Deployment of advanced machine learning models to protection relays

International Conference and Exhibition
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Deployment of advanced machine learning models to protection relays

- Current developments in machine learning, history and future
- Why modern machine learning works much better
- Excellence areas and limitations
- Ensuring reliability of results
- Deployment scenarios
- Technical feasibility and limitations of deployment to protection relays
- Best practice workflow
- Performance comparison for different approaches for the example application of Single Ended Fault Locator
Current developments in machine learning, history and future

- Microprocessors
- AI Winter
- Internet
- Data Analytics (Random Forest, Support Vector Machine)
- Backpropagation
- Shallow Fully Connected Neural Networks
- Deep Learning (CNN, RNN, ...)
- Big Data
- Cloud
- Cross-industry productization & deployment

Time

1985  1995  2017
When and why deep learning works much better

• Loss function & Backpropagation

• **Compositional** data structure with several layers of representations.

• Neural networks often rely on pre-engineered representation (features) and random initialization

• Deep Neural Network facilitate automatic representation learning and reproducible results

• **Probabilistic logic** – useful for complex fuzzy problems where 100% accuracy is not state of the art

• Inefficient learning causes strong data dependency
Data dependency
Areas of excellence

Accuracy

Available real world data

Deep learning – large models

Deep learning – small models

Traditional Methods

Neural Networks

Training data
Supervised learning with neural networks exemplified by Single Ended Fault Location on Power Line

- Supervised learning: pairs of object – label required.
- Object can be a fault record with corresponding line parameters and other metainformation

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Supervised learning: pairs of object – label required.
Object can be a fault record with corresponding line parameters and other metainformation
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• Label can be a distinct class or a set of distinct classes of the object
e.g. Loop information: BG \(\rightarrow\) ABG
Then the model is trained for classification task.

• Label can also be a continuous value
e.g. Fault Distance on the power line
Then the model is trained for the regression task.
Data understanding
Sources of sufficient training data

Data requirements

- Pairs of Object – Label
- Clean, undistorted information
- Metainformation
- Data distribution
- Data amount

Quality data in sufficient numbers can be provided by simulations.

All possible scenarios must be simulated in sufficient amount

Accommodate for possible simulation bias by using different simulation sources.
Ensuring reliability

Model architecture and data cross-validation

Final train and test on previously unused data
Development & Deployment process

Cross Industry Standard Process for Data Mining

- Widely applied recipe for data mining
- Also useful for machine learning due to data centrism
- Cyclic approach with fast iterations
  - Data: Additional Data for previously uncovered effects, Data cleaning
  - Model: Model architecture (CNN, RNN, MLP, …) and fine tuning (activation functions, regularization, learning rate, …)
  - Deployment: Computational speed, Memory consumption, Stability, Safety
Deployment scenarios
Centralized vs Edge (embedded) machine learning deployment

Comparison:
- Communication overhead
- Data integrity
- 3rd party
- Delayed communication

Infrastructure

Results

Data

- Computational performance
- Data security
- Memory utilization
- Reaction speed

Data

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Evaluation - Test systems

- Analytics environment model
- Module test binary model
- Optimized target binary model
Accuracy and Performance Comparison

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Thank you

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