Industry (Industrie) 4.0 and IoT

IBM’s Point-of-View and Potential Technical Approaches
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Outline

• Background
• What is Industry 4.0?
• IBM’s Industry 4.0 Approach
• Motivating Examples
• Summary & Conclusions
Background
Technology trends and the 4th Industrial Revolution
Increasing demand for customization, combined with pressure to lower costs and time to market, are driving Industry 4.0.

In the beginning, we just made them all alike (efficient, but it didn’t meet all customers’ needs)

…or we built them one-by-one for each new customer (it met the needs, but was very expensive)

Now customers demand increasingly specialized and customized products and costs are going through the roof!

Source: http://minicoopergraphics.com/
Technology Trends – The rapid evolution of technology is creating a lot of excitement and questions around what to do…

All coming together to create a perfect storm…

- Inexpensive sensors
- Computing power
  - Cloud
  - Mobility
  - Social
  - Big Data & Analytics
  - Cognition
  - Open Platforms
- Internet of Things (IoT)
- Circular Economy
- Millennials

The way information technology is adopted and consumed is changing…

InterConnect 2016
Various initiatives around the world are seeking to accelerate the potential in manufacturing. Technology trends are fueling the 4th Industrial Revolution.

- Enable Innovation & Differentiation
  - Productivity
  - Efficiency
  - Revenue
  - Customer Value
  - Competitiveness
  - Agility & Flexibility

Create new opportunities to achieve levels of productivity & specialization not previously possible.

Create value opportunities through new services

Respond to demographic change in the workplace

InterConnect 2016
Capabilities required to enable the 4th Industrial Revolution

- Ability to connect and manage devices
- Near real-time data collection
- Insights of what is happening
- New business models
- Flexible machines
- 3D printing
- Machine to machine
- New standards and protocols
- Smart and networked products
- Ability to communicate thru the Internet
- Self diagnose / self awareness
- The API economy
- Vertical / horizontal integration across value chains
- New delivery channels and business models
- Embedded in equipment, products and services
- Predict what may happen
- Prescribe actions for best outcomes
- Self learning
- Communicate in natural language

Sources: Acatech: Recommendations for implementing the strategic initiative Industrie 4.0, April 2013; Gartner: Industrie 4.0: The Ten Things the CIO Needs to Know; Deutsche Bank Research: "Upgrading of Germany's industrial capabilities on the horizon", April 2014
Supporting Custom / Smart Manufacturing

Today

- Static Production Lines: Hard to reconfigure to make new product variant
- Not possible to incorporate individual customer requests

![Rigidly sequenced car manufacture on a production line](image)

Source: Final report of the Industrie 4.0 working group

Tomorrow

- Dynamic Production Lines
- Smart products move autonomously from one CPS-enabled processing module to another
- Dynamic reconfiguration of production lines

![Decoupled, fully flexible and highly integrated manufacturing systems](image)

Source: Hewlett-Packard 2013
What is Industry 4.0?
Vision, goals, characteristics, enabling technologies..
Industry 4.0: An initiative to transition to the fourth industrial revolution ushered by the introduction of the Internet of Things and Services into the manufacturing environment

Vision – Industry 4.0 as part of a smart, networked world

- **Smart factory** – creating smart products, procedures, & processes via CPS
- A new paradigm of autonomous and decentralized control in production via CPS

Strategic Goals

- **Meet individual customer requirements**
  - Individualized customer-specific criteria
  - Profitable lot size of 1

- **Increase efficiency & productivity**
  - Optimize processes across entire value network

- **Flexibility**
  - Dynamic business processes
  - Agile & flexible engineering & manufacturing processes

Key Enablers: Cyber Physical Systems (CPS), and Internet of Things & Services

- CPS: Autonomous entities – Monitor physical processes & make decentralized decisions, Communicate with each other to build ad-hoc networks for self control & self optimization

Connecting machines, people & products to enable new services and business models

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Smart Factory of the Future – the vision of Industry 4.0

- Dynamic & flexible behavior via CPS
  - Manufacturing resources are enhanced to CPS
  - Dynamically create ad-hoc CPS networks to respond to different situations in real-time

- New approach to production enabling:
  - Horizontal & Vertical integration
  - End to end engineering across the value chain
  - Smart Products
    - Uniquely identifiable & maybe located at all times
    - Know their own history, current status, & alternative routes to achieving their target state

In the smart factory, humans, machines, and resources are communicating with each other as natural as in a social network.
Vertical & Horizontal Integration

- The embedded manufacturing systems are vertically networked with business processes within factories and enterprises.
- And horizontally connected to disperse value networks that can be managed in real-time from the moment an order is placed right through to outbound logistics.

### Vertical Integration within Factories & Enterprises

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Source: ISA 95

### Horizontal Integration through Value Networks

![Horizontal Integration through Value Networks](image)

Final report of the Industrie 4.0 working group

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End to end engineering across the entire value chain

- CPS to deliver end-to-end business processes including the engineering workflow
  - IT systems provide end-to-end support to the entire value chain, from product development to manufacturing system engineering, production and service.

- Supports Optimized Decision Making (in Engineering & in Production):
  - provides end-to-end transparency in real time
  - Allows early verification of design decisions in the sphere of engineering
  - more flexible responses to disruption and global optimization across all of a company’s sites in the sphere of production.
Cyber-Physical Systems:
The Next Computing Revolution Enabling Intelligent Environments

• “CPS are engineered products with integrated computational and physical capabilities for automatic and, increasingly, autonomous operations, in interaction with physical entities/environment and humans, to produce the desired physical outcomes.” [NIST]

Source: NIST - “Framework for Cyber-Physical Systems Release 0.8”; September 2015 – Cyber Physical Systems Public Working Group

- Interact with the physical world (sense/measure/effect)
- May operate in isolation or in concert (collaborate directly with each other)
- Connected in clusters of systems (statically and/or dynamically configured connectivity)
- Intelligent – from programmed automation to autonomous operations

- Systems of CPS: CPS clusters are increasingly brought online with broader systems
  – Realize a global view of the states of the vast network of CPS
  – Coordinate / orchestrate their operations to achieve optimization at a global level
Logical Functional Decomposition of the cyber-physical systems

Orchestrates CPS activities at a global scale

Implements the Sense-Actuate Control loop
CPS Domains Explained …

**System of Systems Domain**
- Information Component
  - Gather, transform, persist, & analyze data.
  - Synthesize info from other CPS and other sources for better decision making
  - Analytics to gain insights globally
- Business Component
  - Enable end-to-end operations of CPS including business processes and procedural activities
    - ERM, CRM, Planning & Scheduling, Payment, etc.
- Application Component
  - Coordinates the activities of CPS globally
    - Based on prescribed objective, rules, models, ..
- Entity Management Component
  - Provisioning, configuration, update, decommissioning, etc.

**Cyber-Physical Domain**
- Sense / Actuate Control Loop
- CPS Connectivity & Collaboration
  - Connect & interact with each other
    - Logical communication between cyber components
    - Physical interactions
  - Form communities by configuration or dynamically
  - Activities maybe coordinated by a CPS that communicates logically with other CPSs
- CPS co-design ☐ Coherent model of CPS communication & physical interactions
- Continue to operate with no connectivity
CPS Platform Requirements

- **Decision Processing**
  - Build ad-hoc networks depending on situation
  - Optimize network in local decision-making
  - Enable autonomy in decision-making of CPS
  - Utilize comprehensive models of real production
  - Monitor, diagnose and perform actions online

- **Knowledge Processing**
  - Detect patterns and similarities in production
  - Prepare, compile and filter data
  - Transform know-how and expert knowledge
  - Predict decision parameters based on past data

- **Real-time Processing**
  - Access status & description of CPS in real-time
  - Build networks: Build CPS networks in real-time
  - Control operative production in real-time

- **Data model & data integration**
  - Unify **semantics** (info models & meanings) & **interfaces** (interfaces & communication)
  - Integrate life cycle: Integrate data along the life cycle of CPS
  - Integrate horizontally: Integrate data along the value chain and network
  - Integrate vertically: Integrate data of the automation pyramid

- **Data Content**
  - Include product data and description
  - Include production processes data and description
  - Include business data and parameters
  - Include sensor and actor data from CPS

- **CPS Collaboration- Communication Language**
- **CPS Management Env. (Buildtime/Runtime)**
IBM Industry 4.0 Approach
A foundation for Industry 4.0 CPS Platform
Smart mfg. solutions (aka CPS systems) are composed from IoT, IoS, & IoP using the IBM Watson IoT Platform

Composable smart mfg solutions (aka CPS systems)

Standards based, composable connecting machines, people and products to achieve levels of productivity and specialization not previously possible enabling innovation and differentiation.

Example CPS Solutions

- Employee Safety
- Predictive Maintenance
- Operations Analytics
- Predictive Quality
- Service Advisor

(Deploy and run on premise (factory or enterprise), on the cloud, with or on the edge, or on the device)

InterConnect 2016
Information from Operations devices (machines, vehicles, etc) is accessed through the edge and triggers actions involving services related to existing systems, external systems and people.
The IBM Watson IoT Platform—Enabling IoT Real-Time Insights

- Contextualizes device data
- Monitors streaming data to detect situations
- Acts on insights from the data

Data comes in through IoT Foundation, IBM’s IoT cloud platform. Real-time data drives real-time analytics and business rules. Rules trigger an action, such as creating a work order in EAM (Maximo). Recommendations drive response in EAM (Maximo).

1. Sensors provide information about the device
2. IoT Foundation
3. Data is enriched with master data from Maximo
4. Real-time dashboard
5. Recommendations drive response in EAM (Maximo)

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Analytics at the Edge/Gateway, or in the device itself, are increasingly required to support “CPS” concepts …

Analytics can be applied at the edge, or on the device itself, to filter out a lot of the collected data that is not really relevant for higher level analytics. Anomaly conditions can also be detected and handled at this layer before involving the higher level systems (or, if needed, alerts can be generated and forwarded "above").
“Quarks” is an IBM contribution to the open source community to support edge analytics

IBM’s Open Source Quarks Pushes IoT Analytics to the Edge

By David Ramel  02/17/2016

IBM has open sourced new technology called Quarks to push Internet of Things (IoT) analytics from centralized systems out to the actual edge devices that are collecting and spewing out vast amounts of data.

By taking the analytics to the devices -- instead of the devices streaming data to a central analytics engine -- IBM says organizations can save on communications costs, react quicker to streaming events and reduce the processing load of the main analytics server.

“Quarks is a programming model and runtime that can be embedded in gateways and devices. An open source solution for implementing and deploying edge analytics on varied data streams and devices. Quarks can be used in conjunction with vendor and open source data and analytics solutions such as Apache Kafka, Spark and Storm. Quarks is API driven and modular.”
Asset reliability, process and product quality improvement are very important to achieving Industry 4.0 goals...

Information from Operations devices is used to create and evaluate asset and process performance models to predict maintenance and quality issues. IBM is creating industry specific CPS solutions in this area.
Machine Learning Use Cases:
1. PM’s analytic models creates predictive and dynamic rules thresholds for RTI
2. RTI Identifies significant changes in sensor values, allowing PM to only processes events that matter.
3. RTI rules filter out known conditions that lead to false positives.

Benefits
• Smarter, dynamic rules by leveraging multivariate statistical algorithm
• Reduce machine event ingestion by dynamically pre-selecting events
• Embed SME’s tribal knowledge into analytics-based outcome
• Drive highest levels of reliability by uncovering hidden patterns that can predict failure well in advance

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Analyze manufacturing equipment data to identify impending equipment degradation or failure, impacting production line cycle time.

- Monitor health and condition of manufacturing equipment
- Predict manufacturing equipment failures & deterioration prior to outages
- Forecast repair and replacement requirements
- Integrate with asset management and alert systems to act on impending failure
- Benefits:
  - Reduce downtime and service outages for production line
  - Forecast failures/deterioration for equipment with actions
  - Optimize inventory and spare parts planning
  - Reduce operational, maintenance, and service costs

One example pre-integrated industry solution - IBM Asset Analytics for Manufacturing Equipment
Cognitive Computing helps to accelerate breakthroughs for Industry 4.0

Information from Operations devices can be combined with a Watson “corpus” of knowledge to create advisors for operators and maintenance technicians.
IBM Watson can augment human experience to support analysis and decision making in manufacturing.
End-to-end integration (aka Continuous Engineering) is a key, Industry 4.0 requirement

The CPS platform also supports the flow of information from engineering, to manufacturing, to the field, and back.
IBM Continuous Engineering

Other Data Sources
(Weather, Twitter, Warranty...)

- Product Operation Data
- Maintenance Data
- Warranty Data
- Customers Sentiments
- External Data Sources

Smart Products

IoT Platform

- New Deployments
- Product updates and
- OTA
- Device Configuration
  Management

Design for Analytics

- Requirements analytics
- System Requirements
- System Design
- Virtual Verification

Deployment/ Release to Mfg.

System Test

System Verification and Validation

Implementation

Engineering Data Analytics

Requirements analytics

System Requirements

System Design

Virtual Verification
Industry 4.0 requires a flexible, configurable application environment that support fast and frequent changes and consistent UIs …

Hybrid cloud and application configuration tools support the Industry 4.0 needs for flexible deployment and reconfiguration of CPS solutions.

Likewise, UI development tools provide consistent, cross-platform support for web/mobile user experience.
Bluemix: IBM’s Cloud platform
Build, run, scale, manage, integrate & secure applications in the cloud

Developer experience
• Rapidly deploy and scale applications in any language.
• Compose applications quickly with useful APIs and services and avoid tedious backend config.
• Realize fast time-to-value with simplicity, flexibility and clear documentation.

Enterprise capability
• Securely integrate with existing on-prem data and systems.
• Choose from flexible deployment models.
• Manage the full application lifecycle with DevOps.
• Develop and deploy on a platform built on a foundation of open technology.

Bluemix service categories

- DevOps
- Big Data
- Mobile
- Watson
- Business Analytics

- Database
- Web and application
- Security
- Internet of Things
- Cloud Integration

- API management & Integration

Built on a foundation of open technology.
Examples
Edge & Backend Analytics Solution for Manufacturers

- Problem: A failure of one industrial robot causes serious disruption/costs to manufacturers.

- Acoustic sensors – Crack detection edge analytics – Failure prediction analytics

Source: Hiroshi Yamamoto – IBM
Equipment Health, Worker Safety, & Production Optimization – CPS examples in steel manufacturing

Orders
- Customer
- Order quantity, price, due date
- Production routing

Production data
- Production status
- Inventory (WIP, FG,..)
- Equipment status
- Workstation status, etc.

CPS Equipment Health
- Sub-assembly / component lifetime wear indicators
- Leading failure indicators
- Engine alerts
- Overload / over speed alerts
- Permit to work
- Use of safety equipment
- Unsafe condition of equipment
- Fatigue
- Alertness
- Fall / Injury
- Production real-time status
- Equipment utilization
- Best time to perform maintenance
- Worker productivity

CPS Worker Safety
- Sub-assembly / component lifetime wear indicators
- Leading failure indicators
- Engine alerts
- Overload / over speed alerts
- Permit to work
- Use of safety equipment
- Unsafe condition of equipment
- Fatigue
- Alertness
- Fall / Injury
- Production real-time status
- Equipment utilization
- Best time to perform maintenance
- Worker productivity

CPS Production Optimization
- Sub-assembly / component lifetime wear indicators
- Leading failure indicators
- Engine alerts
- Overload / over speed alerts
- Permit to work
- Use of safety equipment
- Unsafe condition of equipment
- Fatigue
- Alertness
- Fall / Injury
- Production real-time status
- Equipment utilization
- Best time to perform maintenance
- Worker productivity
End-to-End Engineering

**Model:** Combination of collaborative development and local manufacturing

**Local Motors:** World’s First 3-D printed car

**The Edge:** Products to Market 5x Faster and 100x Less Cost
For more on Local Motors, see InterConnect Session: ITI-6266: 3D Printed Cars, Microfactories and Autonomous Vehicles: Local Motors' Partnership with IBM
**Getting Started on your Industry 4.0 Journey**

An approach for your Industry 4.0 Transformation

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**Industry 4.0 approach**

- Leverage existing applications and data sources
- Leverage on the advances in analytics, mobility, cloud and security
- Instrument physical processes as necessary
- Agility: quickly compose new business processes that can be deployed fast and continuously improved
- Manage by exception, automate what is known
- Remote access (mobile)
- Hybrid cloud deployment in a cyber security environment

**Business-driven approach**

- Tackle industry issues that were not properly solved before (existing pain points)
- Implement new business processes of high business value
- Increase company’s agility to respond to customer and market dynamics

**Establish an Industry 4.0 journey**

- Establish the technology foundation
- Prioritize Use Cases based on business value and readiness to implement
- Focus on achieving quick results to get buy-in from stakeholders
- Think big, start small, scale fast

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Getting Started – Industry 4.0 Engagement Model

1. I4.0 Opportunity Assessment Workshop
   - Identify key I4.0 opportunities within enterprise functions and across the value chain
   - Core understanding
   - Opportunity assessment
   - Opportunity prioritization

2. I4.0 Strategy Accelerator
   - Identify I4.0 capabilities, assess business value, and create realization plan
   - Industry context
   - Current state assessment
   - Business value and strategy
   - Solutions and technology
   - Realization plan

3. I4.0 Platform Design and Implementation
   - Define architecture, create detailed designs, conduct testing, and deploy the platform
   - Requirements
   - High-level architecture
   - Detailed design and build
   - Testing
   - Operations and support

Timeframes:
- 2 days
- 6-14 weeks
- 3-9 months

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Summary & recommendations

• Industry 4.0 is an initiative to help manufacturing to transition to the 4th Industrial revolution
  – A multi-year journey to transform the entire company and requires a high-level of investment
  – Involves the digitization and interconnection of products and services across the entire value-chain
  – Requires integrated use & analysis of data, and integration/collaboration for improved management of vertical and horizontal value chains
  – New digital business models enable customer-specific solutions

• Benefits
  – Higher productivity, revenue, better customer satisfaction, and increased competitiveness
  – Shorten time-to-market – the engineering end-to-end value chain

• Challenges
  – Requires extensive change, and high-level of investment (but can be phased)
  – Difficulty in quantifying business benefits
  – Industry standards have to be defined and agreed upon.
  – Requires new skills and qualification of employees

• Develop a comprehensive Industry 4.0 strategy
  – Review existing competencies and define digitization objectives – determine current maturity level
  – Choose an experienced partner (IBM!) for your Industry 4.0 journey
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Industry 4.0 (aka Smart Mfg.) is enabled by IoT & SOA

Industry 4.0

A term invented by Kevin Ashton in 1999

Enables

IoT

A collective term for technologies & concepts of value chain organization

Ind 4.0 - A German hi-tech strategy project in 2013

Similar goals to the Smart Mfg Leadership Coalition (US)

Cyber-physical systems monitoring physical processes, and making decentralized decisions

Design based on interoperability, virtualization, decentralization, real-time capability, service orientation, and modularity.

Network of physical objects or "things" embedded with electronics, software, sensors and connectivity, to exchange data and other business processes

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Cyber-Physical Systems: The Next Computing Revolution Enabling Intelligent Environments

• CPS are systems that bridge the cyber-world of computing & communications with the physical world
  – Build on the discipline of embedded systems – computers and software embedded in devices whose principle mission is not computation, such as cars, toys, medical devices, and scientific instruments
    • A confluence of embedded systems, real-time systems, distributed sensor systems and controls
  – Interact with the physical world, and must operate dependably, safely, securely, efficiently, and in real-time

• Definitions:
  – CPS are engineered systems that are built from, and depend upon, the seamless integration of computational algorithms and physical components (NIST)
  – CPS are integrations of computation, networking, and physical processes. Embedded computers and networks monitor and control the physical processes, with feedback loops where physical processes affect computations and vice versa (cyberphysicalsystems.org)

• Enable Intelligent Environments - Smart building, Smart Highway, Smart Factory, etc.
  – CPS are Intelligent Autonomous entities – Monitor physical processes & make decentralized decisions; Communicate with each other to build ad-hoc networks for self configuration, control, & optimization
Industry Challenges

• Maturity level of required technologies
  – The technology base to build large-scale safety-critical CPS-based solutions correctly, affordably, flexibly, and on schedule is not there yet.

• Difficult to quantify business benefits for Industry 4.0
  – New solutions require significant changes & lack clear cost/benefit case

• Cost pressures in the manufacturing domain

• Industry standards
  – Establish: Define and agree upon / Vendor & Government Support

• New employee skills & qualifications required
  – A digitized enterprise with new processes & business models

• Company cultures may inhibit collaboration and adoption of new technology
ACATECH
National Academy of Science and Engineering

Recommendations for implementing the strategic initiative INDUSTRIE 4.
April 2013

Objective:
Germany (Europe) to increase its global competitiveness and preserve its domestic manufacturing industry by introducing the Internet of Things and Services into the manufacturing environment.

InterConnect 2016
Multiple cloud models exist, but “Hybrid” seems to be best suited to manufacturing.

Firms will need to build across traditional cloud boundaries to maximize investment.
The **IBM MobileFirst Platform** provides integrated, but modular services to enable companies to deliver great mobile apps.

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