Power Line Partial Discharge Detection

A.J. Cross, Xuesong Fan, and Aaron Wilson

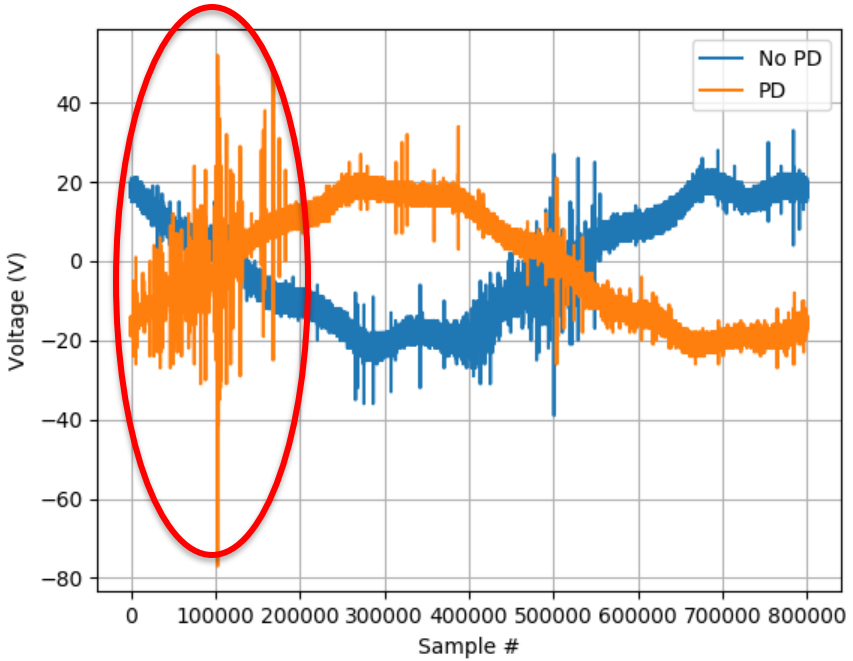
THE UNIVERSITY OF
TENNESSEE
KNOXVILLE

Overview

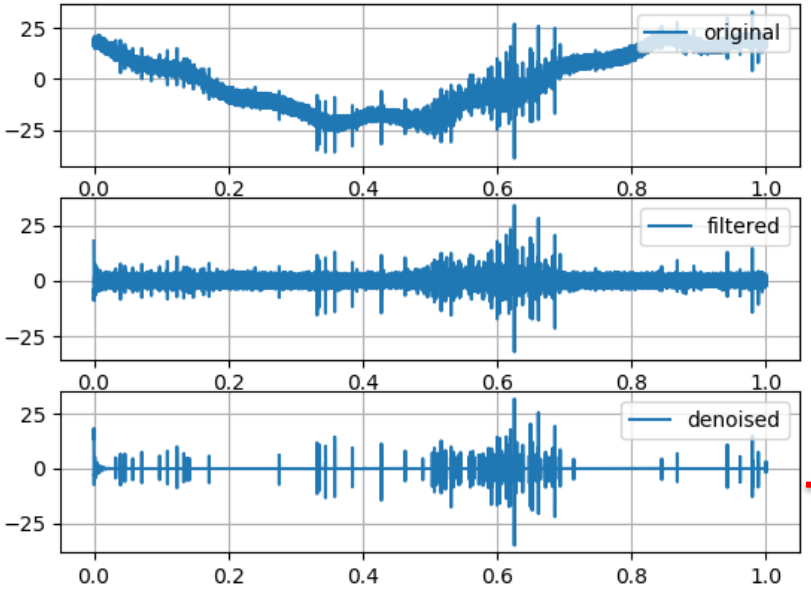
- Problem
- Preprocessing and feature extraction
- State of the art
- Classification techniques
- Results
- Conclusions and comments

Problem

- Overhead power lines run for hundreds of miles to supply power
- Manual inspection is expensive
- Challenge is to detect *partial discharge* patterns in signals acquired from these power lines



Preprocessing and feature extraction



12 Features Extracted
Signal mean
Signal standard deviation
Signal skewness
Signal kurtosis
Number of negative peaks
Number of positive peaks
Mean peak width
Mean peak height
Max peak width
Max peak height
Min peak width
Min peak height

Performance metric and state of the art

- Matthews Correlation Coefficient
- Varies from –1 to +1
- MCC = +1 indicates perfect predictions
- MCC = -1 indicates entirely wrong predictions
- MCC = 0 indicates entirely random predictions

$$MCC = \frac{(TP \times TN) - (FP \times FN)}{\sqrt{(TP + FP)(TP + FN)(TN + FP)(TN + FN)}}$$

Team Members	Score	Entries	Last
	0.71899	31	9mo
	0.71501	16	9mo
	0.70488	32	9mo
	0.70232	27	10mo
	0.69672	115	9mo

Validation technique

- Training set – 8,712 training examples
  - Each contains 800,000 samples
    - Hence need for preprocessing
- Provided testing set is unlabeled
  - m-Fold Cross Validation with m = 10 performed on the training set

Dimensionality reduction

- Normalized data
  - Denoted as nX
- PCA
  - 8 of 12 dimensions kept, with an error rate of 7.60%
  - Denoted as pX
- FLD
  - Denoted as fX

Classification Methods

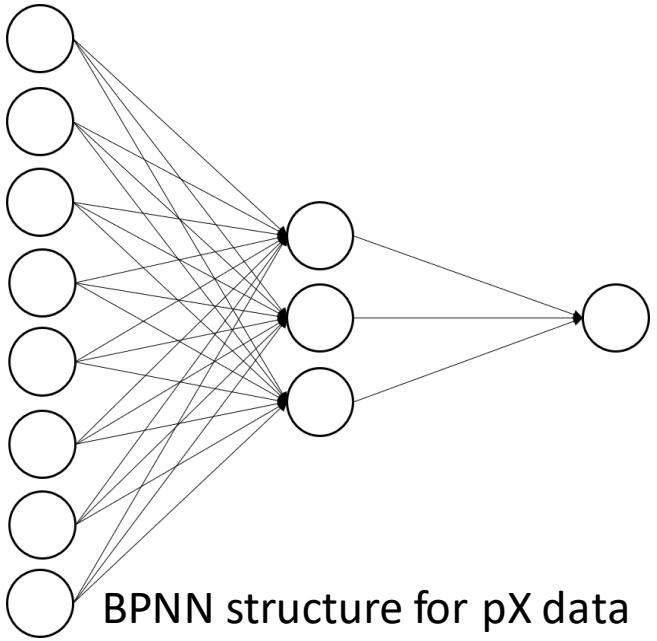
- MPP (case1, 2, and 3)
- kNN
  - k value looped over to find optimal value
  - Optimal value of k=10 used for MCC values
- Random Forest
  - Optimal value of 100 trees for MCC evaluations

Classification Methods

- SVM
  - Sigmoid, RBF, 1st, 2nd and 3rd order polynomial
  - Optimal SVM uses radial based function
- K-Means Clustering
  - Classify by assigning derived clusters to classes

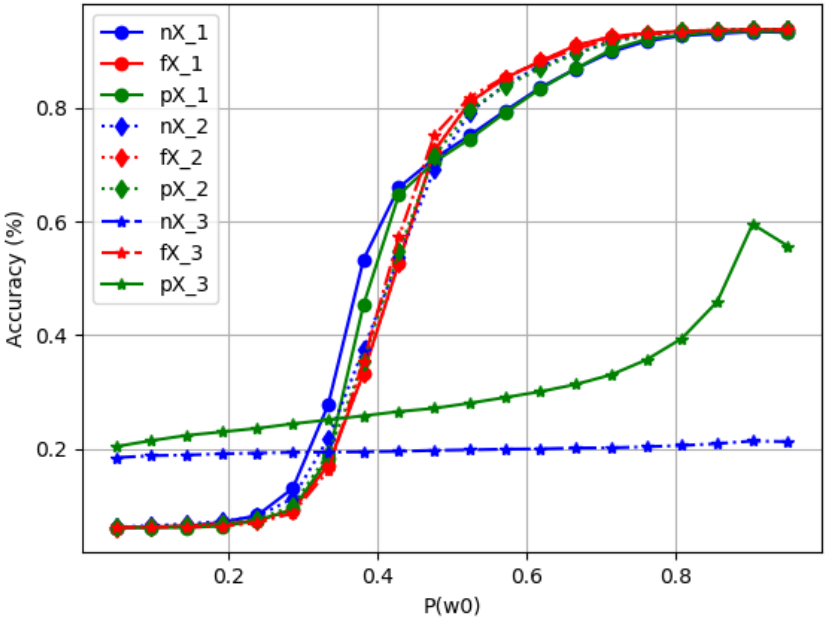
Classification Methods

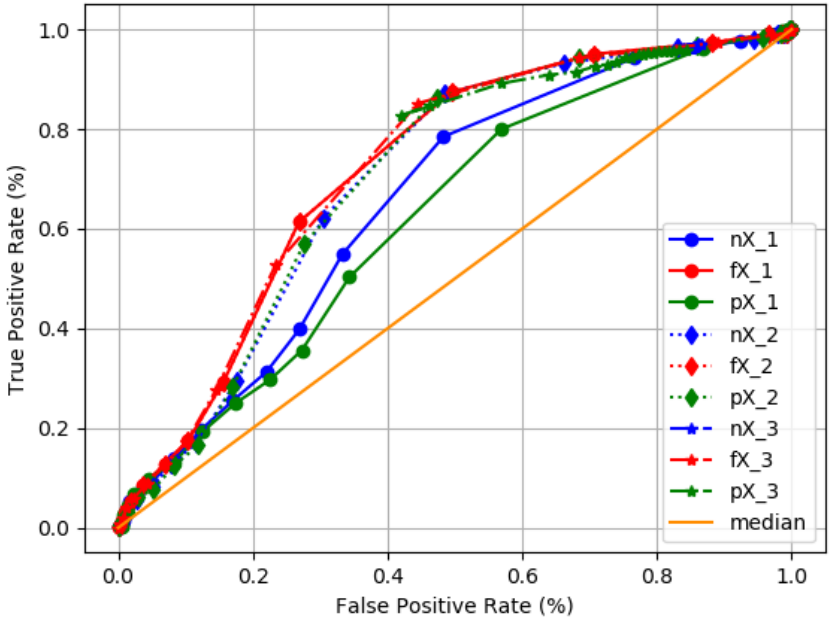
- Back-Propagation Neural network:
  - 12 input neurons for nX data, 1 for fX, 8 for pX
  - One hidden layer, 3 neurons
  - One output neuron
  - Sigmoid activation functions
  - Learning rate = 3.0
  - Implemented using Keras from Tensorflow



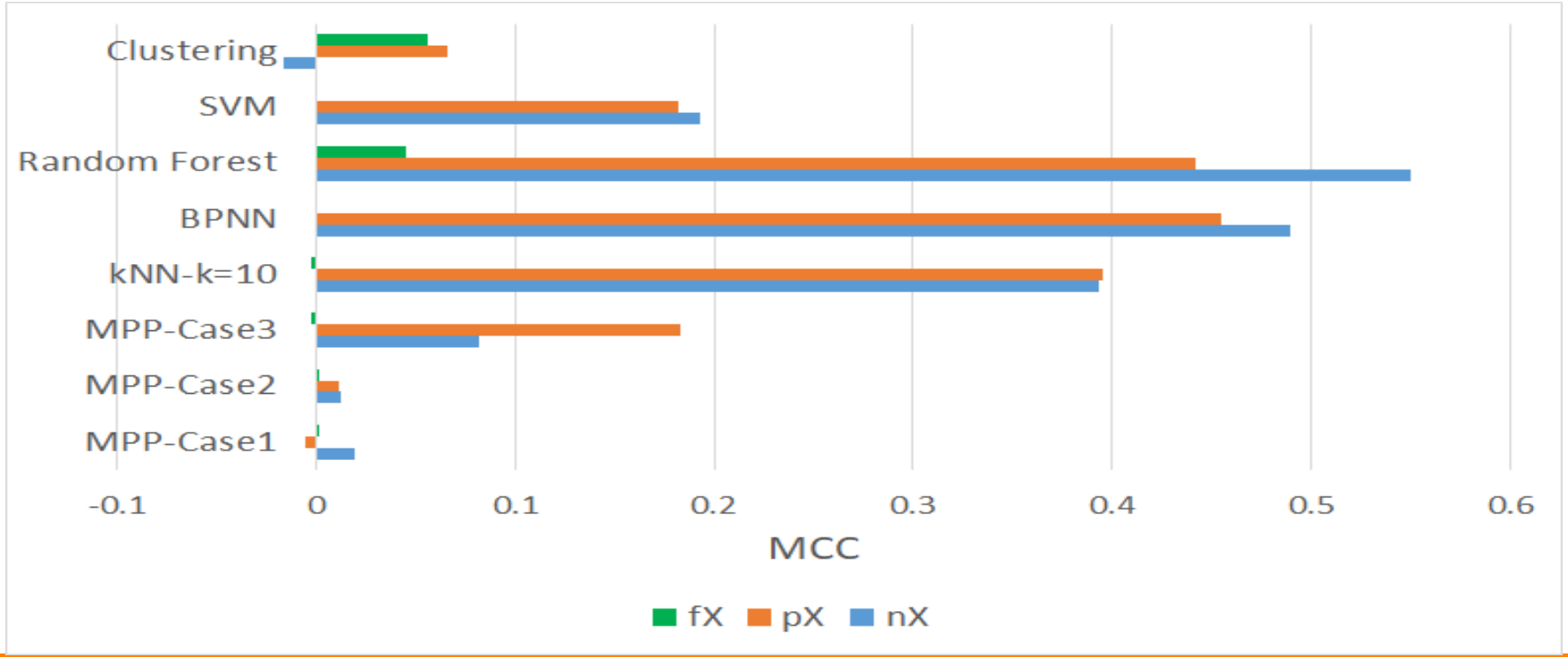
BPNN structure for pX data

Accuracy vs. Performance (MPP)

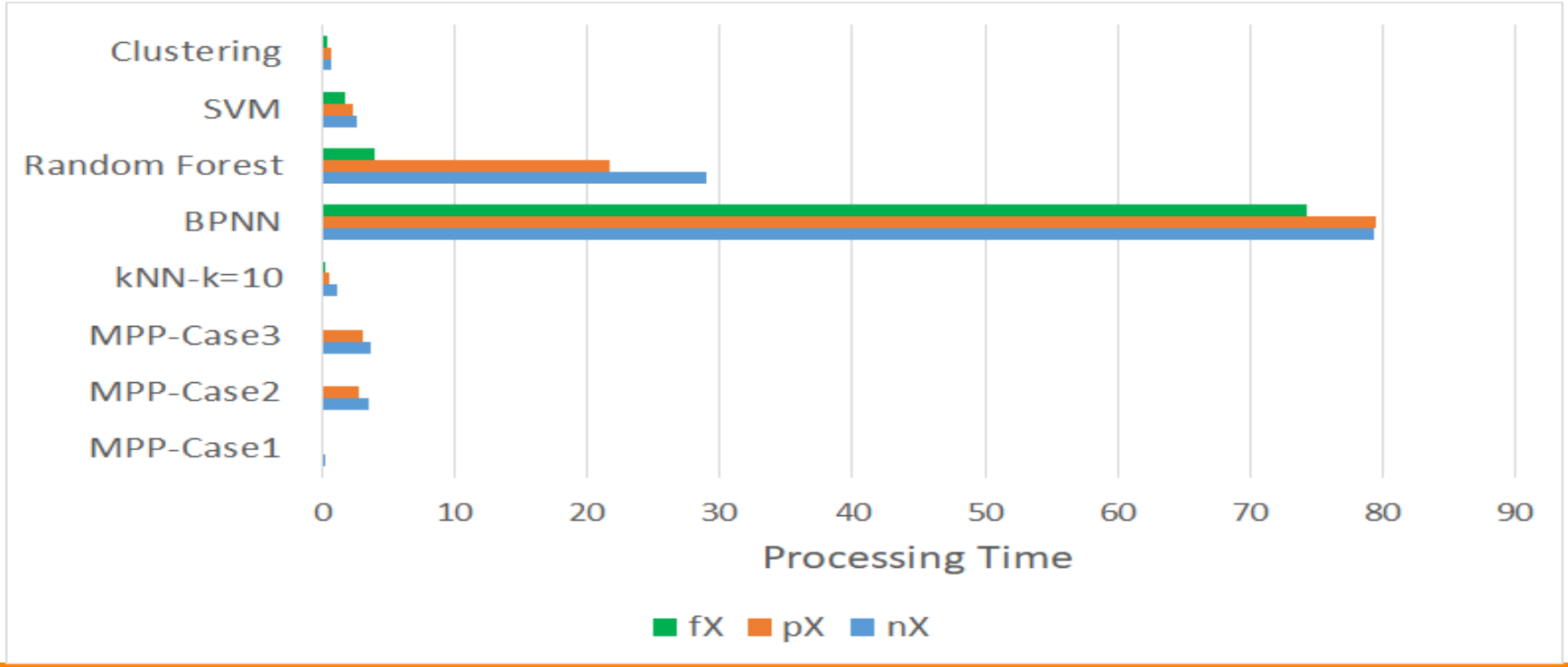




Aggregate results



Processing Time



Classifier Fusion – BPNN & RF

- From the previous plots, the two best-performing classifiers were the BPNN (MCC = 0.49) and the RF (MCC = 0.55)
- Using the Naïve Bayes fusion technique, a new MCC value of 0.47 was achieved.
  - Worse performance!

Conclusion

- Results give an MCC value of ~0.55 compared to a Kaggle score of ~0.72
- A more in-depth analysis is required to have a high accuracy while maintaining sensitivity
  - Requires complicated features extraction techniques

Task Allocation

Aaron:

- Pre-processing, feature extraction, BPNN, classifier fusion

Xuesong:

- Normalization and dimensionality reduction, MPP, Random Forest

AJ:

- kNN, SVM, K-Means clustering

All:

- Presentation slides, report

Summary

- Preprocessed signals to get multiple features via DWT
- Applied algorithms to sort into classes via derived features to obtain accuracy/sensitivity
- Random forest – best MCC value of 0.55
- More complex feature extraction methods may be required

Support Vector Machine (SVM)

- Linear, 2nd and 3rd order polynomials
- Sigmoid function: tanh($\gamma\langle x,x'\rangle+r$)
- Radial Based Function (RBF): exp(-$\gamma||x-x'||^2$) was found to have the best classification (using MCC)

K-Means Clustering

- Number of cluster centers is the same and the number of classes
- Predicted classifier labels for data points are assigned based on the predicted cluster it belongs to