A Framework for IIoT Analytics

Eric Harper
Papermaking has been a human endeavor for 3,000 years
IT Analytics
An iterative process

1. Discover
2. Strategize
3. Develop
4. Deploy
5. Analyze
6. Iterate

Data and Analytics Strategy Framework
Industrial Internet Consortium
Things are coming together

INDUSTRIAL
INTERNET OF THINGS ANALYTICS FRAMEWORK

We are pleased to announce the Industrial Internet of Things Analytics Framework (Industrial IoT Analytics Framework) for system architects, technology leaders and business leaders looking to successfully deploy industrial analytics systems.

Advanced analytics is at the core of the Industrial Internet of Things (IIoT). When analytics are applied to machine and process data, they help optimize decision-making and enable intelligent operations. These new insights and intelligence can be applied across any level of any industry if the appropriate data can be collected and analytics are applied correctly. If data is the new oil, data analytics is the new engine that propels the IIoT transformation.
Agenda
IlOT Analytics

Business Viewpoint
Usage Viewpoint
Functional Viewpoint
Implementation Viewpoint
Crosscutting Concerns
Questions and Answers
Creating Business Value

**Who:** Business and technology leaders

**What:** Increase throughput, reduce expenses and inventory

**Why:** Generate higher margins to create business value

**How:** Identify performance bottlenecks in overall operations continuously and remove them one-by-one

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**Market Context**

- IloT Strategy
- IloT Business Model Innovation
- Ideation
- Preparation
- Evaluation
- Initiation
- IloT Foundations

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Agenda
IloT Analytics

Business Viewpoint
Usage Viewpoint
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Implementation Viewpoint
Crosscutting Concerns
Questions and Answers
Papermaking Process

- **Softwood**
  - Builed pulp slushing
  - Paper mill
  - Refining
  - Paper mill
  - Pulp mill

- **Hardwood**
  - Broke/recycle
  - Pulp mill

- **Broke/recycle**
  - Balse pulpers
  - 2ps

- **Blending**
  - Broke reject chest
  - 25m³
  - Broke reject chest
  - 20m³

- **Cleaning**
  - Wet-end
  - Press section
  - Decalator

- **Dry-end**
  - Press pulper
  - Skin-press pulper
  - Calendar pulper

- **Wet-end**
  - Decalator
  - Headbox
dil.

- **Dry-end**
  - Press section
  - Shower water tank
  - Wire showers
  - Warm water tank
  - Shower water tank
  - Wire showers

- **White water**
  - White water silo
  - 5 Bar dilution water
  - bottoms of silo
  - Balse pulpers dilution water

- **Ret. aid dilution**
  - Recovered fibre
  - 30m³

- **Ret. aid dilution**
  - Disc filter
  - Ultra clear filtrate
  - 30m³

- **Ret. aid dilution**
  - Clear filtrate
  - 80m³

- **Ret. aid dilution**
  - Cloudy filtrate
  - 80m³

- **Ret. aid dilution**
  - 5 Bar dilution water
  - Bottoms of silo
  - Balse pulpers dilution water

- **Ret. aid dilution**
  - Balse reject chest
  - 10m³

- **Ret. aid dilution**
  - Deflaker
  - Broke proport.
  - 80m³

- **Ret. aid dilution**
  - Wet broke chest
  - 80m³

- **Ret. aid dilution**
  - To blend chest
  - 80m³

- **Ret. aid dilution**
  - Recovered fibre
  - 30m³

- **Ret. aid dilution**
  - Ultra clear filtrate
  - 30m³

- **Ret. aid dilution**
  - Clear filtrate
  - 80m³

- **Ret. aid dilution**
  - Cloudy filtrate
  - 80m³

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  - Bottoms of silo
  - Balse pulpers dilution water

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  - Broke reject chest
  - 25m³

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Analytics Framework
Getting started

**Descriptive Analytics**
Gain insight from historical or current data streams including for status and usage monitoring, reporting, anomaly detection and diagnosis, model building or training

**Predictive Analytics**
Identify expected behaviors or outcomes based on predictive modeling using statistical and machine-learning techniques, e.g. capacity demand and usage prediction, material and energy consumption prediction, and component and system wear and fault predictions

**Prescriptive Analytics**
Uses the results from predictive analytics as guidance to recommend operating changes to optimize processes and to avoid failures and the associated downtime. An example of prescriptive analytics is on-demand production from a solid geometric assembly model to find the optimal set of manufacturing processes to achieve the final product
Agenda

IIoT Analytics

Business Viewpoint
Usage Viewpoint
Functional Viewpoint
Implementation Viewpoint
Crosscutting Concerns
Questions and Answers
Pulp and Paper Plant

Data sources and systems

1. Energy Management
2. Order Management
3. In Line Measurement
4. Paper Controls & Optimization
5. Lab Measurement System
6. Quality Controls System
7. PM Drives System
8. Web Inspection System
9. Production Planning & Measurement
10. Pulp Mill Controls & Optimization
# Analytics Deployment Considerations

<table>
<thead>
<tr>
<th>Evaluation Criteria</th>
<th>Analytics Location</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Plant</td>
</tr>
<tr>
<td><strong>Analysis Scope</strong></td>
<td></td>
</tr>
<tr>
<td>Single Site</td>
<td>✔</td>
</tr>
<tr>
<td>Multi-Site</td>
<td>✔</td>
</tr>
<tr>
<td>Multi-Customer</td>
<td></td>
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<tr>
<td><strong>Response Time</strong></td>
<td></td>
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<tr>
<td>Control Loop</td>
<td>✔</td>
</tr>
<tr>
<td>Human Decision</td>
<td>✔</td>
</tr>
<tr>
<td>Planning Horizon</td>
<td>✔</td>
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<tr>
<td>...</td>
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</table>
Analytics Design and Implementation Process

- Business Case
  - Customer Profile Analysis
  - Value Proposition Design
  - Environment and Data Catalog

- Stakeholder Engagement
  - Subject Matter Expert Review
  - Customer Story

- Data Exploration and Preparation

- Modeling and Analytics

- Automation
  - Data Integration
  - Application Integration

- Continuous Improvement
Analytics Design and Implementation Process

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Data Exploration and Preparation

Modeling and Analytics

Automation
- Data Integration
- Application Integration

Continuous Improvement

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March 13, 2020
Slide 17
Challenges in Papermaking Process

Measure, Control and Optimize

Papermaking needs to **measure** many process variables and product qualities for monitoring production operations and control automations.

Papermaking consists of many complex processes that require various **control** solutions and techniques to produce high quality products.

Papermaking is an energy intensive production process. There are many opportunities to **optimize** consumption of raw materials, utilities, and energy.
Analytics Design and Implementation Process

Stakeholder Engagement

Stakeholder Engagement
- Subject Matter Expert Review
- Customer Story

Continuous Improvement

Automation
- Data Integration
- Application Integration

Modeling and Analytics

Data Exploration and Preparation

Business Case
- Customer Profile Analysis
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Data Science vs. Model-Based Analytics

Prescription
- How do I make it happen?
- What am I missing?

Optimization
- What is the best that can happen?

Prediction
- What will happen if I take this action?
- Why might this be happening?
- What will happen next?

Confirmation
- What is happening now?
- What has just happened?

Discovery
- What has just happened?

Description
- What has just happened?

System models using subject matter expertise, physics, mechanics and dynamics of component interactions
Approximations using linear simplification of non-linear behavior
Effective with small amounts of data

Health index assessment for a single asset
- Statistical data
  - Statistical function
  - RL, Statistical
- Utilization data
  - Degradation function
  - RL, Utilization
- Condition data
  - Condition function
  - RL, Condition

Extract knowledge from data, using scientific discipline
Collect and clean raw data, explore relationships, develop models and algorithms, uncover patterns and predict outcomes
Effective with large amounts of data
Analytics Design and Implementation Process

Data Exploration and Modeling

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- Extend Value Proposition

- Revise Algorithms
Simulation of Water Papering Process
Multi-scale, Multi-physics Modeling

HPC for Manufacturing

Leverage advanced simulation capabilities, high performance computing resources and industry paper press data to help develop integrated models to accurately simulate the water papering process.

Researchers used a computer simulation framework, developed at LLNL, that integrates mechanical deformation and two-phase flow models, and a full-scale microscale flow model, developed at Berkeley Lab, to model the complex pore structures in the press felts.

Save paper manufacturers up to 20 percent of the energy used in the drying stage – up to 80 trillion BTUs (thermal energy units) per year – and as much as $400 million for the industry annually.
Model Building Process

- Prepared Data (Selected Features)
- Apply Learning Algorithm to Data
- Candidate Model
- Iterate to find best model

Machine Learning Algorithms
AI / Machine Learning

Algorithms

Artificial Intelligence
- Deduction, Reasoning, Problem Solving
- Knowledge Representation
- Planning
- Perception: Computer Vision

Machine Learning
- Supervised Learning
  - Decision Tree Learning
  - Inductive Logic Programming
- Association Rule Learning
- Support Vector Machines
- Unsupervised Learning
  - Clustering
  - Sparse Dictionary Learning
  - Similarity and Metric Learning
  - Genetic Algorithms
- Reinforcement Learning
  - Bayesian Networks
  - Deep Learning
  - Manifold Learning

Social Intelligence

Natural Language Processing

Robotics: Motion and Manipulation

Computer Vision
Analytics Design and Implementation Process

Automation

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- Data Exploration and Preparation

- Modeling and Analytics

- Data Integration

- Application Integration

Continuous Improvement
Streaming and Batch Integration

Individual Processes

Data source/Message queue

Speed (Real-time) processing

- Machine learning model
- Events, anomalies

Batch processing

- Diagnostics, predictions

Applications

- Hot, temporary storage
  - Queries
  - Responses

- Cool, permanent storage
  - Queries
  - Responses
## Analytics Technology Choices

<table>
<thead>
<tr>
<th>Type</th>
<th>Example Technology</th>
<th>Development</th>
<th>Motivation</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hadoop</td>
<td>Hive/Pig</td>
<td>SQL</td>
<td>Large static capacity and fault tolerance through data replication</td>
<td>Computations are disk bound, high latency and response execution times</td>
</tr>
<tr>
<td>Indexed</td>
<td>Solr/Lucene</td>
<td>Indexed Query</td>
<td>Real-time, scalable search with support for almost any type of data and file format</td>
<td>Latency to create and maintain indexes</td>
</tr>
<tr>
<td>RDBMS</td>
<td>JDBC</td>
<td>SQL</td>
<td>High productivity, legacy data store use requires no retraining. Support for transactions</td>
<td>Scalability, limited to structured data</td>
</tr>
<tr>
<td>Key-Value Pair</td>
<td>NoSQL</td>
<td>CQL</td>
<td>Simplicity of design, reliability (fault tolerance), and scalability</td>
<td>Unstructured and schema-less data</td>
</tr>
<tr>
<td>Time Series</td>
<td>Time Series</td>
<td>Summary, Aggregates</td>
<td>Efficient storage and processing for high frequency data</td>
<td>Data access as single columns, robustness is of importance given susceptibility to error due to missing data</td>
</tr>
<tr>
<td>Streaming</td>
<td>Storm</td>
<td>Java, Topology</td>
<td>Quick insight from streaming and real-time data</td>
<td>Slow recovery from faults</td>
</tr>
<tr>
<td>In-Memory</td>
<td>Interactive</td>
<td>SQL, Script</td>
<td>Scalable dynamic capacity, low latency, and low (quick) overall response time</td>
<td>Large main memory (RAM) requirements</td>
</tr>
<tr>
<td>Single Node</td>
<td>R / Python</td>
<td>Script and Packages</td>
<td>High productivity, quick prototyping and proof of concept; rich data science libraries</td>
<td>Limited in terms of scalability</td>
</tr>
<tr>
<td>Graph</td>
<td>GraphX / GraphLab</td>
<td>Spark, TensorFlow</td>
<td>Intuitive and visual representations of computational problems, represent arbitrary data and systems as nodes and connections</td>
<td>Not all algorithms can be represented as graphs</td>
</tr>
<tr>
<td>Custom</td>
<td>Custom</td>
<td>Java</td>
<td>High level of data and algorithm flexibility</td>
<td>Custom programming, lower productivity</td>
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</tbody>
</table>
Analytics Design and Implementation Process

Continuous Improvement

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  - Customer Story

- Data Exploration and Preparation

- Collect More Data

- Identify New Tools

- Identify New Technologies

- Automation
  - Data Integration
  - Application Integration

- Model and Analytical

- Continuous Improvement

- Propose New Products and Services
Agenda

IIoT Analytics

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System Characteristics Related to Analytics

Industrial analytics requires many services from IIoT

**Safety**
Design industrial analytics processes and computations to prevent unintended operation and independently validate that the resulting actions do not harm life or property

**Security**
Provide defense in depth so that if a malicious or un-intended action compromises one security or accountability measure then another measure still guards the assets

**Data Management**
Common across tiers and accessible using a federated information model that supports search, classification and markup to enable rapid industrial analytics application development

**Connectivity**
Distributed architecture requires connectivity between components, not only between collocated processes but also across wide-area and global networks
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