoustic Emission (AE) testing detects the onset and progression of mechanical flaws.
- AE has proven useful in detecting tribological characteristics of mechanical systems.
- It has recently emerged as a diagnostic tool for providing a tribological assessment of human joints and orthopaedic implants.
- AE has potential as a tool for diagnosing joint pathologies such as osteoarthritis and implant failure.
- Research Question: **How can AE signals be analysed to differentiate between wear mechanisms?**

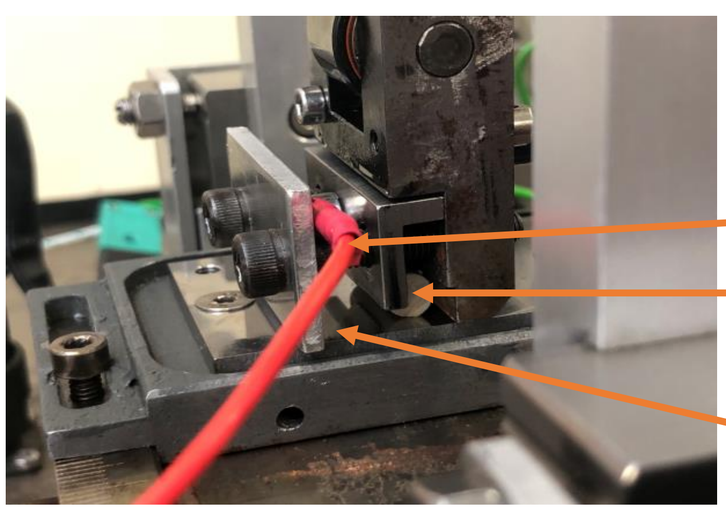


Charite Implant

Methodology

Acquisition of AE signals:

- Two simulated wear mechanisms: adhesive and abrasive wear.
- Acquisition of AE signals using bio-tribo-acoustic testing under controlled joint conditions.
- Materials: PEEK rod and Stainless Steel plate.
- Classification of AE signals using supervised learning.



Experiment Layout

Supervised Classification of AE signals:

- AE feature extraction using principal component analysis (PCA)
- Labelling & merging of AE hits from adhesive and abrasive wear tests.
- Ratio of training and test data: 85% to 15%
- Logistic regression model: $P(\boldsymbol{X}) = \frac{1}{1+e^{-(\alpha+\sum \beta_i X_i)}}$
- K-nearest neighbours classifier (KNN)
- Back Propagation(BP) neural network using the resilient backpropagation (Rprop) algorithm.

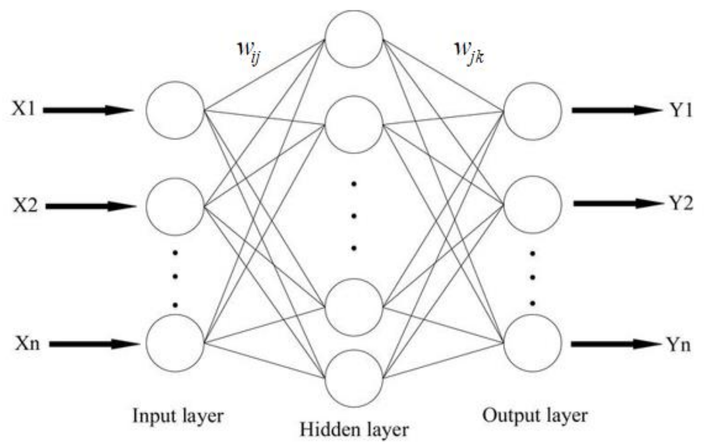
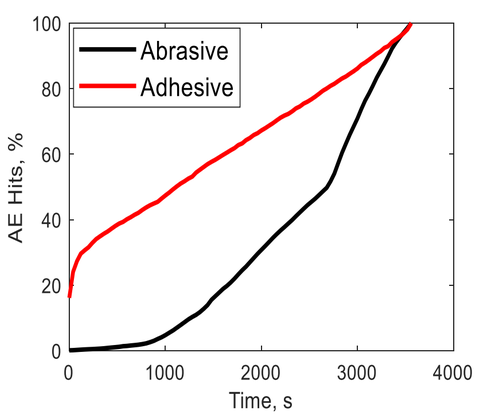


Illustration of a three-layer BP neural network

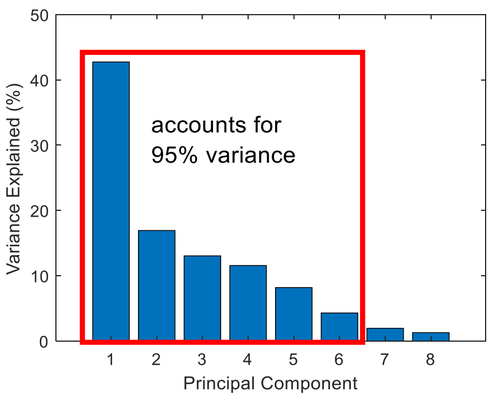
Results



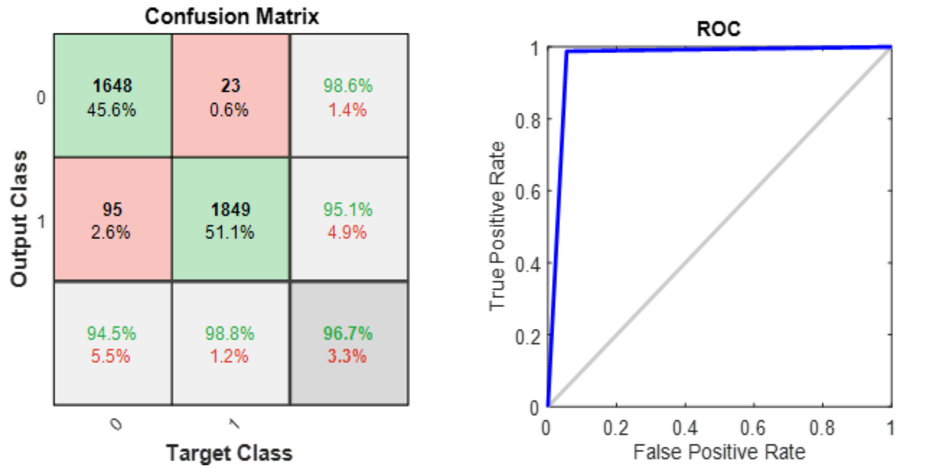
Cumulative AE hits plot

Classification accuracy summary

CLASSIFIER	TRAINING ACCURACY	TEST ACCURACY	AUC VALUE (Area under ROC curve)
Logistic Regression	72.3% (14789/20460)	72.7% (2628/3615)	0.72
Weighted k-Nearest Neighbour	96.6% (19756/20460)	96.3% (3480/3615)	0.96
Resilient BP Neural Network	96.15% (19673/20460)	96.71% (3496/3615)	0.97



Principal component analysis output



Confusion matric and receiver operating characteristic (ROC) curve for resilient BP neural network

Conclusion

- BP neural network has the best classification accuracy.
- Successful classification of AE signals based on different wear mechanism.
- Potential for classifying AE signals acquired during natural and artificial joint movements..
- Joint pathology diagnostic capability of AE testing is achievable.

Acknowledgement

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