TIP 319: Multidimensional Learning on PMU Data for Event Detection, Characterization, and Prediction

Context

In the emerging era of big data, machine learning techniques have become the de facto standard for processing and analyzing large amount of data, with little or no human involvement.

As BPA expands the number of deployed synchrophasors, it will be increasingly difficult to leverage the latent knowledge in this vast data stream without computational assistance. Data analysis and machine learning has proven to be the dominant technology in other data-intensive fields and we expect the power sector will follow a similar trend.

The project is an initial effort in this direction, aiming for converting synchrophasor data into valuable information effectively and at scale. This effort will enhance situation awareness and assist grid operators in making informed decisions.

Description

This project takes techniques that have been successful in laboratory, proof-of-concept, and experiments typically performed with simulated data, and evaluates their performance in a large-scale, real-world setting.

We examined historical records of BPA's synchrophasor (PMU) data and developed technologies in: **event detection** to identify anomalies from the normal operation data; **event characterization** based on classification and clustering methodologies; **outcome prediction** using machine learning techniques to predict likely outcomes following an event; and **data cleansing** to detect erroneous data from the synchrophasor data stream and flag specific PMUs producing the error for replacement, calibration, or maintenance.

Unlike other projects that target a single specific learning technology, our aim was to develop a useful software platform and in so doing to characterize the strengths and weaknesses of a variety of potentially useful approaches that have been successful in small scale or proof-of-concept settings. Simultaneously, we will benchmark our approaches against hand crafted rule-based methods developed by domain experts.

Benefits

As the first utility agency to a comprehensively implement synchrophasors in their wide-area monitoring system, BPA is now in position to develop and deploy corresponding analysis techniques for the synchrophasor data. A successful deployment of synchrophasors along with effective data analysis also helps BPA establish a leading role in the emerging fields of smart grid technologies.

Accomplishments

In this 2-year project, we have developed and evaluated event detection, classification, and outcome prediction methods for BPA's PMU data stream using machine learning techniques. Unlike other projects which target a single specific learning technology, our aim was to develop a useful software platform and in so doing, characterize the strengths and weaknesses of a variety of potentially useful approaches that have been successful in small scale or proof-of-concept settings. The results from this project show that machine learning techniques are effective in performing various tasks on PMU data streams. Multiple event detection methods we developed significantly outperform the expert's rule-based model. The comprehensive evaluation we carried out on various techniques may also shed light on BPA's future adoption of relevant machine learning techniques

Deliverables

The deliverables from the project includes set of software tools for mining the PMU data stream as well as the models obtained from learning on our data set.

The project team delivered a written project report along with existing software algorithms and experimental infrastructure. These digital artifacts comprise a complete specification of our technology (source code, learned models, and experimental documentation). This specification could then be used by BPA as a prototype to guide the development of a full system for mission qualification and other uses.

The research results of this project have been published in four research papers referenced below.

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Project Start Date: October 1, 2014

Project End Date: September 30, 2016

Funding

Total Project Cost: $464,000

Reports & References

Research Paper on Event Detection:

Smart Grid Line Event Classification Using Supervised Learning Over PMU Data Streams; Duc Nguyen Richard Barella Scott Wallace Xinghui Zhao Xiaodong Liang; Proceedings of the 6th International Green and Sustainable Computing Conference (IGSC 2015)

Research Paper on Event Characterization using Supervised Learning:
Finding Needles in a Haystack: Line Event Detection on Smart Grid PMU Data Streams; Duc Nguyen Scott Wallace Xinghui Zhao
Proceedings of the 6th International Conference on Smart Grids, Green Communications and IT Energy-Aware Technologies (Energy 2016) ***Best Paper Award***

Research Paper on Event Characterization using Unsupervised Learning:
Unsupervised Clustering on PMU Data for Event Characterization on Smart Grid; Eric Klinginsmith Richard Barella Xinghui Zhao Scott Wallace;
Proceedings of the 5th International Conference on Smart Cities and Green ICT Systems (SmartGreens 2016)

Research Paper on One-Class Learning and Data Cleansing
Big Data Analytics on Smart Grid: Mining PMU Data for Event and Anomaly Detection; Scott Wallace, Xinghui Zhao, Duc Nguyen, Kuei-Ti Lu;
R. Buyya, R. Calheiros, and A. Dastjerdi, eds, Big Data: Principles and Paradigms

For More Information Contact:

TI Project Management Officer:
TechnologyInnovation@bpa.gov

Participating Organizations

Washington State University, Vancouver WA