PREDICT PROCESS AND EQUIPMENT PROBLEMS WITH UNIFORMANCE ASSET SENTINEL

Bart Winters
June 2017

Honeywell
THE POWER OF CONNECTED
Digital Transformation Example… Where is my bike rack?

Where its been?

When will it get there?

Travel History

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Activity</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/14/2017</td>
<td>In transit</td>
<td>SANTA ROSA, NM</td>
</tr>
<tr>
<td>8:02 am</td>
<td>In transit</td>
<td>SANTA ROSA, NM</td>
</tr>
<tr>
<td>6/13/2017</td>
<td>In transit</td>
<td>TULSA, OK</td>
</tr>
<tr>
<td>8:53 pm</td>
<td>Departe FedEx location</td>
<td>CHICAGO, IL</td>
</tr>
<tr>
<td>8:36 am</td>
<td>Left FedEx origin facility</td>
<td>DUBUQUE, IA</td>
</tr>
<tr>
<td>11:13 pm</td>
<td>Arrived at FedEx location</td>
<td>CHICAGO, IL</td>
</tr>
<tr>
<td>6:21 pm</td>
<td>Left FedEx origin facility</td>
<td>DUBUQUE, IA</td>
</tr>
<tr>
<td>5:15 pm</td>
<td>Arrived at FedEx location</td>
<td>DUBUQUE, IA</td>
</tr>
<tr>
<td>3:06 pm</td>
<td>Picked up</td>
<td>DUBUQUE, IA</td>
</tr>
<tr>
<td>10:00 am</td>
<td>Shipment information sent to FedEx</td>
<td>DUBUQUE, IA</td>
</tr>
</tbody>
</table>

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What is ‘Prediction’?

To Tell in Advance of Foretell
Why Prediction?

• To drive proactive response:
  - … to prepare for, intervene in, or control an **expected occurrence** or situation, especially a negative or difficult one; anticipatory
Elements of Predictive / Proactive Solutions

• Continuous monitoring “Digitization” / Digital Twin

• Run-time analytics
  - Data pre-processing / cleansing
  - Basic calculations
  - First Principles Models
  - Data driven / parameter estimation

• Fault Detection
  - Simple limit violations
  - Complex logic

• Fault Management (workflow)
  - Detect
  - Decide
  - Act
How these decisions are made today

Manually Search & Collect

Isolated Tools & Systems

Manual Periodic Calculations

Reactive & Informal Work Process

Time Consuming

Find / Import Data

Find / Import Data

Analyze Data
(Excel & Other Tools)

Reports

• Missed Opportunities
• Difficult to Sustain

• Varied Approaches & Results
• Difficult to Share Information

T1

T2

T3

Blind Spots

86.19

88

91.4

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Uniformance® Suite Creating the Digital Twin

**Connect**
Connect and store relevant real-time process and event data both on-site & in the cloud

**Analyze**
Calculate, analyze, and detect risks and opportunities with asset-centric advanced analytics

**Visualize**
Interactive visualization of trends, charts, and graphics across variety of data sources for process & manufacturing intelligence

**Act**
Notifications and workflow for accelerated decision-making to maximize business performance
Uniformance Suite – Along with PHD… the following

**Asset Sentinel**

- **Calculations** (Actual & Predicted)
  - Pre-Processing / Cleansing
  - User Defined Calculations
  - UniSim® - Estimate/ Predicted
  - Data Driven

- **Even Detection** (Compare Actual to Predicted)
  - Fault Models

- **Event Management**
  - Event Management
  - Notifications

- **Investigations**
  - Fault Prioritization (Fault Severity * Asset Criticality)

- **Performance Curves**

**Executive**

- Business Dashboards
- Insight
- Process Graphics & Trends
Example Equipment Models

Pump
Required instrumentation:
- Pump Flow
- Pump Suction & Discharge Pressure
- Driver Power

Available Outputs:
- Power, Load
- Actual Head, Efficiency
- Expected Head, Efficiency
- Head & Efficiency Deviation

Faults
- Compressor Load High / Low Limit
- Performance Warnings High & Critical
- Surge Warning
- Bearing Vibration & Temp Faults

Heat Exchanger
Required instrumentation:
- Inlet and Outlet Temp for shell and tube streams
- Inlet and Outlet Pressures for shell and tube streams
- Shell & Tube Stream Flow

Available Outputs:
- Heat Exchanger Duty
- Actual Heat Transfer Coefficient
- Expected Heat Transfer Coefficient
- Fouling Factor
- Heat Transfer Efficiency

Faults
- Heat Transfer Efficiency Warning / Critical
- Coolant Temperature High
- Fouling Warning / High
- Tube Pressure Difference Warning / High
- Shell Pressure Difference Warning / High
Process Model - CDU

**Process Operations:**
- Column head temperature & pressure
- Feed temperature
- Condenser duty
- Bottom stripping steam
- Reflux ratio
- Sidestream tray temperature
- Pumparounds duty
- Tower flooding proactive detection with impact on fractionation yields and fractionation capacity
- Monitoring of unit yields and fractionation by correlating operating condition such as total pump around heat recovery, condenser capacity, reflux ratio, steam/hydrocarbon ratio.

**Quality:**
- LPG C5+ content
- Naptha RVP
- Naptha PT95%
- Jet / Kero Flash point
- Jet Freezing point
- Gasoil PT95%

**Corrosion / Reliability**
- monitoring thickness and acid crude properties
Event Management – Orientation
Event Management - Detect

Column Alert

Alert Details

Fault Tree

Alert Logic

Alert triggers

Fault Details for: Column T100 / Column is not Steady

Description:
Category: Performance
Priority: 4

Associated Events:
Active State
- ColumnUnStable
- 6/14/2017 3:56 PM

Associated Data:
- Column_Imbalance
- Flow_Imbalance
- 6/14/2017 3:55 PM

Expression:
Column_Imbalance = abs(Flow_Imbalance) > 41
Feed_Temp = Feed_Temp

VARIABLE DISPLAY NAME TIMESTAMP VALUE UNITS
Column_Imbalance 6/14/2017 3:56 PM 1
Flow_Imbalance Flow_Imbalance 6/14/2017 3:55 PM 41.411 %
Event Detection - Decide

Fault

Column is Unstable

6/14/2017 4:00 PM

Column is Unstable due to Feed Change

High ROC in Btm Temperature

Symptoms
Event Management - Decide

Help Tab

Recommendations

Links to supporting documentation

- **ASSETS**
  - Equipment Monitoring
    - Refinery
    - Alky Unit
    - Crude Distillation
    - Debutanizer
    - Column T100
      - T100 Reflux Pump
        - K101
        - K102
    - Logical
    - LOPA
    - Process Sensors
    - Process Streams
    - Utilities

---

**Event Monitor | Column T100**

- **ASSET NAME**: Column T100
- **START TIME**: 6/14/2017 3:56 PM
- **NAME**: Column is not Steady
- **STATUS**: Active
- **CONDITION**: New
- **PRIORITY**: 4
- **TYPE**: Symptom

**Fault Details for: Column T100**
- Column UP is high

**Recommendation:**
- **Cause:** Low reflux rate, high reboiler duty, loss of cooling duty of any of the overhead exchangers, too much light component in feed
- **Consequence:** Inefficient operation; Overpressure of the column leading to potential flaring
- **Corrective Action:** Reduce bottoms temperature, increase reflux rate, trend reflux temperature and check overhead exchangers for fouling/loss of cooling if temperature increased.

**Associated Links**

<table>
<thead>
<tr>
<th>NAME</th>
<th>CATEGORY</th>
<th>LINK</th>
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</thead>
<tbody>
<tr>
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<td>Reliability</td>
<td><img src="https://www.example.com" alt="Furnace Graphic Link" /></td>
</tr>
<tr>
<td>ProcessTrends</td>
<td>Process</td>
<td><img src="https://www.example.com" alt="Process Trends Link" /></td>
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</tbody>
</table>
## Performance Monitoring – Column Attribute Overview

<table>
<thead>
<tr>
<th>Asset</th>
<th>Attribute</th>
<th>Description</th>
<th>Current</th>
<th>Timestamp</th>
<th>Low Limit</th>
<th>High Limit</th>
<th>Historical</th>
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<tbody>
<tr>
<td>Column T100</td>
<td>Btm_Pressure</td>
<td>Btm_Pressure</td>
<td>13.530</td>
<td>6/14/2017 4:00:49 PM</td>
<td>882.77</td>
<td>1513.3</td>
<td></td>
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<tr>
<td>Column T100</td>
<td>Btm_Product_Flow</td>
<td>Btm_Product_Flow</td>
<td>161.80</td>
<td>6/14/2017 4:00:49 PM</td>
<td>17.500</td>
<td>30.000</td>
<td></td>
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<tr>
<td>Column T100</td>
<td>Btm_Product_Recover</td>
<td>Btm_Product_Recover</td>
<td></td>
<td>1/1/0001 12:00:00 AM</td>
<td>64.350</td>
<td>118.80</td>
<td></td>
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<tr>
<td>Column T100</td>
<td>Btm_Product_Temp</td>
<td>Btm_Product_Temp</td>
<td>285.01</td>
<td>6/14/2017 4:00:49 PM</td>
<td>129.35</td>
<td>238.80</td>
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<tr>
<td>Column T100</td>
<td>Btm_Temperature</td>
<td>Btm_Temperature</td>
<td>220.12</td>
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<td>139.30</td>
<td>238.80</td>
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<tr>
<td>Column T100</td>
<td>DeltaP</td>
<td>DeltaP</td>
<td>-0.87129</td>
<td>6/14/2017 4:00:51 PM</td>
<td>13.650</td>
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<td>Column T100</td>
<td>DeltaP_Btm</td>
<td>DeltaP_Btm</td>
<td>-0.920656</td>
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<td>641.55</td>
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<td>Column T100</td>
<td>DeltaP_Top</td>
<td>DeltaP_Top</td>
<td>0.05124</td>
<td>6/14/2017 4:00:51 PM</td>
<td>595.73</td>
<td>1099.8</td>
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<td>Feed_Flow</td>
<td>Feed_Flow</td>
<td>432.83</td>
<td>6/14/2017 4:00:49 PM</td>
<td>304.15</td>
<td>521.40</td>
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<tr>
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<td>Feed_Temp</td>
<td>30.000</td>
<td>6/14/2017 4:00:51 PM</td>
<td>150.00</td>
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<tr>
<td>Column T100</td>
<td>Flow_Imbalance</td>
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<td>6/14/2017 4:00:51 PM</td>
<td>78.850</td>
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</table>
## Process Monitoring – Performance Attributes

<table>
<thead>
<tr>
<th>ASSET</th>
<th>ATTRIBUTE</th>
<th>DESCRIPTION</th>
<th>CURRENT</th>
<th>TIMESTAMP</th>
<th>LOW LIMIT</th>
<th>HIGH LIMIT</th>
<th>HISTORICAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column T100</td>
<td>Feed_Pressure</td>
<td>Feed_Pressure</td>
<td>13.510</td>
<td>6/12/2017 12:21:08 PM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Column T100</td>
<td>Feed_Temp</td>
<td>Feed_Temp</td>
<td></td>
<td>6/14/2017 4:01:51 PM</td>
<td>30.0000</td>
<td>150.0000</td>
<td></td>
</tr>
<tr>
<td>Column T100</td>
<td>Reflux_Feed_Rat</td>
<td>Reflux_Feed_Rat</td>
<td>0.40660</td>
<td>6/14/2017 4:00:51 PM</td>
<td>35.7500</td>
<td>66.0000</td>
<td></td>
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<tr>
<td>Column T100</td>
<td>Top_Pressure</td>
<td>Top_Pressure</td>
<td>12.847</td>
<td>6/14/2017 4:01:49 PM</td>
<td>30.5000</td>
<td>66.0000</td>
<td></td>
</tr>
</tbody>
</table>
Performance Monitoring – Integrated Trending
Event Management – Act (Close-out)

Reason Code, Cause, Action

Impact
- Cost – negative
- Savings - positive
There is no magic weight loss pill – it is HARD WORK.
Runtime Analytics & Off-line Analytics

Asset Sentinel
(Complex Event Processing)

Event Management
- Notification
- Investigation
- Close-out

Event Detection
- Deviation Detection
  - Heuristic
  - Trained

Model
- Normal & Abnormal
  - First Principles
  - Statistical
  - State estimation

Process Data
Real-time & Historical
(Small Data)

Rule Definition and Creation Process

Manual Rule Creation

T_Diff = L_EGT - R_EGT
If T_Diff > T_Diff_Hi_Limit
T_Diff_Hi_Alarm = TRUE

- Calculations
- If-then-else rules
  logic

Analytics Algorithms

Visual Analytics
(Process Data)

- Pattern search
- Value Search
- Combinations
- Cleanse / Filter

Statistical Analytics
(Process Data)

- Multivariate statistical
  (PCA, PLS, Kernel Regression...)
- Black-box (Neural Nets...)

Big Data Analytics

- Data vol. & variety
  (unstructured / text)
- Feature Selection / Extraction
- ML (Random Forest, SVM, Naïve Bayes...)

Analytics Data Infrastructure & Management

Storage - (Cloud Historian)

Data Prep

Connectivity (Time-series, Event, Transactional)
## Proactive Detection Approaches — Start at the top and work down

<table>
<thead>
<tr>
<th>Approach</th>
<th>Technique</th>
<th>Examples</th>
<th>Complexity</th>
<th>Risk</th>
</tr>
</thead>
</table>
| 1. Physical & Heuristic | Basic perf mon for broad set of assets & detection deviation from predicted vs actual | • UOP – Connected Perf. Services  
• Middle East Gas co.– 1200 assets | Low | Low |
| 2. Univariate Prediction | Predicting single variable time to reach a value Regression e.g. (H_TimeFit) or Soft Sensor | • Heat Exchanger Fouling prediction  
• Transmitter Inferential Model* | | |
| 3. Adaptive Filtering/Thresholding | Data cleansing and moving window of historical window & compare current short term to historical | • Extensively used on offshore O&G compressor vibration | | |
| 4. Basic Pattern Recognition | Detect behavior of single or group of sensors according to know heuristic relationships | • O&G – Spike with amplitude of Xpsi occurring Y times over Z minutes | | |
| 5. Data Driven - Multivariate Early Event Detection | Statistical pattern detection and recognition including OLS, PLS, PCA, Neural Nets, etc. | • Choke Valve Leak Detection*  
• Multiple projects*  
• Furnace Flooding POC* | | |
| 6. Big Data | Big Data using variety of data sources including maintenance and reliability data | • Haul Truck Engine Prediction Example*  
• Honeywell Aero APU Example* | High | High |

*see slides for more details

### Hybrid Approaches Needed
### Exception Based Surveillance (EBS)
- Gulf of Mexico & Brazil
- Fully operational for 4-5 yrs
- Doubled in capacity in last 2-3 yrs
- Integrated with Remote Ops

### Production surveillance & diagnostic system to provide predictive notifications to reduce 'deferment'
- Pure data-driven models not actionable and too many false positives.

### Workprocess for event detection, triage (investigation) and close-out
- Developed over 220+ 'algorithms' using 1st principles models, adaptive thresholding, univariate prediction & pattern recognition

### Report $30M/year reduction in deferment & costs
- Application of heuristic / engineering rules reduces # of false positives and increases actionability.
- Evaluated 'data driven' models with limited results.
- POC on 'visual' analytics to accelerate 'algorithm development

<table>
<thead>
<tr>
<th>Background</th>
<th>Problem / Need</th>
<th>Solution</th>
<th>Results / Lessons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exception Based Surveillance (EBS) Gulf of Mexico &amp; Brazil</td>
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<td></td>
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<td></td>
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</tr>
</tbody>
</table>

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Visual Analytics – Accelerating Surveillance Model Development

Step#1: Period of Interest +30min and -30min of lab sample – Propane data

Step#2: Calculate Analyzer Average Value in the period of interest and mark timestamp as middle i.e. 7:00 AM

Step#3: Calculate the deviation between average analyzer value and Raw Lab data

Step#4: Identify period where the deviation are higher than 30%

Step#5: Tune threshold to desired level of sensitivity
Asset Sentinel / Seeq Integration

Asset Sentinel

- Calculations
  - Pre-Processing / Cleansing
    - Head = 3960 * HP
    - Flow
  - User Defined Calculations

- Event Mgt.
  - Fault Models
  - Event Investigations

Asset Model

- Asset Library
  - Pump
  - Heat Exchanger
  - Compressor
  - Furnace
  - Gas / Steam Turbine

Trends & Graphics

- Asset Model
  - Visual Rule Discovery
    - Conditions, Series, Patterns

Seeq (Visual Analytics)

- Visual Rule Discovery
- OPC-HDA & DAS
- OPC-DA
- PHD
- Other

OPC-HDA & DAS

OPC-DA
ESP Standing Valve Leak Detection

Example of Data Driven Model for more complex problem

Background

- Offshore Oil & Gas with large population of aging electrical submersible pumps and choke valves

Problem / Need

Challenge to accurately detect choke valve seal leakage when ESP stops with minimum # of false positives. When is flow & riser pressure change considered to be a leak?

Solution

Dynamic PCA trained with leak and no leak data. Dynamic PCA determines lag in data and shifts matrix accordingly. T2 (representing variance from mean) & SPE (indicating residual variance) indices on moving time window used to detect leakage when pump stops

Results / Lessons

DPCA markedly better than PCA in this use case confirmed leaking conditions detected in training data set

<table>
<thead>
<tr>
<th></th>
<th>DPCA</th>
<th>PCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>True Positive</td>
<td>31</td>
<td>22</td>
</tr>
<tr>
<td>False Positive</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>False Negative</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
Data Drive Modeling – Lessons & Recommendations

• Start with clear objective of what problem you are trying to solve
  - Trained fault detector
    - High “failure to feature” ratio to reliably predict particular failure model
    - Lower false positive rate
    - Only detects what you have experienced in the past
    - Tend to be more ‘actionable’ to diagnose the problem
  - Generic Anomaly Detector
    - Trained on normal data – detects all anomalous behavior
    - High false positive rate
    - Difficult to attribute specific action associated with model anomalies
    - 50% - 80% of problems found are sensor problems

• Set realistic expectations –
  - Model should match operating situation at scale
  - Machine learning and statistical methods are not flawless
  - Define work process and event management infrastructure to deliver results (i.e. Bridge)

• Signal to perform the task is not always in data (no volume will help)
• Sufficient volume of quality data required to perform the task
• Selection of correct machine learning technique critical to success
  - Packaged product vs. programming environment like R
IIoT by Honeywell Ecosystem

- Smart and Secure Collaboration
- Advanced Analytics
- Self Serve Analytics
- Data Management and Onsite Control
- Smart & Connected Assets & Devices

Honeywell IIoT Open & Secure Framework

- Honeywell App Store
- External App Developers
- Knowledge Vendors
  - EPCs
  - OEMs
  - SIs
  - Process Licensors
- Data Scientists

Uniformalence Suite

- Time Series Data
- Context Model
- Big Data Storage

Cloud Historian

- Uniformance Suite (on-prem)

Equip. Vendors
ex. Flow Serve, MHI, etc.

DCS Process Data

Ancillary System Data
ex. SAP, ERP, LIMS, etc.

Collaboration & Visualization

KPI & Calculation engine

Enterprise Historian

Analytics Framework

Ecosystem Critical to Add Domain Knowledge to Solve Challenging Problems
Digital Transformation Benefits

**Formalize Work Processes & Standard Work**
- Decide
- Detect
- Inform & Improve
- Act

**Apply High Skill Resources to High Skill Tasks**
- Current 0%
- Future 100%
- Data Gathering
- Analyzing
- Solving

**Single Version of the Truth Enabling Process Intelligence**

**Reduce Missed Opportunities & Accelerate Response**
- Alerts!
- T1
- T2
- T3
Value – Reduce Unplanned Capacity Loss / Lost Profit Opps

- Reduced Capacity Loss
- Mitigation Strategies
- Original Capacity Loss
- Leading Cause

- Unit Shutdown
- Critical Eq. Failure
- Non-Critical Eq. Failure
- Process Deviations
- Degraded Efficiency

Cost Impact

Health Mon.

Performance Mon.

Frequency

Rare

Frequent
Check it out!

- Visit Unifomance Asset Sentinel Website
- Visit UOP Connected Performance Services for examples of Asset Sentinel at work
- Brochure, Case Studies, and More
- See it at Honeywell Users Group Americas and EMEA
- Watch product demo videos on the Unifomance YouTube playlist at www.hwll.co/UniformanceVideos
- Watch the Lundin Edvard Grieg Video Case Study
- Visit Uniformance.com for quick access to more information or to request a product demonstration
• Visit Uniformance Asset Sentinel Website
• Visit UOP Connected Performance Services for examples of Asset Sentinel at work
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