Equipment Anomaly Detection Using an Auto-Encoder Neural Network
“IT’S TOUGH TO MAKE PREDICTIONS – ESPECIALLY ABOUT THE FUTURE.”
(Yogi Berra or Niels Bohr, depending whether you prefer physics or baseball)

A Machine Learning algorithm walks into a bar
The bartender asks, "What'll you have?"
The algorithm says, "What's everyone else having?"
Agenda

- CW Nuclear Overview
- What is Anomaly Detection?
- What is CW Background?
- APS Innovation Solution
  - Current Design
  - Challenges
- Licensing/Commercialization
  - Challenges
  - Features
- The Future
Curtiss-Wright

- Founded by Wright Brothers and Glenn Curtiss

Innovators of controlled, powered man flight
Divisions / Brands

- Commercial/Industrial
- Defense
- Power

- Industrial Group
- Valve Group
- EST Group
- EMS Division
- EMD
- Nuclear Division
- AP Services
- Nova
- Scientech
- Enertech
- QualTech NP
- Target Rock
- Phönix
- Farris
- Solent & Pratt

Operations primarily aligned with Nuclear Industry Standards
Innovation as a Service

INNOVATION COOPERATIVE

LEAN CONSULTING ENGAGEMENT

Customer discovery, outcomes
Identification of improvement opportunities
Collaborate focused on problem solving & solutions

STRUCTURED PROCESS

Observations & Insights → Design Thinking
Concept Design → Prototype → Execute

learn → technology → perform
dashed lines indicate feedback loops

EFFECTIVE SOLUTIONS
The Challenge

❖ Aging equipment
  • Average age of nuclear plant in the US is 37 years old
  • Nine Mile Point started producing power 12/14/69
❖ Reduced workforce
❖ Need for increased efficiency

A study by Boeing found that 85% of all equipment failed at random no matter how much preventive maintenance measures were applied to equipment.*

ARC Advisory Group reports 82% of failures cannot be avoided with traditional equipment monitoring.*

*https://www.processingmagazine.com/maintenance-safety/article/15587836/why-times-up-on-preventive-maintenance
Equipment Anomaly Detection

“The identification of rare items, events or observations which raise suspicions by differing significantly from the majority of the data.”

-- Wikipedia

Equipment anomaly detection uses existing data signals available through plant data historians, or other monitoring systems for early detection of abnormal operating conditions.

Equipment failures represent the potential for plant shutdowns and a significant cost for field maintenance.
Anomaly Detection vs Traditional Alarming
By detecting equipment anomalies nuclear plants can:

❖ Anticipate potential failures
❖ Perform significantly less expensive preventative maintenance
❖ Reduce the risk of catastrophic failure
❖ Protect plant personnel and equipment
Pattern Recognition Methods

The field of pattern recognition is concerned with the automatic discovery of regularities in data through the use of computer algorithms

❖ **Static Pattern Recognition**
  • System State Analysis

❖ **Sequential Pattern Recognition**
  • Recurrent Neural Networks
    • Long-Short-Term Memory (LSTM)
### Our History

**Pattern-Recognition Software For Plant Surveillance**

**United States Patent**

<table>
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<th>Patent</th>
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**Patent Number:** 4,937,763

**Inventor:** Jack E. Mott, Idaho Falls, Id.

**Assignee:** E I International, Inc., Idaho Falls, Id.

**Filed:** Sep. 6, 1988

**Int. Cl.** G08B 17/00

**U.S. Cl.** 364/550, 364/551.01, 364/148

**Field of Search** 364/550, 551.01, 552, 364/150, 571.02, 571.05, 364/492, 496, 148

**References Cited**

**ABSTRACT**

A process for monitoring a system by comparing learned observations acquired when the system is running in an acceptable state with current observations acquired at periodic intervals thereafter to determine if the process is currently running in an acceptable state. The process enables an operator to determine whether or not a system parameter measurement indicated as outside preset prediction limits is in fact an invalid signal resulting from faulty instrumentation. The process also enables an operator to identify signals which are...
Real-Time Data + Advanced Analytics = PdP

**REAL-TIME DATA**
- Pressures
- Temperatures
- Flows
- Vibrations
- Positions
- Speed
- Load
- Performance results
- Efficiency
- Calculated values

**APR Models**
Normal / Abnormal Anomaly Detection

**Early Warning**
The Technical Challenge

❖ Requires marriage of equipment/process SMEs and technical SMEs (data scientist)

❖ Requires a high technical competency to implement and maintain

❖ Requires processing power beyond computing horsepower
The Data Challenge

❖ Lack of volume
❖ Lack of good data for training
❖ Seasonality
❖ Start-ups and shut-downs
❖ Changing environmental conditions
APS Equipment Anomaly Detection

❖ Uses open-source packages
❖ Built as a platform rather than a solution
❖ Team has full access to plant data
❖ Unsupervised Learning

System Framework

Flexible, General, Scalable, Expandable
- Each step is performed independent module
- Groups of sensors are associated with set of steps (pipelines), run independently and in parallel

Light Water Reactor Sustainability Program

Seamless Digital Environment – Data Analytics Use Case Study
The APS EAD Architecture

- 40,000 sensors
- 30 models
- 2-hour training
- 15-minute updates

- 3 servers
- 8 cores
- 32GB RAM/server
- No GPU
Graphical display of anomaly data, plus real-time connection to plant systems for control room logs, condition reports and work orders
The APS EAD Toolkit

Open Source
❖ R Programming
❖ Keras LSTM Autoencoder
❖ TSOutliers outlier detection

Commercial Products
❖ Oracle Database
❖ Domino Labs Containers
❖ NextAxiom Hyperservices
❖ PI Data Historian
The Autoencoder Analysis

Autoencoder Analysis
The System State Analysis

PdP System State Analysis
The Comparison
Limitations in Existing Product

❖ “Kitchen Sink” Approach
❖ Lack of Investigative Tools
❖ No User Modeling
❖ No Sensor Controls
The APS EAD Platform Architecture
Commercialization Tasks

❖ Remove Client-Specific Tools
❖ Remove Client-Specific Interfaces
❖ Provide Insights into Model
❖ Develop Documentation
❖ Develop Implementation Strategy
❖ Develop Support Model
Current Commercialization State

- Database installed and validated
- Code base installed and compiled
- Code review on-going
- GUI framework installed (angular.js)
- User interface review complete
- Design documents on-going
- Requirements documents started
Commercialization Enhancements

- Model Maintenance
- Time Periods Management
- Sensor Management
- Alarm Thresholds
- Calculated Fields
- Rules Engine
- GPU Support
Future Applications

❖ Start-Up/Shut-Down Models
❖ Hydro Plants
❖ Steam Plants
❖ Ultrasonic Data Analysis
❖ On-Board Diagnostics
❖ Wind Turbines
❖ Gas Turbines
❖ Switchyards
Conditioned Based Monitoring

**CONDITION BASED MONITORING (CBM)**

- On Board Diagnostic Unit
- Real time data collection to monitor critical parameters.
- Monitor, pressure, temperature, position, power, vibration
- Display live data, warnings, step-by-step instructions
- Assessment of equipment condition and service life

- Visualize data on the integral touchscreen, external HMDI monitor or mobile device
- Ethernet, Wi-Fi, USB port connections

**Electro Hydraulic Actuator with CBM under test > 50,000 cycles**
ASHBURN, Va. – December 3, 2019 – Curtiss-Wright’s Defense Solutions division, today announced that, through its Reseller Agreement with WOLF Advanced Technology, it has expanded its family of open architecture high performance embedded computing (HPEC) processors designed for demanding ISR applications with the addition of three new NVIDIA Quadro Turing (TU104/6) GPU/inference engine-based OpenVPX™ modules. Curtiss-Wright also announced the availability of a new AMD Radeon™ (E9171) based XMC graphics engine card.

Designed to support compute-intensive ISR and EW systems, the fully rugged VPX3-4925, VPX3-4935, and VPX6-4955 modules feature Tensor Cores (288, 384, and 768 respectively) that are ideal for accelerating tensor/matrix computation used for deep learning neural network training and inference used in deployed and artificial intelligence (AI) applications requiring TFLOPS of accelerated processing. These applications include high-performance radar, SIGINT, EO/IR, data fusion ingest, processing and display, and autonomous vehicles.

Questions?