Factories of the Future:
How Symbiotic Production Systems, Real-Time Production Monitoring, Edge Analytics and AI Are Making Factories Intelligent and Agile

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Hitachi America R&D
Outline

- Manufacturing Trends and Opportunities
- Requirements for Manufacturing Automation
- Lumada for Smart Manufacturing
- Crowd Manufacturing Solutions
- Advanced Manufacturing Applications
- Customer Co-creation
Multi-factor productivity has been stagnant for the last decade due to separation of OT and IT.

Source: https://data.oecd.org/lprdty/multifactor-productivity.htm
Manufacturing: Productivity Issues

LACK OF VISIBILITY INTO SHOP-FLOOR OPERATIONS

LOST PRODUCTIVITY DUE TO UNPLANNED DOWNTIMES

IT SYSTEMS, PRODUCTION LINES OPERATING IN SILOS

DILEMMA TO INNOVATE OR CONTINUE 24/7 OPERATIONS?
Requirements for Manufacturing Automation
Manufacturing: IoT Opportunities

Traditionally separate OT and IT are now starting to merge

- Pervasive connectivity
- Holistic sensing
- Localized analytics

= Insights that enable:

- Improved overall effectiveness
  - Overall equipment effectiveness (OEE)
  - Overall process effectiveness (OPE)
- Better asset management
- Reduced costs
- Innovation in process and business model

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Overview of Manufacturing Automation

An IoT solution with service-oriented architecture (SOA) is needed to enable manufacturing automation.

Source: ANSI/ISA 95 Standard
Manufacturing Automation Requirements

SOA enablers

Connectivity
- Interoperability
- Real-time capability
- Modularity
- ...

Data management
- Extract data from complex environment
- Add context to tag data
- Event-driven data flow
- ...

Actionable insights
- Data flow monitoring
- Distributed analytics
- Centrally managed, locally decided
- ...

Trustworthiness
- Reliability
- Security
- Privacy
- Safety

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Lumada for Smart Manufacturing
Physical Layer
Data generated from assets and sensors
Manufacturing IoT: Functional Architecture

- **Data Acquisition Layer**
  - Physical Layer: Sensors and assets generating real-time data
  - SCADA
  - Sensors
  - I/O
  - Sensor Fusion
  - Holistic Sensing
  - Zero-latency Edge Apps

- **Architecture**
  - Pervasive Connectivity
  - Holistic Sensing
  - Edge Analytics

- **People**
  - App Manager
  - Executive
  - Manager
  - Worker

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Manufacturing IoT: Functional Architecture

**Architecture**

Device gateway Layer:
- Low-latency edge apps
- OT x IT security
- IoT protocol/data abstraction

Data Acquisition Layer:
- IoT-GW-1
- IoT-GW-2
- IoT-GW-n

Physical Layer:
- Sensors and assets generating real-time data

**Pervasive Connectivity**

**Holistic Sensing**

**Edge Analytics**

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Manufacturing IoT: Functional Architecture

**Architectures**

- **Data Processing and Storage Layer**
  - Device Gateway Layer
    - Low-latency Edge Apps
    - OT x IT Security
    - IoT Protocol/Data Abstraction
  - Data Acquisition Layer
    - SCADA
    - Sensor Fusion
    - I/O
    - Sensors and assets generating real-time data
  - Physical Layer

- **Pervasive Connectivity**
  - Edge Server
  - Edge Applications
    - Visualization & Alerts
    - OT x IT Security
  - Zero Latency Edge Apps

- **Holistic Sensing**
  - Holistic Sensing

- **Edge Analytics**
  - App Manager
  - Executive
  - Manager
  - Worker

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Zero Touch Deployment (ZTD)

Empowers non-IT staff to easily provision and manage IoT devices

- Network connection setup
- Configuration exchange with directory server
- Scan QR Code
- Get installer’s location
- Get installer’s fingerprints
- IoT gateway and all attached devices are authenticated and registered with asset manager
- Verification of installation using asset viewer and data lake viewer
Context-Based Connectivity

Scenario

PdM application in the cloud detects certain anomaly in Asset#1

Cloud "requests" Edge to increase reporting frequently for
sensor data for that asset

Edge parses the request and updates reporting interval for
relevant sensors

Architecture

Pervasive Connectivity

Holistic Sensing

Edge Analytics

Cloud services are mapped to logical constructs which are in turn mapped to individual endpoints

Scalable, accommodates phased deployment of sensors

Context-based Approach

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Holistic Sensing for Shop-Floor

Augment IoT data by absorbing contextual information pertaining to machines, workers, and material movements.
Real-time monitoring of industrial operations is critical for minimizing unplanned downtimes.

Edge analytics detects early warning signs based on raw data analysis.

- Unusual vibrations
- Fatigue evidence
- Audible noises
- Too hot to touch

**Preventive Actions**

**Architecture**
- Pervasive Connectivity
- Holistic Sensing

**Edge Analytics**
- Edge Analytics for early failure detection
- Reactive action
- Equipment failure

**Control Center**
- Asset condition measurement
- Failure signature detection
- Raw data analysis

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Subscription-Based Notification Service

- Allows different stakeholders to subscribe to topics based on their role and requirements
- Rules can be defined to subscribe to desired event alerts. No cloud connectivity required.

Architecture
Pervasive Connectivity
Holistic Sensing
Edge Analytics

Stakeholders
Subscription
Events alerts
Decentralized design
Metallurgical Plant

Improve first time yield and reduce unplanned downtime
IoT Deployment

- Asset Location
- Asset List
- Sensor Data-lake
- Statistical Analysis
- Production Analytics
Real-time Monitoring of Shop Floor Operations
Reducing Unplanned Downtimes

1. Process “Start” detection
2. Analyze “material flow”
3. Process “End” detection

Robot error detected?

Alert

Subscription-based Edge Notification Service
Yield Monitoring

- Enabled real time quality monitoring, 24/7.
- Provided actionable insights to right stakeholders
Cross-linking Scheduling w/ Shop Floor Operations in Real-time
Cross-linking Scheduling w/ Shop Floor Operations in Real-time (2)
Hitachi’s Global Initiatives for Smart Manufacturing
# Hitachi’s Global Open Activities for Smart Manufacturing

<table>
<thead>
<tr>
<th>Consortium</th>
<th>Activities</th>
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</table>
| **FAPaaS** | Test-bed “FA-PaaS”  
Collaborated with NIST |
| **Robot Revolution Initiative** | Co-leader of WG1 “Mfg. Business Revolution”  
Member of “International Standardization” |
| **IVI** | Managing Leader  
Platform / Use-case Provider |
| **acatech** | Only-one Normal Member from Asia  
Continuous Meetings |
| **INDUSTRIE4.0** | Normal Member of WG1 “Reference Architecture, Norms & Standardization” |
| **IEC**  
**ISO** | IEC-MSB “Factory of the future” White Paper  
ISO-SAG “I4.0-SmtMfg”, IEC-SEG7, etc. |

**FAPaaS:** Factory Automation Platform as a Service, National Institute of Standards and Technology,  
**MSB:** Market Strategy Board, **SAG:** Strategic Advisory Group, **I4.0:** Industrie4.0, **SmtMfg:** Smart Manufacturing
Key Contributor for IEC-Market Strategy Board
“Factory of the future” Project

- White Paper as Next Generation Manufacturing Policies
- Agreed our “Crowd Manufacturing as Symbiotic Production Systems”

Published on Oct. 2015

http://www.iec.ch/whitepaper/futurefactory/

4 of 16 Figures are from Hitachi

22 Attendees as International Expert
LUMADA as Real-time & Bi-Directional Technology for Crowd Manufacturing Eco-system

Video
Audio
Sensors

Feedback for the best services

Analytics
Studio

Core
Asset Avatar
Asset Model
Behavior Model
Asset Profile
Simulator
Foundry

Edge
S-Model as Smart Manufacturing Solution of LUMADA

- Autonomous Statistical Analysis
- Autonomous Mfg Simulation
- Closed PDCA Cycle
- Proactive Measure Services

Feedback for the best services

Efficiency Maximization

S-Model: Statistical and Simulation Model-based Production System, PDCA: Plan, Do, Check, and Action
Challenges of S-Model

Autonomous Statistical Analysis → Autonomous Mfg Simulation

Closed PDCA Cycle

Autonomous Data Acquisition → Proactive Measure Services

Select Serious One from Many Problems in Mfg

Efficiency Maximization

Contain:
- Signal Noise
- Accessory Works
- Net Processes

S-Model: Statistical and Simulation Model-based Production System, PDCA: Plan, Do, Check, and Action
Challenges of Net Process Data Extraction from IoT Data

Sequential process

- Wait for unload
- Wait for load
- Net processing time

Lot | Work num. | Start time acquisition | End time acquisition
---|---|---|---
A  | 4  | | 
B  | 2  | | 
C  | 3  | | 

Time

RFID, bar code, etc.

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Mfg Simulation Accuracy Improvement by Autonomous Statistical Analysis

Autonomous Statistical Analysis → Autonomous Mfg Simulation

Contain
- Signal Noise
- Accessory Works
- Net Processes

Sensors

Mfg Field

Autonomous Data Acquisition

S-Model: Statistical and Simulation Model-based Production System, PDCA: Plan, Do, Check, and Action

Accuracy Gains from 60% to 90%

Actual Simulation

Cumulated Product Volume vs. Manufacturing Day

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How to acquire simultaneous error-occurrences in real time?
How to predict the influence?
How to take measures proactively?

S-Model: Statistical and Simulation Model-based Production System, PDCA: Plan, Do, Check, and Action
Dashboard for Mfg TSUNAMI (Domino Effect) Visualization & Prediction

Process Chain

System Halt and Resume

Productivity Detraction by Tool Failure

Mfg TSUNAMI (Domino Effect) as Mfg Fluctuation Propagation

NEXT 2017
# Dashboard for Mfg TSUNAMI (Domino Effect) Visualization & Prediction

## Process Chain

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<th>Now</th>
<th>Future</th>
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## Autonomous Statistical Analysis

## Autonomous Mfg Simulation

## Propagation Prediction

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Dashboard for Mfg TSUNAMI (Domino Effect) Visualization & Prediction

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Next 2017

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Autonomous Statistical Analysis | Autonomous Mfg Simulation | Propagation Prediction
Real Example of Mfg TSUNAMI (Domino Effect) Visualization & Prediction
Real Example of S-Model Performance: Mfg TSUNAMI (Domino Effect) Reduction

Before

After
S-Model has been delivered since 2011
Awards: 4, News Releases: 3

S-Model: Statistical and Simulation Model-based Production System, PDCA: Plan, Do, Check, and Action

Video
Audio
Sensors

Autonomous Statistical Analysis
Autonomous Mfg Simulation

Closed PDCA Cycle

Mfg Field

Proactive Measure Services

Feedback for the best services

Efficiency Maximization

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Co-Creation with Customers for Factories of the Future

DAICEL-HITACHI Co-creation

OKUMA-HITACHI Co-creation