Recent Advances of Industrial Big Data Analytics for Smart Product Service and Social Innovation

Jay Lee

Founding Director
NSF Industry/University Cooperative Research Center on Intelligent Maintenance Systems (IMS)
Univ. of Cincinnati, Univ. of Michigan, Missouri Univ. of S&T, and Univ. of Texas Austin
www.imscenter.net

Outline

▶ Changing Role of Data and Value Creation

▶ Industrial Big Data Analytics, CPS, and Social Innovation

▶ Examples

▶ Conclusions
IMS Vision and Grand Challenges

Zero-Downtime (ZDT)

Fail and Fix or Fly and Fix

Productivity Transformation Tools

Predict and Prevent

Near-Zero Downtime (ZDT)

Products and Systems

IMS Vision in 2000

Closed-Loop Life Cycle Design

Near "0" Downtime

Just-in-Time Service

Product Development

Product Redesign

Smart Design

Enhanced Six Sigma Design

Watchdog Agent® Degradation Assessment
(Machine Feature Monitoring)

Smart Infotronics (Twin-Model)

- Decision Support Tools for Maintenance Scheduling
- Asset Optimization Predictive and Prescriptive Analytics

Health Monitoring Sensors & Embedded XYZ/Connected XYZ

Communications - Tether-Free (Bluetooth) - Internet - TCP/IP

Self-Maintenance

- Redundancy
- Active
- Passive

Health Information

NSF I/UCRC IMS Vision in 2000 www.imscenter.net
GE Industrial Internet System

IMS Adventure in 2001 → Catalyst → GE Venture in 2011

Outline

► Changing Role of Data and Value Creation

► Industrial Big Data Analytics, CPS, and Social Innovation

► Examples

► Conclusions
Competitiveness Transformation Strategy

<table>
<thead>
<tr>
<th>1990s</th>
<th>2000s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoid</td>
<td>Solve</td>
</tr>
<tr>
<td>Visible</td>
<td>Invisible</td>
</tr>
<tr>
<td>Utilize New Knowledge/Technologies For Value-added Improvement</td>
<td>Value Creation using Smarter Information For Unknown Knowledge</td>
</tr>
<tr>
<td>Problem Solving Through Continuous Improvement and Standard Work SS Surprise</td>
<td>Utilize New Methods/Techniques to Solve The Unknown Problems</td>
</tr>
</tbody>
</table>

Industrial Big Data in 1990s

- GM OnStar®
- UTC Otis Elevator REM®
- GE Medical InSite®
Industrial Big Data in 2000s

- John Deere Agir Service® 2002
- Komatsu Komtrax® 2002-2005
- GE Aviation OnWing Support® 2005
- Alstom Train Tracer® 2006
- Goodyear FuelMax® 2008

Product/Manufacturing Evolution

- Product/Services
  - Manufacturing
- Avoid
  - Smart Sensors & Prognostics and Health Mgt
  - GE Power By the Hour
- Solve
  - On-Wing Support
  - Komatsu Komtrax
  - Improved Productivity/Lean Manufacturing
  - Improved Product Design
  - Cyber-Physical Systems & Industry 4.0 in Manufacturing (Self-Configure & Resilient Machine)
  - Predictive Healthcare (Sports and Analytics, Medicine)

Visible

Invisible

Predictive Big Data Analytics

GE Aviation
John Deere Agri Service
Goodyear Smart Tire
Outline

► Changing Role of Data and Value Creation

► Industrial Big Data Analytics, CPS, and Social Innovation

► Examples

► Conclusions

Industry Transformation

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lean/6-Sigma</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PLM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smart Service &amp; Customer Value Creation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Methods & Tools

TPM (Organization Centric - Practice & Culture)
- SPC and TQM
- Time Series Models
- Expert Systems-based Diagnostics
- AI Tools
- Fuzzy Logics
- Mechatronics/Robotics
- Smart Sensors
- Real-time Monitoring/Control
- Sensor Networks
- Machine Learning
- Data Mining
- Embedded Systems
- 6-Sigma Design
- Degradation Measurement
- Remote Monitoring
- Web-enabled Monitoring/ eMaintenance
- On-Board Diagnostics / Prognostics
- Product Life Cycle Design
- Prognostics and Health Management (PHM)
- Twin-Model Systems
- Virtual Metrology
- Decision Support
- Digital Thread
- Predictive Big Data Analytics
- Cyber-Physical Systems
- Industry 4.0 Systems
- Cyber Security
- Digital Twin
Value of Predictive Analytics

► Apply Data Analytics to large amounts of data of a variety of types to uncover hidden patterns, unknown correlations and other useful information from industrial and manufacturing systems and integrate with business automation software for improved productivity and innovation.

Watchdog Agent® → Self-Aware Machine

(Vibration | Current | Acoustic | Temperature)

Before Errors Happen | Regularly Inspect | Act

Health Map | Risk Radar Chart | Degradation (Confidence Value)

6Cs in Big Data System

1. Connection -- RFID, Wireless, Sensor Networks
2. Cloud – Computing and Data on Demand
3. Cyber— Model and Memory
4. Content/Context – Relationship and Reference
5. Community -- Relationship and Sharing
6. Customization – Service and Value

Challenges of Industrial Big Data

1. Broken
2. Bad

3. Background

What are Cyber-Physical Systems?

- **Physical**
  - natural and human-made systems governed by the laws of physics and operating in continuous time

- **Cyber**
  - computation, communication, and control that are discrete, logical, and switched

- **Cyber-Physical Systems**
  - systems in which the cyber and physical components are tightly integrated at all scales and levels

Ref: NSF CPS Program, 2007

Architectures for 5 Levels (5C) of CPS

- **I. Smart Connection Level**
  - Plug & Play
  - Tether-free communication
  - Sensor network

- **II. Data-to-Information Conversion Level**
  - Smart analytics for
    - Component machine health
    - Multi-dimensional data correlation
    - Degradation and performance prediction

- **III. Cyber Level**
  - Twin model for components and machines
  - Time machine for variation identification and memory
  - Clustering for similarity in data mining

- **IV. Cognition Level**
  - Integrated simulation and synthesis
  - Remote visualization for human
  - Collaborative diagnostics and decision making

- **V. Configuration Level**
  - Self-configure for resilience
  - Self-adjust for variation
  - Self-optimize for disturbance
Outline

- Changing Role of Data and Value Creation
- Industrial Big Data Analytics, CPS, and Social Innovation
- Examples
- Conclusions
Fleet Cluster-based Health Analytics

Data was prepared similarly with unit-specific modeling method. Daily wind speed measurements were used for regime similarity evaluation, power curve data was used for health metric evaluation.
Rethink the “Fleet Systems”

What is a fleet? (1/2)

- Scenario 1: For manufacturing, in one factory, there are equipment/assets of the same type. These similar assets are referred to as a fleet.

Fleet: a group of similar machines/assets in one factory.
What is a fleet? (2/2)

- Scenario 2: Assets/machines of similar type that are experiencing similar working conditions, while located at different factories, can also be considered as a fleet – focus of this research.

Smart ECU to Save Lives
Smart Wearable Systems for Sports and Peer-to-Peer Personal Healthcare

Application Example

- New Sensor technology allows long-term studies with consistent electrode placement, unlocking previously unattainable connections between muscle activity and any number of factors (mood, weather, time of day, sleep, etc).
- Develop conformable force-measurement device to make set-up completely wearable, allowing for in-the-field analysis of fatigue.
- Apply methods and technology to other muscles of interest within the body (such as leg-foot interactions)
Outline

► Changing Role of Data and Value Creation

► Industrial Big Data Analytics, CPS, and Social Innovation

► Examples

► Conclusions

Transformation

Visible → Invisible
Data → Analytics
Solve → Avoid
Product → Value
Experience → Evidence
IMS Major Impacts

1. IMS is the “Catalyst” of GE Industrial Internet and Fanuc ZDT Technologies.

2. Ranked the highest Economic Impacts (1:270) by NSF Economic Impact Study Report in 2012.


5. 5 Spin-off Companies (U.S., Japan, Taiwan, China)


---

Thank You!

www.imscenter.net

Google Jay Lee, Prognostics, E-Manufacturing, E-Maintenance, Dominant Innovation, Cyber Physical Systems

---