Connected Factory and Digital Manufacturing: A Competitive Advantage

Presented by:
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Shantanu Rai is a Mechanical Engineer from IIT-Roorkee, INDIA with a minor in Mathematics and Computer Graphics.

Some of his major achievements are about bringing together Process Automation, Instrumentation, IoT into Digital Manufacturing and Connected factory.

- Implemented a Real-time Cooling Control for a Rolling Milling.
- Computer Aided Machining of Hydro Turbine blades
- Neural Network & Machine learning in Plant Cooling Applications.
- Supplier Collaboration and Integration for Aerospace supply chain.
- New Vehicle development process for multiple types of vehicles
- Production part Approval process implemented for automotive ancillaries.
- Plant Schema Design for Oil Refineries

His current research and business interest include solutions that bring together “Design, Supply Chain and Manufacturing in a Connected Factory” environment.

This new paradigm combines elements of Digital Thread, Industrial IoT, Micro services and Data Busses and standardized architecture / interfaces for manufacturing stations and machining centers.
Definitions

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**Industry 4.0** is the current trend of **automation** and data exchange in manufacturing technologies. It includes **cyber-physical systems**, the **Internet of things**, **cloud computing**[1][2][3][4] and **cognitive computing**.

While often used interchangeably and very similar, these terms have subtle differences.
Contents

Digital Manufacturing and Connected Factory – Background

Digital Manufacturing – Trends & Technology

Elements of Digital Manufacturing and Connected Factory

Roadmap to Digital Manufacturing
Digital Manufacturing and Connected Factory

Background
Industry 4.0: Disruption on the Horizon

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- Considered to be driving the Fourth Industrial Revolution; based on the application of digital technologies / “digitalization” in the supply chain and manufacturing
- Underlying technology drivers include AI, Robotics, IoT, 3D Printing and others. These technologies are rapidly becoming mainstream
- Potential business value is expected to be significant -- innovation, customer experience, product quality, productivity, efficiency
- Talent and skill will be a key factor of production going forward
- Expect to see more transparency and consumer engagement in the way companies design, develop, manufacture and sell products
Fundamental Components of Industry 4.0

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Digital Thread

Sharing of information (using standards) throughout all stages of the product lifecycle, including design, manufacturing, supply chain, and aftermarket support.

Digital Manufacturing

Digital Model of a particular asset or system, encompassing design specifications, engineering models and as-built and operational (in-use) data. Used for improving the loop between design, manufacture and customer-use.
HCL Capabilities in Smart Manufacturing and Industry 4.0

HCL’s CAMWorks helps to increase productivity using best-in-class technologies and adaptable automation tools to maximize CNC machining efficiency.

HCL’s Imaging Tech Lab enables end-to-end imaging solution development and porting & optimizing to various vision platforms.

HCL has designed SLU which serves as a component to monitor product usage in the field.

HCL has YVR (Visualization and Virtual Reality) approach to enable manufacturers manage their plants, products, and processes.

HCL has created AR/VR based approaches to test for quality control checks and manufacturing standard compliance. HCL has developed “Pick to Light” solution based on Augmented Reality in Plant Maintenance.

HCL has developed MyCloud, MCOO, CART, and other tools around Cloud services to assist enterprises in propelling business growth and enabling superior digital experience.

HCL has developed proprietary tools to leverage Big Data Analytics, which can read data from multiple sources and provide insights based on pre-defined algorithms.

HCL’s Cognitive Robotics Lab is to service various cognitive functionalities in the Robot architecture using open-source technologies.

HCL has developed Tools and Accelerators to support faster deployment of COTS applications & improving tool capability to meet industry expectations.

HCL’s strong alliance with multiple ISVs (Dassault Systems & Siemens) for joint product development of their digital manufacturing portfolio and providing implementation services of plant simulations.

HCL’s proprietary solution DPMPro provides global best practices in additive manufacturing.

HCL Defines, Build & Run offerings and IoT solutions cater to organizations at different IoT adoption levels.

HCL has developed frameworks, create vendor-agnostic solutions that are tailored to fit the clients’ IT requirements, assist with security transition transformation programs.
Components of Industry 4.0: Digital Thread and Digital Manufacturing

Key Challenge Today:
- Islands of excellence (e.g. Manufacturing, Quality, Suppliers, etc)
- Integration and information sharing across the Product Lifecycle is very difficult (lack of standards, customization, etc)
- No feedback from Customer and Services back to Product Design
- Result: High costs of development and manufacturing. High Cost of Quality. Low Customer Sat

Digital Thread:
- Interconnected and linked data across the entire product lifecycle

Digital Manufacturing / Smart Manufacturing / Connected Factory is a subset of the Digital fabric

Source: Thomas Hedberg, NIST
Digital Manufacturing and Connected Factory

Elements
Elements of Digital Manufacturing and Connected Factory

Manufacturing Automation  
Manufacturing Execution  
Manufacturing Simulation  

3D Printing / Additive Mfg  
Manufacturing /Industrial IoT  
Manufacturing Data Analytics  

Robotics & Artificial Intelligence  
Cloud & Plant Cybersecurity  
Augmented / Virtual Reality  

Smart Maintenance  
Small Batch Manufacturing  
Cost Savings  

ERP/PLM  
MES/QMS  
HMI/SCADA  
I/O Sensors/Drives  

Erp/PLM Enterprise Applications  
MES/QMS Plant Applications  
HMI/SCADA Control Systems  
I/O Sensors/Drives Instrumentation  

System Hierarchy as defined in ISA-95 standard  

OEM Products (COTS)

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1. IIOT Strategy Development
2. IOT & Cloud Platforms
3. Connectivity
4. IOT Resourcing
5. Predictive Maintenance
6. Artificial Intelligence
7. Augmented Reality
8. Device Management
9. Data Capture & Analytics
10. IOT Security
11. IOT Testing & Measurement
12. Wearables
13. Change Management
14. Developing New Business Models
15. Systems Hardware
16. Smart Sensors
Digital Manufacturing and Connected Factory

Manufacturing Execution
Connected Factory: Manufacturing Execution

Proactive Production Monitoring

The PPT solution is a proactive production and inventory monitoring & support solution. It guide production facilities for improving Productivity, reduction in downtime and improving the quality thus increasing the Overall Efficiency (OEE).

Integrated Maintenance Analytics

Integrated Maintenance Analytics offers deeper insight into key Maintenance parameters, history and real time status of the connected assets. The solution has analytical capabilities for RCA and predictive maintenance.

Manufacturing Analytics Dashboard

Enterprise dashboard with unified visibility on financial & plant level KPIs. This solution connects key plant metrics and with business KPI and monitor them in real time. The solution as multi-plant comparison dashboards along with detailed RCA capabilities on selected metrics.

WIP Inventory

WIP Tracking module tracks and controls the manufacturing execution including status and history of products and resources on the production floor. It also enables a real-time view of production activity.
Manufacturing Execution: Proactive Production Monitoring

Challenges

- Management and Real time monitoring of
  - Different MES, plant automation and shop floor systems
- Manage product flow through discrete work centers
- Multiple / Remote manufacturing facilities such as off-shore facilities, sub-contracting of manufacturing
- Poor quality of business focused manufacturing information
- Disconnect between plant and enterprise

Solution Features

- Web based visualization of real time manufacturing and enterprise level KPI’s based on roles
- Built in using SAP MII for providing easy integration to shop floor for retrieving real time information from SAP ME system
- PPM solution pulls data from multiple data sources such as SAP ERP, equipment, operator input etc.
- Supports easier and better decisions with raw data converted into meaningful and actionable source of information

Benefits

- Improve productivity of manufacturing investments provides the ability to monitor, support and guide manufacturing facilities
- Improved Product Quality by reducing defects & increase OEE
Manufacturing Execution: Integrated Maintenance Analytics

**Business Problems**

- Are there indications that a major component failure is likely to occur in the immediate future?

**Analytical Resolution**

- Classification model to Predict Major Component Failures
  - Sensor Data
  - Alarm Data
  - Repair History

- Regression models to Predict Component Life Based on Specific Machine History
  - Repair History
  - Events

- Association Models to Identify Failures that Occur Together
  - Warranty Data
  - Repair History

**Business Benefits**

- Product health score used to predict impending failures
  - Understand impacts of individual low level failures, estimate component life

- Identify components that have a high probability of experiencing similar failures
Manufacturing Execution: WIP Inventory Tracking

Challenges

• Poor visibility into location, quantity and status of the WIP Inventory
• WIP location is frequently moved and cannot be tracked using conventional MES
  • WIP Inventory on hold is not properly tagged in MES
• Rapid WIP Buildup as Equipment downtime Vs WIP buildup analysis is not done online

Solution Features

• Provides RFID based WIP movement, location reference and Ambient conditions
• Provides easy configuration and can be plugged into conventional MES as a separate module
• Leverage latest IoT Technologies and available in .NET and J2EE versions
• Ability to link WIP Inventory with Production order, equipment and shifts
• Web based application which can be accessed through tablet/mobile browsers

Benefits

• Improved Geolocation based WIP tracking
• Real-time alerts on Inventory buildup, locations anomalies and shelf-life expiry
• Reduction in WIP (smart management of Inventory buildup) and ability to operate lean
Digital Manufacturing and Connected Factory

Manufacturing Simulation
Connected Factory: Manufacturing Simulation

Industry Type based on
• Volume
• Variants
• Low inventory & WIP
• Area
• Components Size
• Process time

Opportunity To add Value
• Throughput analysis
• Resource Utilization analysis
• Production scheduling
• Annual Demand Vs Production analysis
• Internal logistics simulation
• Resource (Man, Machine & Area) Utilization analysis
• Layout analysis (simulation of multiple options)
• Annual Demand Vs Production analysis
• Traffic congestion analysis
• Inventory & WIP analysis
• Supply chain logistics simulation
Manufacturing Simulation : Line Balancing

Client: Off highway equipment OEM

Need: New facility layout modeling for line balancing

Objective: Client is building new assembly line. Assembly line is already been designed and plant building is under progress. Client wants to balance the line with the help of discrete event simulation to optimize and justify their decisions. We built a flexible model with different options for selecting the number of resources with kinematics, which will be used by clients production planning team.

Tool Used: Tecnomatix PlantSimulation

Solution:
• Layout study and process study
• Defining model parameters with flexible programming to run the model by changing number of resources and process speed
• Utilization report and bottleneck identification report for line balancing
Manufacturing Simulation: Material Line Optimization by using Plant Simulation Technique

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Project Details

Client: U.S based company leading in agricultural, construction equipment and automotive parts manufacturer

Overview of Engagement: Geometric partnering with the client to restructure the existing powertrain material and equipment station layout to support new product line

Project name: Manufacturing and Material Line Optimization

Inputs: 2D layout

Execution location: Onsite/Offshore

Tools: Process Planning

Customer Requirement

Required a partner to re-design a new product line for powertrain production as per the world class standards to initiate new material delivery strategy and lean manufacturing

Business Challenges

Revamp new production line to enhance the manufacturing process of powertrain

Solution Approach

- Project charter created with dependencies/Objectives
- Designed flexible material handling, packaging and line presentation equipment with better visual aids
- Identified components for kitting and sequencing to reduce the footprint of the material at line side
- Minimized the non-value added work and balanced the workload between the resources to eliminate wait time and WIP
- Optimized the material delivery routes to improve the utilization of the material handling equipment station with appliance of lean/JIT concept

Key Benefits

- 20% cost savings to customer due to outsourcing
- Our solution reduced fork truck usage and floor space requirements,
- Eliminated non-value added work and increased productivity by 20%
Digital Manufacturing and Connected Factory

Manufacturing Analytics
Connected Factory: Manufacturing Analytics

Enterprise Interoperability & Business Visibility

- Supply/demand match
- Yield & Quality prediction
- Real time data
- Root cause & defect detection

Asset Management

- Predictive maintenance
- OEE & RUL
- Track & Trace
- Inventory Management

Operational Effectiveness

- Increased Productivity
- Reduced Waste
- Enhanced Safety
- Better resource utilization

Informed Decisions
New Service models
Profitability & Cost savings

Enables more timely product manufacturing and shipment, reduced rate of product rejection, faster product repair turnaround, and enhanced production throughput.
Manufacturing Analytics – Lost Time and OEE Analytics

Manufacturing productivity depends upon many factors, including Lost Time (due to setup / changeovers, unplanned line downtime, etc) and Overall Equipment Effectiveness (OEE). Analytics on data from manufacturing operations systems are critical to understanding reasons for low productivity and identifying improvement opportunities.

Manufacturing Plant

1. Data Ingestion
   - Data collected from production operations systems

2. Exploratory Data Analytics

3. Predictive Modeling

Lost Time Analysis

OEE Analytics

OEE Dashboard
Manufacturing Analytics: Predict Quality Deviations & Root Cause Analysis

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**Pain Point:** Lack of visibility of Quality Deviations and Production Shortfalls impacting delivery commitments

**Solution:** Machine learning based predictions of quality and output. Data driven approach to identify hidden patterns and relationships that impact quality/production outcomes

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**Use Case Description**

1. Acquire machine data and process parameters from IoT enabled devices & equipment

2. Data exploration and feature elimination. Correlation Analysis of state variables to Outcomes (Pass or Fail) through supervised learning.

3. Multinomial Logistic regression to Predict Quality Shortfalls. Correlations driven remedial action to prevent undesirable outcomes

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**Analysis Techniques**

- Correlation Analysis to identify impact of state variables and process settings on Yield outcomes
- Prediction of Quality Shortfall based on regression analysis to create a mathematical model of learning
- Trace back causes for quality deviations and anomalies associated with equipment & process settings

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**Benefits of Using Advanced Analytics**

- **Ability to Predict Shortfall** – Enable Manufacturing Unit to predict their ability to meet delivery commitments
- **Proactive Remediation** – Preempt quality and output shortfalls up-front so that remedial actions may be taken preemptively
- **Ensure high OEE** – Root cause analysis driven isolation of problem sources and recalibration of equipment, as needed
**Manufacturing Analytics: Inventory Management & Dynamic Replenishment**

**Use Case Description**

**Pain Point:** Excessive costs associated with overstocking of inventory. Inability to track critical assets.

**Solution:** Provide role based access and visibility of inventory in real-time and Optimize routing.

**Analysis Techniques**

- A wide range of tracking devices & sensors were used to create the data ingestion layer for the IoT infrastructure.
- Time histories of asset movement & site specific demands were built into the Optimization model for dynamic replenishment & optimal re-routing to critical sites.
- External event predictions were made.

**Benefits of Using Advanced Analytics**

- **Role based visibility** – Enable role based visibility and traceability of assets in custom dashboards.
- **Excess Inventory Cost Reduction** – Predict changes in demand, leverage historical data and minimize stocking of excess inventory.
- **Dynamic Re-routing** – Optimization based dynamic replenishment of inventory to ensure supply to critical sites.

1. Implement tracking of assets/pallets through GPS sensors and RFID.
2. Implement cloud based monitoring and inventory management solution.
3. Optimization wraparound to dynamically replenish stock to critical sites.
4. Build role based dashboards to monitor asset locations and client site demands.
Digital Manufacturing and Connected Factory

Smart Maintenance
Area of Engagement
Available via cloud or on-premise
Flexible extension concept for customers to build industry or customer specific models and analytics
A scalable Machine Learning Engine that drives data science insights into our business processes
Flexible visualizations across equipment structures
End-to-end process integration... Alert, Discover, Remedy
Smart Maintenance management with Android

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Customer Profile
A Japanese multinational electronics corporation

Business Objective
To develop a MMS product for vendors and partners that provides innovative solutions through their mobility devices

Technologies Used
Web: ASP.NET, C#, MVC4, SQL Server, JQuery
Android: Android SDK, Java, HTML5, JQuery Mobile, Metaio

Platform
Multichannel: Web & Android

HCL Solution

1. Created Mobile specific layouts
2. Created native container for hybrid application
3. Used Bar Code and Bluetooth scanning for “Scan On”
4. Used AR Markers to identify the Machines
5. Used the positions of AR Marker to identify the parts and Maintenance Order History

Accomplishments
- Enhanced user Experience with various views like line view, AR view.
- Multi-lingual support for easier customization
- Maximum Code Reuse resulting the reduced cost
Smart Maintenance: Virtual / Augmented Reality in Manufacturing

- HCL has developed “Pick to Light” solution based on Augmented Reality in Plant Maintenance.

- Anark MBEWeb™ - Joint solution developed with Anark to re-purpose 3D data for downstream usage

Solutions frameworks - Drone Based Semi-Automatic/ Automatic Solution for Grid Inspection Proposition
More than 160 patents filed for a single customer in the past 4 years in Image processing

Virtual Pick to Light using Augmented reality

Solutions frameworks - Mfg. material line optimization for flexible material handling, packing and line presentation equipment’s with better visual aids, sequencing to reduce footprint of material and minimize the non-value added work.

Virtual Reality in Manufacturing

Visual Analytics in Manufacturing

Augmented Reality in Manufacturing
Digital Manufacturing and Connected Factory

Roadmap Development and Next Steps
HCL has developed Industry 4.0 Assessment Framework based on Best Practices and leading / disruptive technology trends in the Industry.

The Assessment provides deeper insight into client Manufacturing IT capabilities and Readiness to adopt Industry4.0 change.

Client systems and practice are rated on a 5-point scale and compared with Industry Best Practices for improvement planning.

Ten Industry Best Practices in focus for this assessment include:
1. Manufacturing Data Analytics
2. Robotics & Artificial Intelligence
3. Manufacturing Automation
4. Digital Clone or Simulation
5. 3D Printing
6. Manufacturing IoT
7. Cloud & Plant Cybersecurity
8. Augmented / Virtual Reality
9. Visual Analytics
10. Small Batch Manufacturing
HCL’s proposition for Digital Manufacturing – from shop floor to top floor

Integrated Customer Portal
Integrated Command Center
Product Management
App Store

API’s
API Management
Developer Portal

Customer Specific IoT Platform
- Integration platform
- Device Management
- Customer and Partner Equipment Data

Customer Specific IT Systems
- CRM
- ERP
- Production Planning
- Product Technical Information
- Service Contract Management

Device Communication (Zigbee, Bluetooth, Wi-Fi, RS-232, RS-485)

Visualization and Portals
Ecosystem enablement
Connected Applications
Analytics
IT-OT Converged Middleware

Remote Monitoring
Device commissioning & Provisioning

Customer Equipment (All Divisions)

Partner Apps
## Key Benefits

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### 1. Improving Line Productivity
- Increased line productivity with better work process design and tools/fixtures.
- Automation and integration of specific operations and functions.
- Reduce line rejection thru better mistake proofing.

### 2. Recall, Return Management, Parts Traceability, Multiple Models on Line
- 360 degree view of parts movement.
- End to end supply chain traceability.
- Flexibility to manufacturing multiple products on the same line with small setup downtime.

### 3. Reduction in Rejections & Line cost control & throughput
- Operations process Monitor & control at Level0 – Level1.
- Predictive analytics to help control QA issues before they occur.
- Line / Cell operations automation to harmonize sequencing, helps control cost & improve throughput.

### 4. Best practices of plant ergonomics & capacity optimization
- Support new plant design and layout optimization thru simulation.
- Plant Asset utilization and capacity throughput optimization.
- Monitoring of Plant Assets during setup phase.
Thank You

End Of Presentation
Thank You

Q&A