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Collaborative Manufacturing Systems

Module II Machines Collaboration on a Shop Floor

Collaborative Manufacturing Processes

Universidade do Minho

Curriculum Development
of Master's Degree Program in
Industrial Engineering for Thailand Sustainable Smart Industry

padlet

Brainstorming Ideas about Collaborative Manufacturing Processes for Industry 4.0

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Collaborative Manufacturing Processes

Evolution of Manufacturing Processes

- Individual skill-oriented enterprise
- Technology-oriented mass production process
- Rapid response to market changes
- Globally distributed manufacturing

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Collaborative Manufacturing Processes

Global Manufacturing

Three features for the future manufacturing

- *Close collaborations between companies and organisations all over the world, to provide a specific product or outcome.*
- *The needs to integrate the whole lifecycle of a product from initial conception through to final disposal, to fully satisfy the needs of the customer and society.*
- *Adoption of Information Technologies in ways that integrate global enterprises, to achieve really close relationships between widely scattered groups and people.*

  (Specialisation, differentiation, and integration taking place at the same time).

Source: Globman21 Feaasibility Study

Examples of Global Manufacturing

Several smaller companies that cooperate to design and manufacture a product

A large manufacturer and its supply chain

A global partnership that integrates its activities via computer communication

A flexible organization that changes when new opportunities appear

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Collaborative Manufacturing Processes

Benefits of Global Manufacturing

- Elimination of travel time and associated expenditure
- Availability of world wide expertise
- Maximum possible use of scarce expertise
- The production of the right product at the right place
- Elimination of product shipment time and costs
- Better utilization of manufacturing capacity in remote locations
- Increased competitiveness and profit

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Global Manufacturing Models

Set of business models for distributed manufacturing systems

MPN: The owner-based template is structured as a network of small sized mini factories for the production of goods for the local or regional market responding to the specific needs of customers.

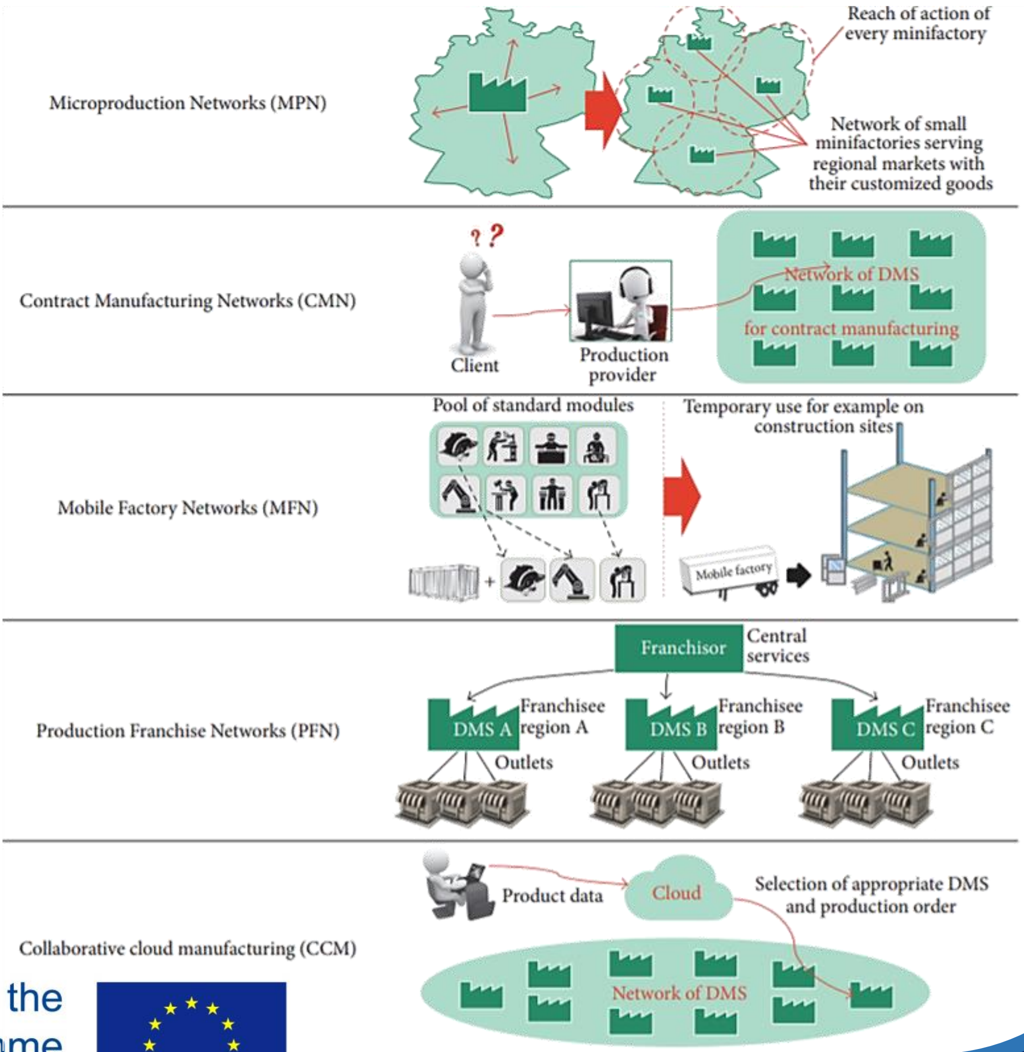
CMN: The service-based template is applicable for service providers or cooperatives with a network of highly flexible and geographically distributed mini-factories for contract manufacturing.

MFN: The rental-based template is suitable for mobile non-location-bound and highly flexible as well as reconfigurable model factories for temporary production on-site.

PFN: The franchise based template shows a concept of DMS-factories operated independently by franchisees with more or less flexible and adaptable production units for geographically distributed production in a franchise network.

CCM: The collaborative-based template enables active participation of the customer in the product development/configuration process through the use of innovative cloud solutions.

(Matt et al., 2015)



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What is Collaborative Manufacturing (CM) ?

- Collaborative Manufacturing allows multiple groups to act together as they set plans and policy, agree to actions, and execute operations.
- CM can boost responsiveness, agility, and customer-centricity. It also fosters the most cost-effective methods to design, source, make, deliver, and service standard, mass-customized or to-order products.

Aims of Collaborative Manufacturing

- Identification of critical business processes across a manufacturing company, even as those processes extend out to its customers and its network of trading partners; and then
- Making those business processes as efficient and flexible as possible to meet both the market demands of today and the “unknowns” of tomorrow.
- To identify critical business processes and make them as efficient and flexible as possible. For agility, data must flow between systems.

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Collaborative Manufacturing Essentials

- Enterprise Digitalization which integrates information and modern manufacturing technologies employing IOTs and big data to deal with product life-cycle and other facets of enterprise operation to attain integration and digitalization of product design, manufacturing, production control processes and manufacturing equipment is needed.
- The rapid development of Information and Communication Technologies (ICT) has helped in the utilization of the Cyber-physical Systems (CPS) tools such as cutting edge sensors, information procurement framework, wireless communication devices, and appropriated processing arrangements.
- CPS is an arrangement of teaming up computational elements which are in escalated association with the encompassing physical world and its on-going procedures, giving and utilizing, data accessing and data-processing services available on the internet.
- Interoperability is defined as a measure of the degree to which diverse systems, organizations, and/or individuals are able to work together to achieve a common goal.
- Syntactic interoperability relies on specified data formats, communication protocols, and the like to ensure communication and data exchange.
- Semantic interoperability exists when two systems have the ability to automatically interpret exchanged information meaningfully and accurately in order to produce useful results via deference to a common information exchange reference model.

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Collaborative Manufacturing Essentials

- The Internet of Things (IoT) provides real-time based information and status of the machines, services and processes in manufacturing environment.
- IoT infrastructure senses the real-time state of service execution to increase the visibility of task progress.
- The IoT technologies can increase the visibility of the real-time scenario and data from the shop floor or manufacturing facility.
- The use of IoT create a dynamic and efficient service selection, adjustments made in the selection due to delay, along with resource allocation.
- Big Data alludes to examination in view of expansive information accumulations.
- IoT enables designers to approach information, for example, machine use, hardware conditions, and the rate of damaged items from any area.
- With the big data produced by the IoT-related gadgets, professionals may apply big data analytics for determining, proactive support, and automation.

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Collaborative Manufacturing Strategy

- An effective Collaborative Manufacturing strategy requires business processes to include more inputs and interactions than most traditional processes.
- To support Collaborative Manufacturing, information systems must integrate and aggregate information from across the manufacturing business and from its suppliers, trading partners, and customers.
- It must also provide the means to intelligently distribute that information across various business entities.

Big Challenges

- The Manufacturing world has turned upside down with the introduction of digitization and Industry 4.0.
- Technologies like Internet of Things, Horizontal & Vertical value chain integrations, Cloud, and Data Analytics are making big waves.
- The boundaries, both inside the enterprise (between shop floor & boardroom) and between enterprises are fast fading away.
- With Customer centricity as the goal, the extended digital enterprise is a reality; organizations are joining hands both internally between departments and with other organizations to provide value to the end customer.

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Collaborative Manufacturing Trends

Digital Benchmarking

Enterprises need a technology that brings information onto a single platform in real time with error-free data and enables benchmarking to avail deeper insights for proactive, dynamic decisions.

There is a burning need to create and use such technologies that enable benchmarking, to invest in innovation, that will take industries to the next level of performance.

With benchmarking at the machine level, plant level, and across multiple plants, enterprises will be able to calibrate their systems and predict throughput.

https://www.thedigitalbenchmark.com/

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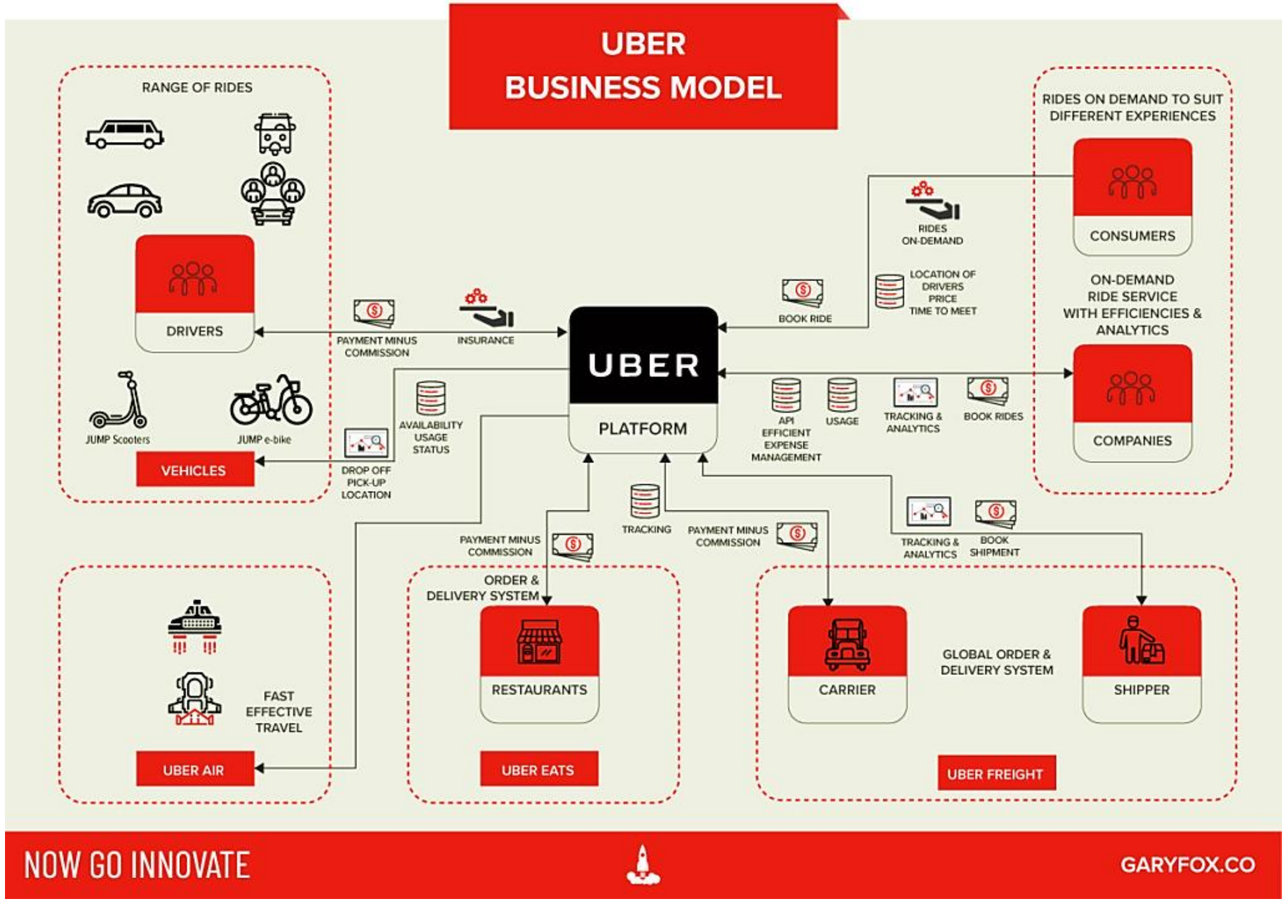
Collaborative Manufacturing Trends

Uber for Manufacturing Assets

IIoT (Industrial IoT) unleashes that opportunity, enabling the decision makers to take a holistic view of all the resources/systems and potentially freeing up these locked up resources for use by supply chain partners.

A marketplace like a model for costly manufacturing resources such as press machine, CNC machines, laser cutting m/c, milling/grinding, turning machines can be created to ensure that the assets are utilized to their full capacity.

In such situations, an Uber-like marketplace model can serve as a boon to the manufacturers



https://www.garyfox.co/uber-business-model/

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Collaborative Manufacturing Trends

Mass Personalization for a Lot Size of 1

The customer is the king & the buying process is customer centric.

The output of the manufacturing process needs to be customized & personalized.

The need of the hour is to make manufacturing more agile & personalized while maintaining their cost advantage.

The software, with its dynamic nature, is now enabling all sectors to use a power of algorithms, digitization, real-time processing to create new products and be more proactive.

https://brandtrends.com/entertainment/mass-personnalisation/

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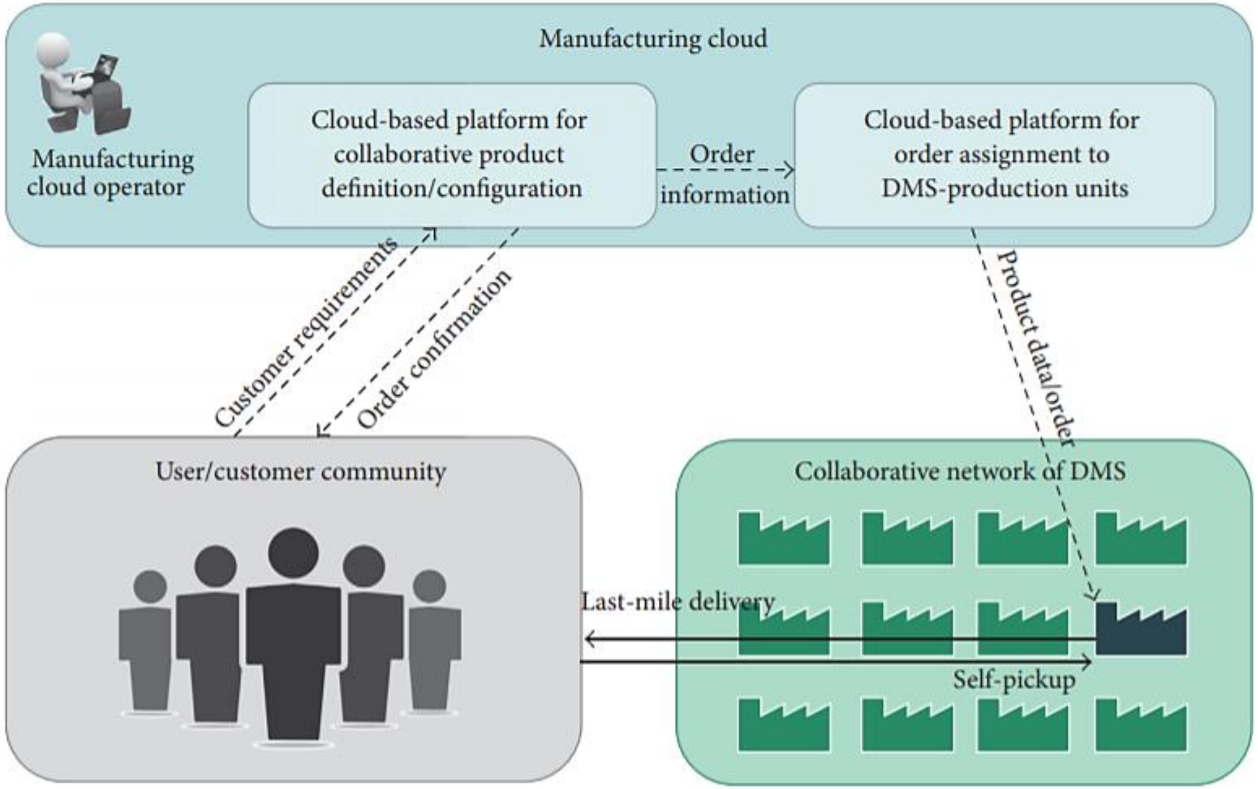
Collaborative Manufacturing Model

Concept of collaborative cloud manufacturing

In ***collaborative cloud manufacturing***, customers or users can *access directly* or through an external operated community to the manufacturing cloud.



Pervasive and efficient allocation and coordination of resources and free capacities or capabilities can be *achieved* by a ***centralized and intelligent manufacturing cloud solution***

(Rauch et al., 2016)

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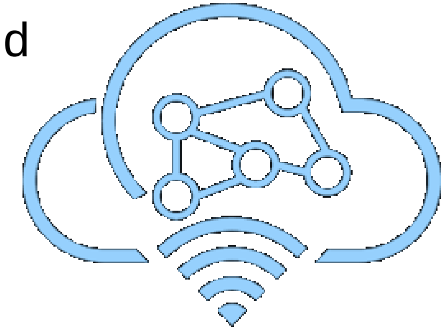
Collaborative Manufacturing Networks

- The fundamental basis of collaborative manufacturing is the organization of production units in collaborative networks.
- The organization in networks through collaborative manufacturing multiplies the available capacities without the need for further investments.
- Hence, companies in collaborative networks can adapt to volatile markets and shortened product lifecycles with high agility.
- In contrast to the many benefits, the decoupling and spatial separation of production units as well as handling of complex production data by multiple production-sites drastically increase the need for coordination.
- Here are mainly new technologies and possibilities in cyberspace to support and facilitate coordination in collaborative networks by digital technologies reducing also complexity.



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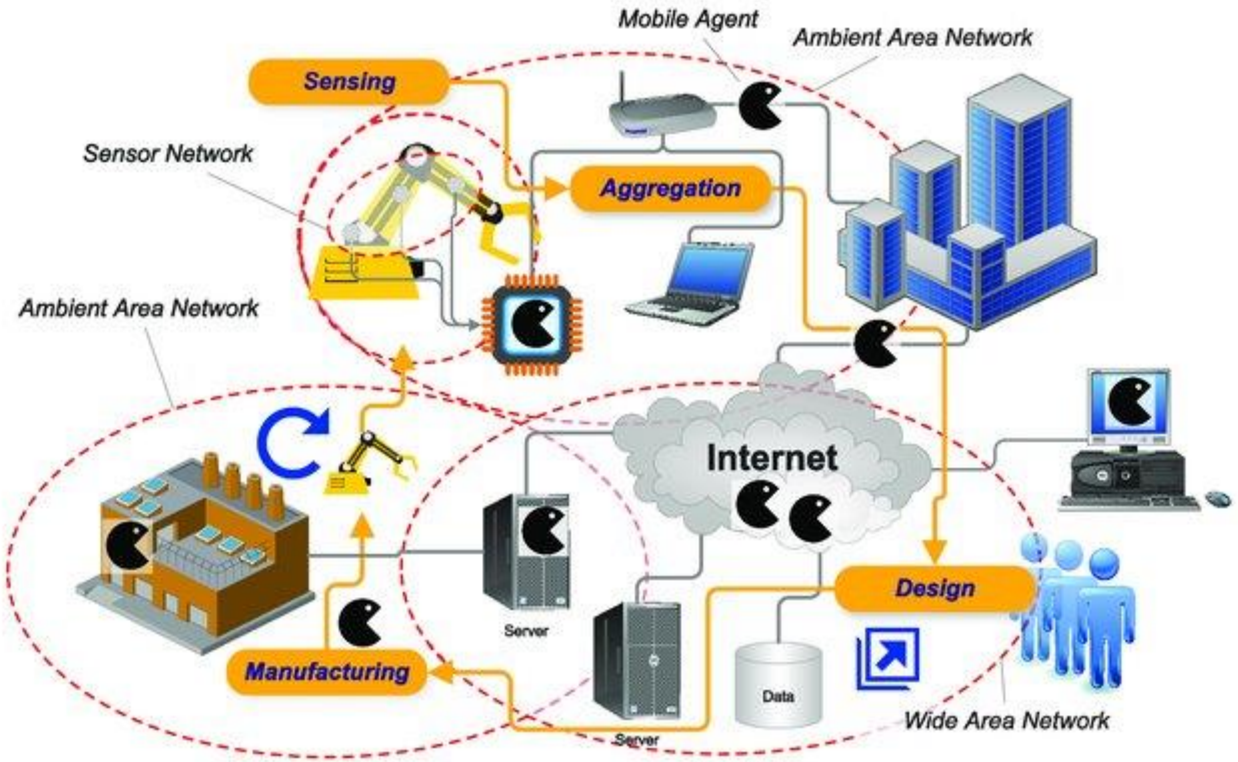
Internet-based Manufacturing

- The internet-based manufacturing is currently raising high expectations for the still-visionary value concept.
- Industrial production changes in the medium and long term through the wider use of advanced manufacturing technologies by no longer selling the physical product but only the product data.
- The transport of products could be replaced in the future via the data transfer of product data according to visionary approaches.
- The products could then be manufactured and assembled in distributed networks of small factories with highly adaptive and changeable manufacturing systems

Cloud Based Adaptive Manufacturing and Robots



(Bosse, 2016)

Digital Twin Shop-Floor:

Process optimization and business models with digital twins

https://www.youtube.com/watch?v=JIYefVc_zsw&ab_channel=Siemens

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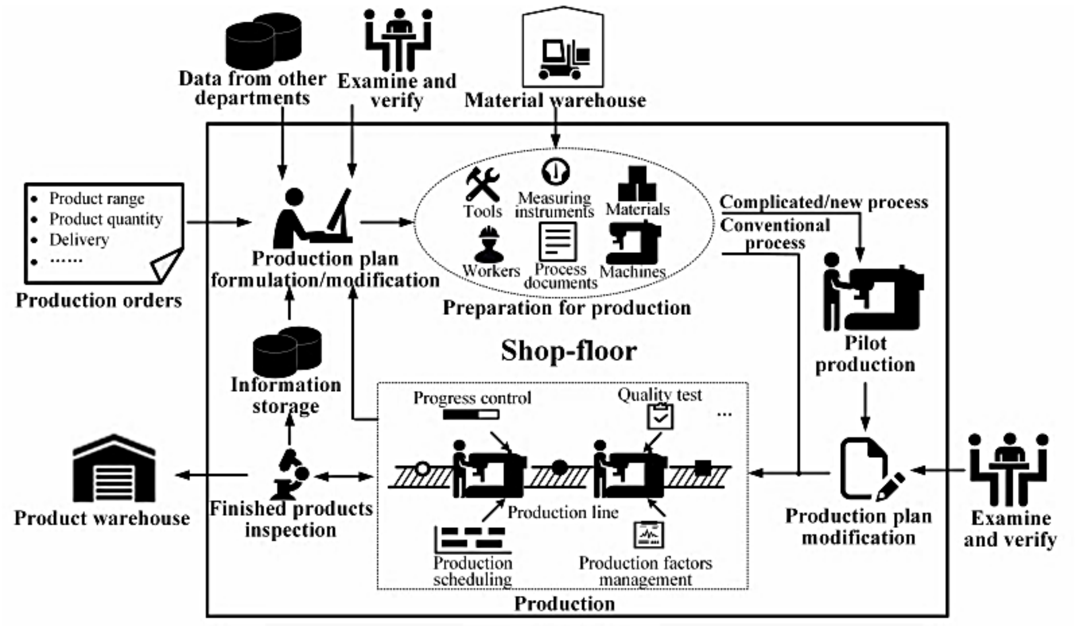
Digital Twin Shop-Floor:

A New Shop-Floor Paradigm Towards Smart Manufacturing

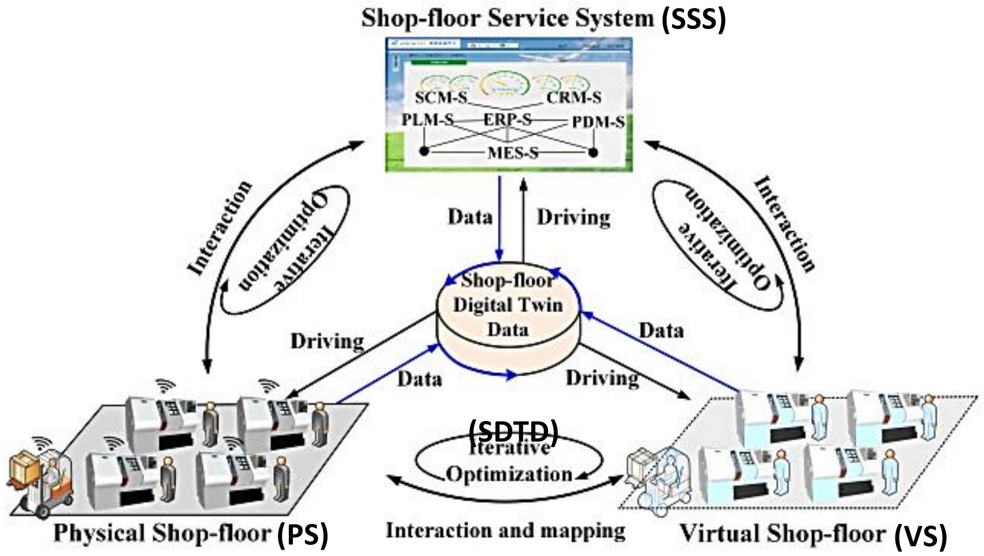
Traditional production process of shop-floor



Traditional production plan is generated based on the orders, advice from other departments and history production data, etc. It illustrates specific tasks for groups, workstations and individuals.

(Tao and Zhang, 2017)

Conceptual model of Digital Twin Shop-floor (DTS)



DTS consists PS, VS, SSS and SDTD. PS includes a series of entities, such as human, machines and materials, existing objectively in physical space. Strictly following the predefined orders from both VS and SSS, PS organizes production meeting the requirements of delivery, cost and quality, etc.

(Tao et al., 2017)

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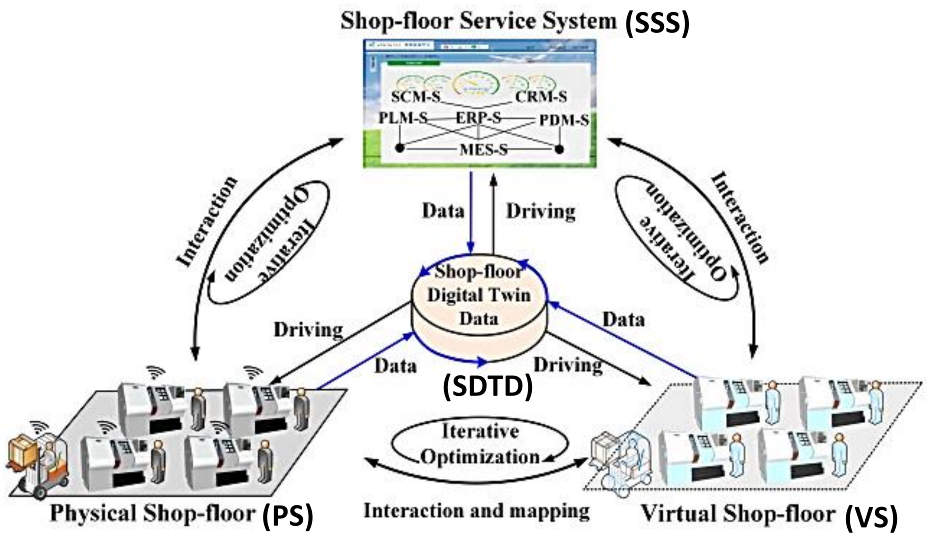
Digital Twin Shop-Floor:
A New Shop-Floor Paradigm Towards Smart Manufacturing

Conceptual model of DTS



Interactions between PS and VS, VS and SSS, SSS and PS are interpreted respectively as:

- ***PS*** generates *actual states to update* the models in VS, while **VS** *feedbacks control* orders to make PS achieve synchronism with the predefined process.
- ***SSS*** provides *services to support* normal operation and evolution of VS, while the services provided for PS are *transmitted* to VS for verification and VS feedbacks modification advice to SSS.
- *Actual states monitored* in PS are transmitted to SSS. After the demand analysis, SSS provides services for PS to optimize the production.

With PS, VS and SSS evolving with time, continuous interactions make them keep in consistency with each other and optimized iteratively.

(Tao et al., 2017)

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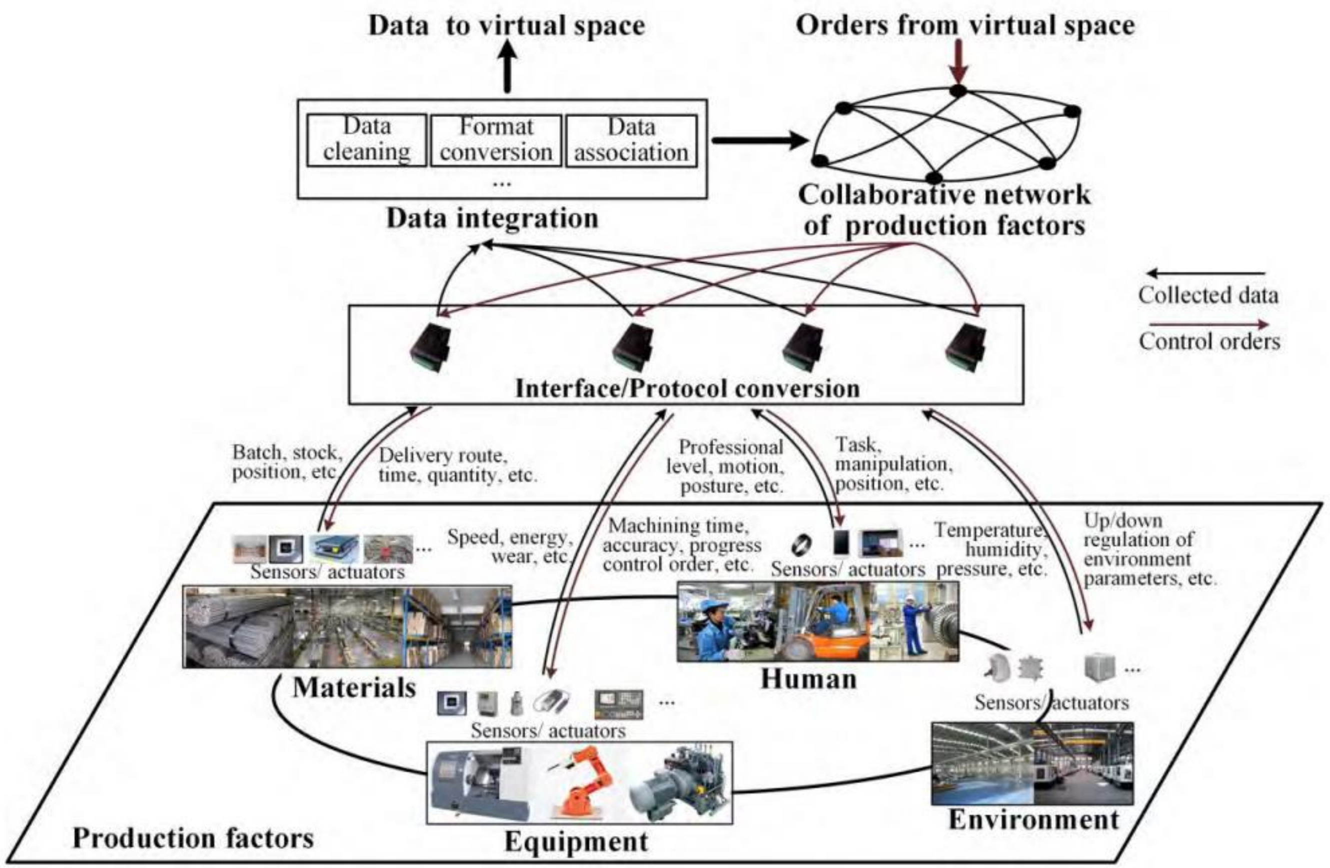
Digital Twin Shop-Floor:

A New Shop-Floor Paradigm Towards Smart Manufacturing

Interconnection and interaction in Physical Shop-floor.



Orders from collaborative network are transmitted to customized access modules for interface and protocol conversion to adapt to different communication modes of actuators in Physical Shop-floor. Finally, the orders are performed to control and coordinate the production

According to the orders from virtual space, the node asks others to cooperate with it and also responds to requests propagated by others, which makes Physical Shop-floor own stronger adaptability, flexibility and robustness.

(Tao and Zhang, 2017)

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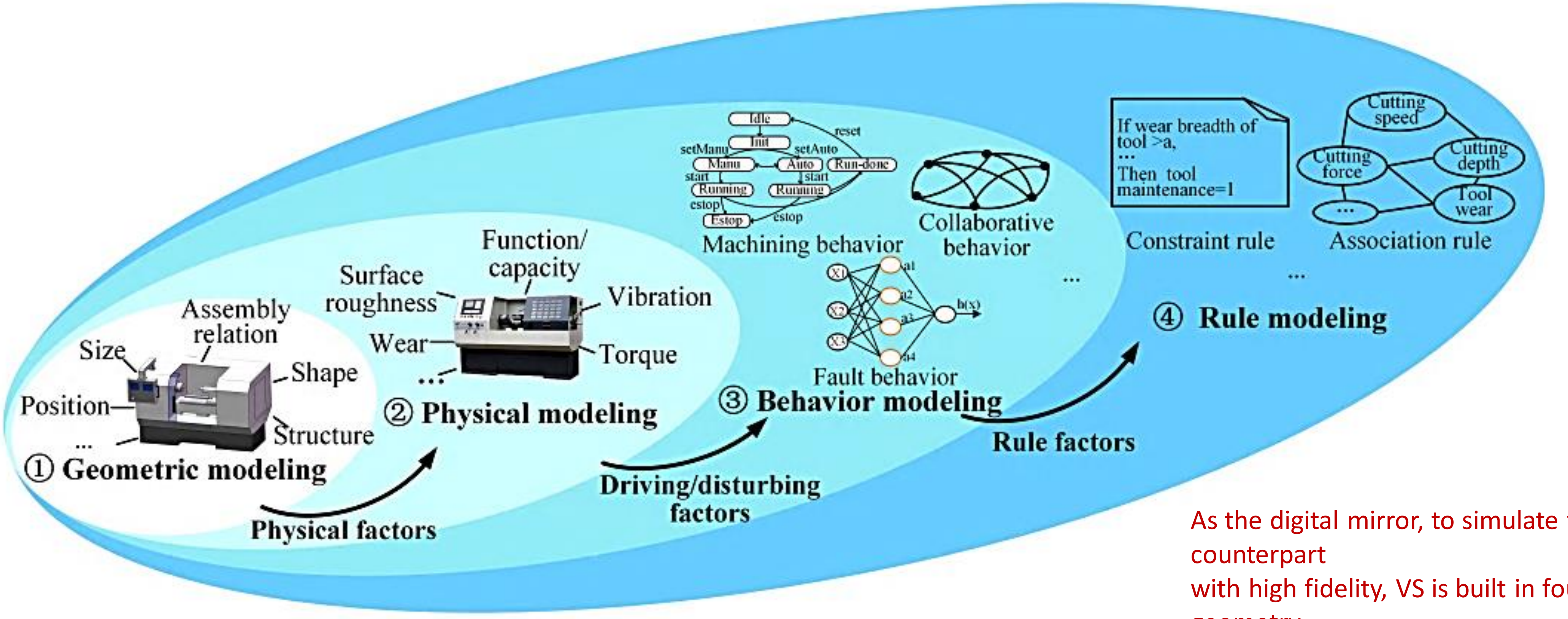
Digital Twin Shop-Floor:
A New Shop-Floor Paradigm Towards Smart Manufacturing

Four steps of modeling for CNC machine in Visual Shop-floor.



As the digital mirror, to simulate the physical counterpart
with high fidelity, VS is built in four levels, i.e. geometry,
physics, behavior and rule.

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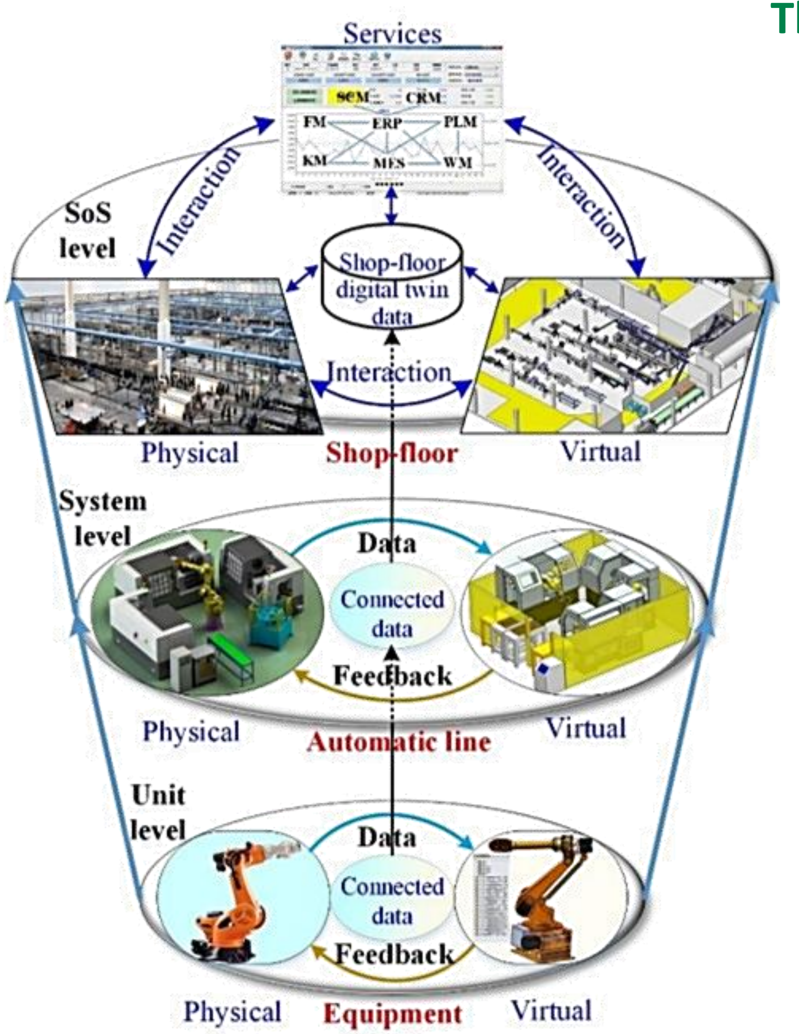
Digital Twin Service towards Smart Manufacturing



The unit-level, system-level and System of System-level digital twin and 5 dimensional model

1. ***Physical entities:*** the set of objective entities, specify functions to complete manufacturing tasks.
2. ***Virtual models:*** the digital images of the physical entities, which can completely and truly reflect the lifecycle of the physical entities.
3. ***Services integrate various functions*** such as management and control, to provide application services according to the requirements.
4. ***Fusion data:*** the core driver of the digital twin, including the data from physical entities, virtual models and service and their fusion data.
5. ***The connections among systems in pairs***, ensuring real-time interaction and iterative optimization.

The digital twin shop-floor provides a new way to practice smart manufacturing

(Qi et ail., 2018)

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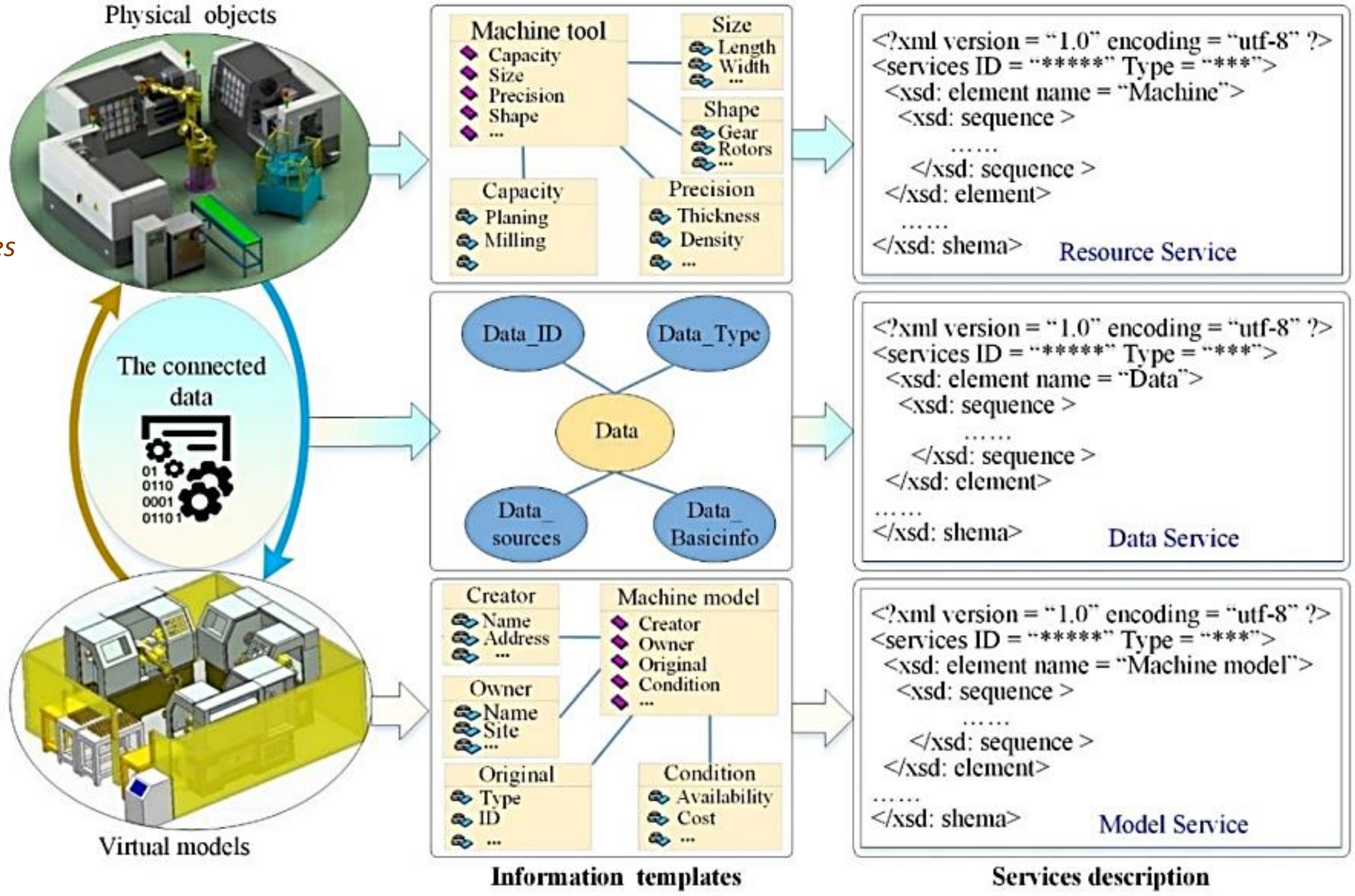
Service encapsulation of digital twin

The ***service encapsulation*** is to *translate* various *components of digital twin* into *services* with uniform description.

The important step of service encapsulation is to ***establish the information template***, which consists of a variety of information.

For the physical objects, the information includes

- Basic attributes (name, ID, address)
- QoS (time, cost, reliabilities, satisfaction)
- Capacities (precision, size, process)
- Real-time status (overload, idle, in maintenance)
- Input and output



(Qi et ail., 2018)

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Smart factories through connected equipment

Real-Time CNC Machine Monitoring

Manufacturing Process Control and Monitoring

Multi-Factory and Cross-System Integration

First Step to Industry 4.0 - Connected Equipment

- Integrate existing PLC, instrumentation signals, and communication exchange protocols, followed by performing system integration
- Establish data acquisition for enclosed machines and mechanical equipment
- Unify equipment diversity within the factory as well as achieve real-time remote system management and monitoring

https://select.advantech.com/smartfactory/en-my/

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Robotics and Teleoperation

Server Site

Web Server**:** Waiting for a client to open a connection and request information

Control Server: Receiving command code from a client site and then translates the code into commands that will use to control a robot

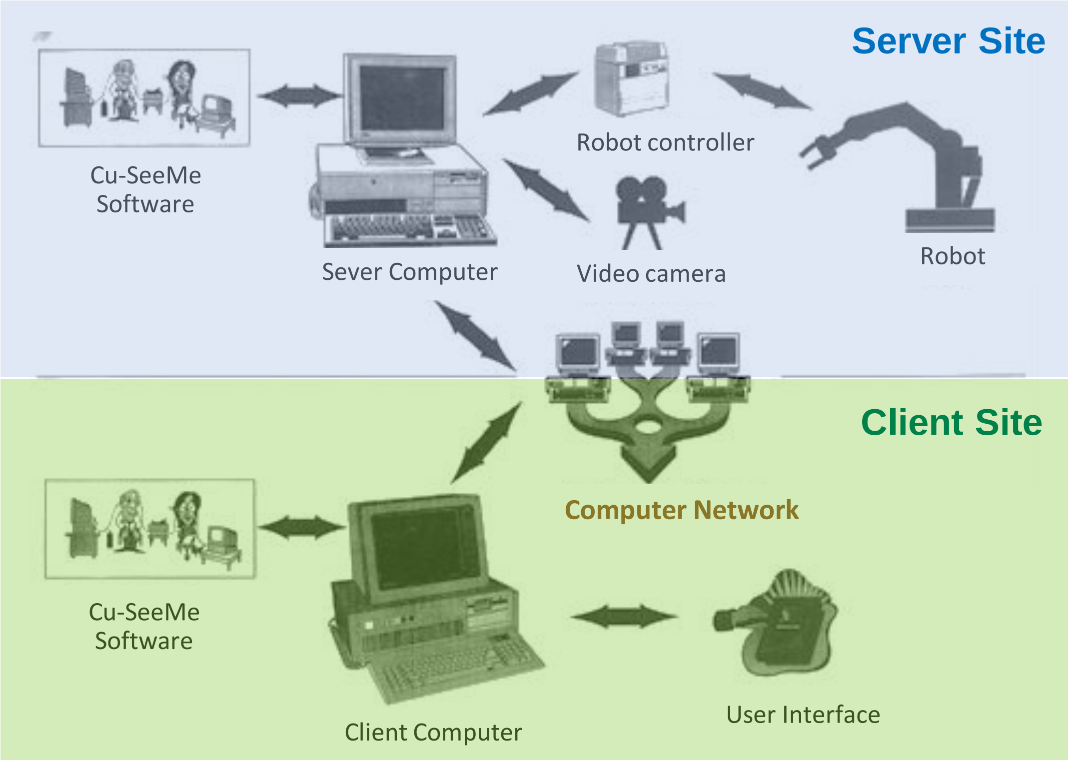
Video Sender: Providing live video from the production site back to a client computer to help an intelligent agent monitor the operation

Client Site

Internet-based Application: The application allow a user to control a robot

Monitor Program: The program give a video feedback from the server site

Internet-based robot teleoperation



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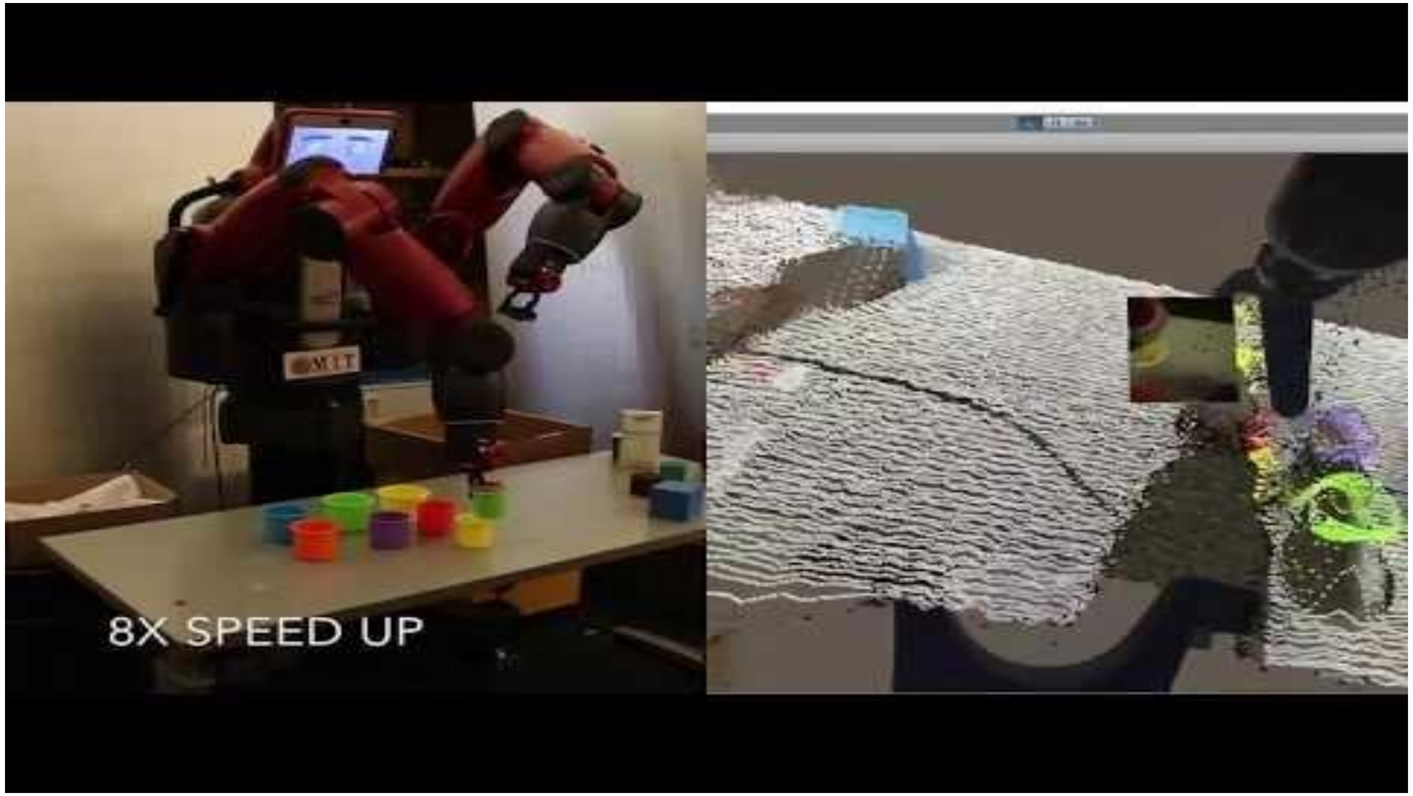
Comparing Robot Grasping Teleoperation across Desktop and Virtual Reality with ROS Reality



https://www.youtube.com/watch?v=e3jUbQKciC4&ab_channel=BuildMaster

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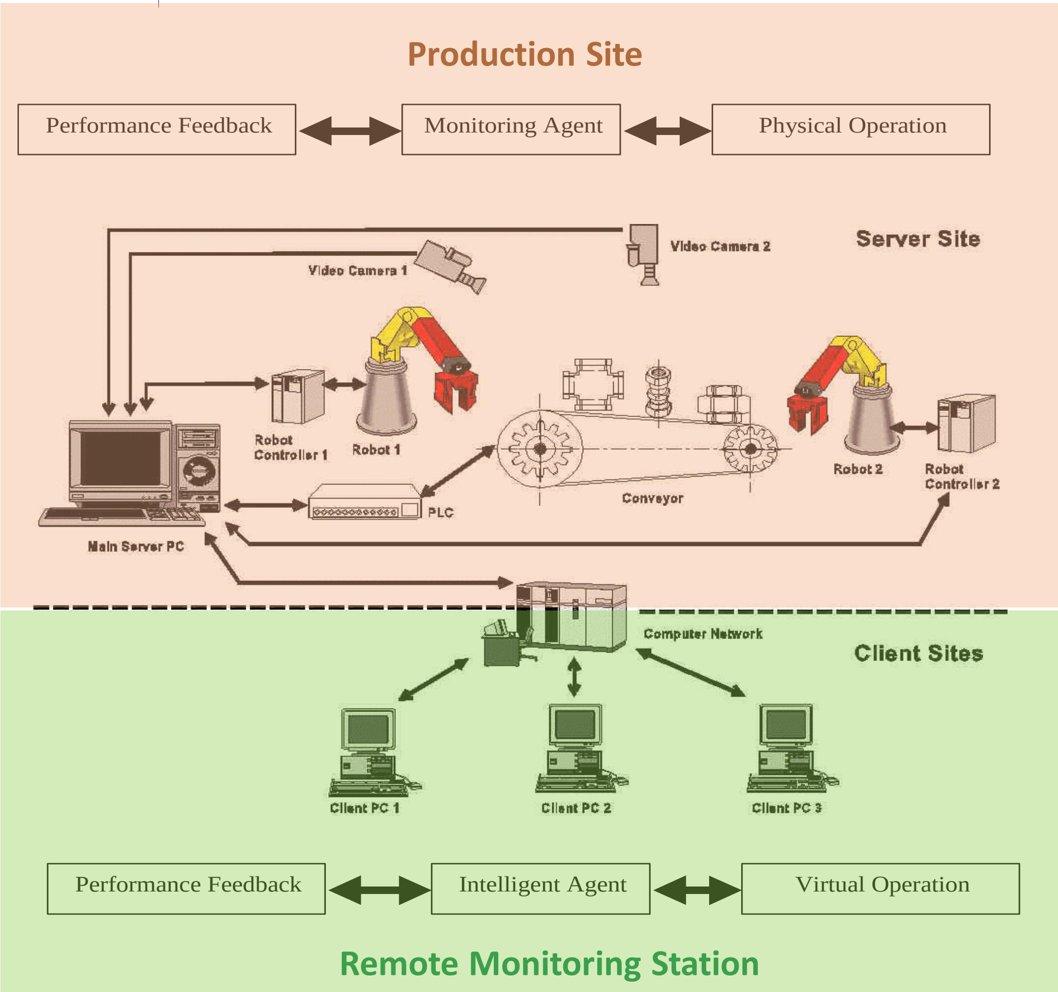
Remote Monitoring System for Manufacturing



Production Site

Web Server: Waiting for a client to open a connection and request information

Manufacturing Server: Receiving command code from a remote monitoring station and then translates the code into tasks that all working resources could understand

Video Sender: Providing live video from the production site back to a client computer to help an intelligent agent monitor the operation

Remote Monitoring Station

Internet-based Design Application: The application that allow an intelligent agent to design a product.

Monitor Program: The program that let an intelligent agent monitor the real production at the production site.

Communication Channel

Video Conferencing: This channel allow the users to experience the feeling of being together in the same location, even though they may be thousands of miles apart.

Data Conferencing: This channel allow a large number of people to chat among themselves in real time, from various locations.

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Infosys Remote Equipment Monitoring Solution

https://www.youtube.com/watch?v=QxDdMAnuViI&ab_channel=Infosys

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