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Collaborative Manufacturing Systems

Module II Machines Collaboration on a Shop Floor

Collaborative Manufacturing Processes (Cont.)

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

CIM for collaborative manufacturing processes

https://www.youtube.com/watch?v=OZs3WcBtksc&ab_channel=TrainingSystemsAustralia

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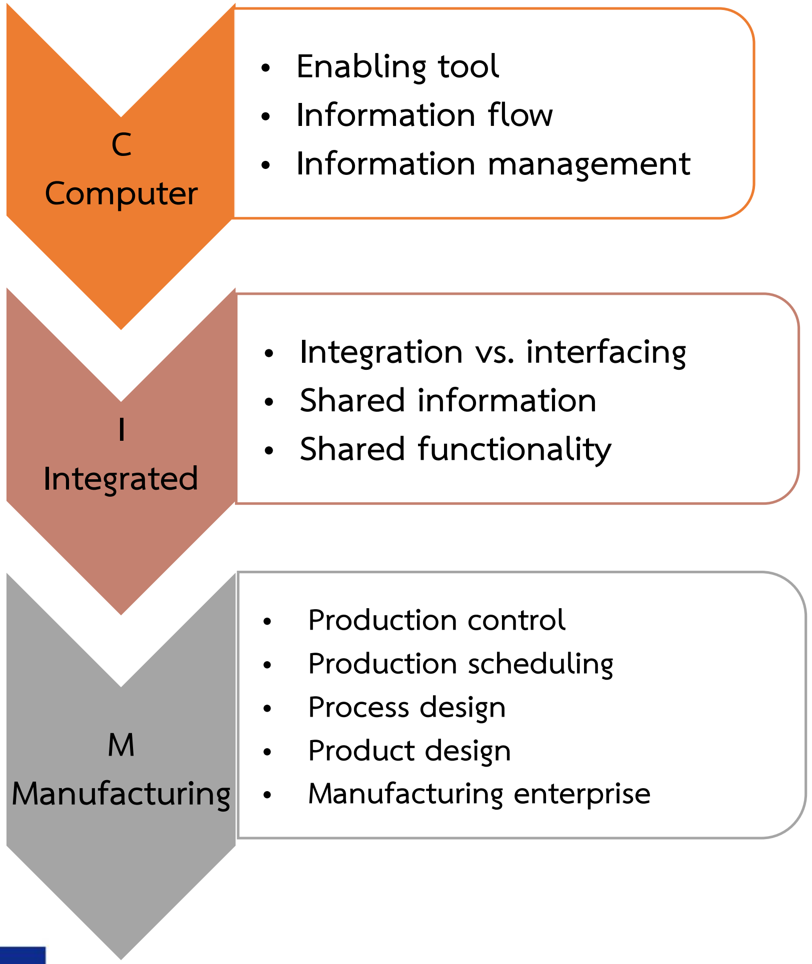
Collaborative Manufacturing Processes

Computer Integrated Manufacturing (CIM)

CIM is concerned with providing computer assistance, control and high level integrated automation at all levels of the manufacturing industries, including the business data processing system, CAD, CAM and FMS, etc. by linking islands of automation into a distributed processing system.

Subsystems in computer-integrated manufacturing

- Computer-aided techniques (e.g. CAD, CAE, CAM, CAPP)
- Devices and equipment (e.g. CNC, PLCs, DNC, robotics)
- Technologies (e.g. FMS, AGV, ASRS)



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Collaborative Manufacturing Processes

Factors involved when considering a CIM implementation

- The production volume,
- The experience of the company or personnel to make the integration,
- The level of the integration into the product itself and the integration of the production processes.

Challenges of using CIM

- Integration of components from different suppliers
- Data integrity
- Process control

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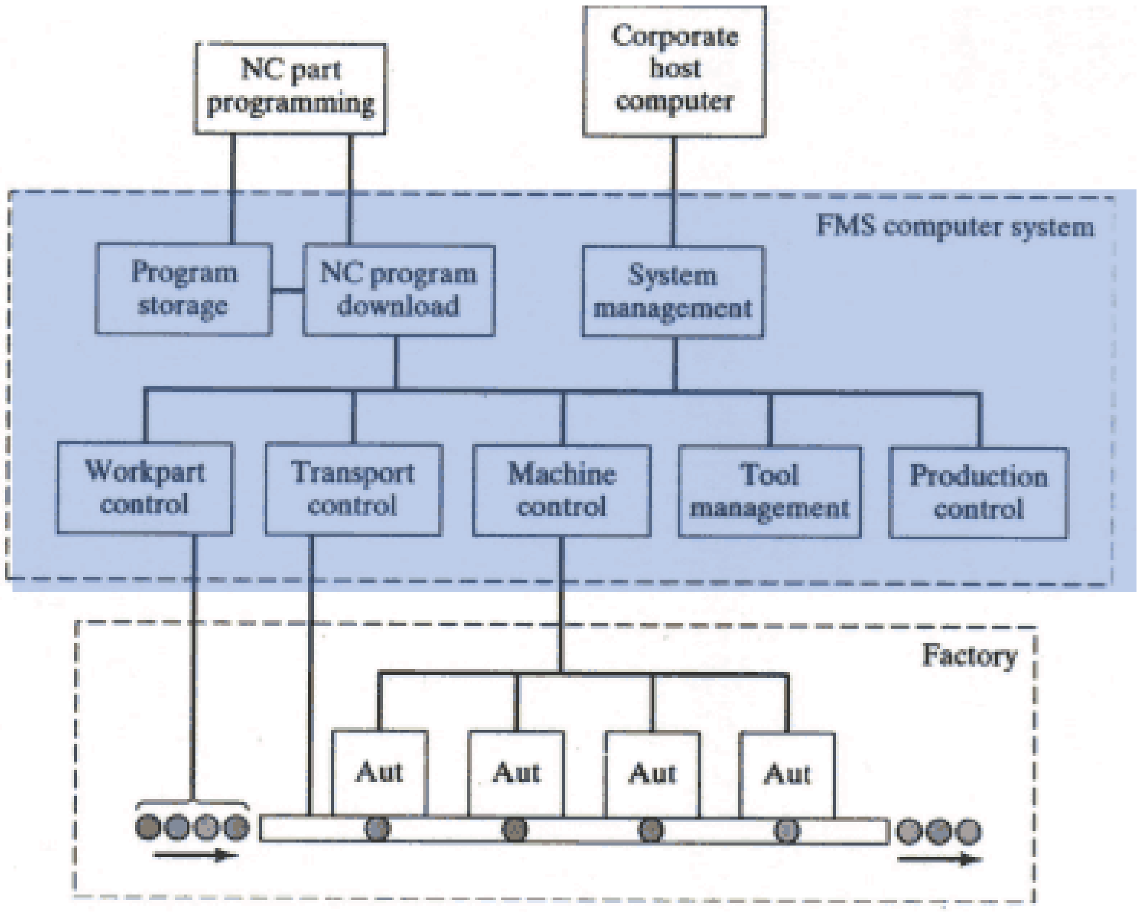
Collaborative Manufacturing Processes

Flexible Manufacturing System (FMS)

- Flexible manufacturing system (FMS) is a form of flexible automation in which several machine tools are linked together by a material-handling system, and all aspects of the system are controlled by a central computer.
- FMS is distinguished from an automated production line by its ability to process more than one product style simultaneously.
- At any moment, each machine in the system may be processing a different part type.



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Fastems Flexible Manufacturing System

https://www.youtube.com/watch?v=Br2eEpiiwvU&ab_channel=Fastems

FMS with robotic loading, unloading and deburring at Drabo B.V.

https://www.youtube.com/watch?v=4g2dHrW39Hg&list=PLJgrk28CUD4hMDASNohI8g3&ab_channel=Fastems

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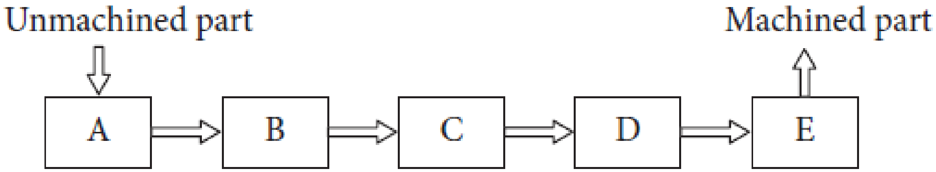
Hybrid Manufacturing

Architecture for hybrid manufacturing combining 3D printing and CNC machining (Müller and Wing, 2016))

Currently, several *CNC machines* are required for hybrid manufacturing: one machine is required for ***additive manufacturing*** and one is required for ***subtractive manufacturing***.

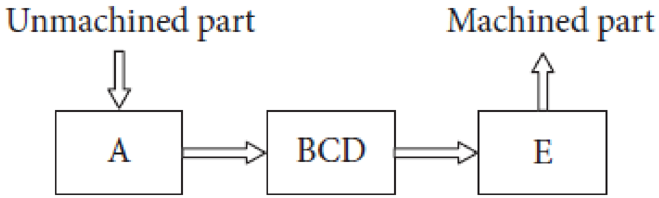
Hybrid manufacturing with *one CNC machine* enables manufacturing of parts with higher accuracy, less production time, and lower costs.

Hybrid Manufacturing with a Production Line.



A organized workpiece transport is flexible but not effective: each machine requires re-clamping and its own setup, which takes time and reduces the achievable accuracy

Hybrid Manufacturing with a Machining Center in a Production Line.



A machining center combines several manufacturing processes in one machine. This enables several different process steps with a minimum of clamping to reduce time and costs.

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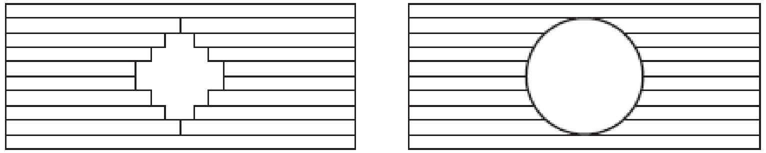
Collaborative Manufacturing Processes

Hybrid Manufacturing

Architecture for hybrid manufacturing combining 3D printing and CNC machining (Müller and Wing, 2016))

Case study: Additive part manufactured by fused layer modeling (FLM) and Subtractive post processed by drilling



(a) Undersized hole (b) Drilled out hole

Thus, the system requires

- A special extrusion tool
- A heated clamping device for both processes ←
- The process-specific M-codes of additive manufacturing, integrated into the CNC machine

Commonalities and Differences between FLM and drilling

Commonalities: Both manufacturing processes *need a precise control* to *move the tool and the workpiece* on several axes. The NC program can be generated with CAM software from a drawing created using CAD software.

Differences: *Subtractive* process *needs a clamping device* to withstand the mechanical load occurring during manufacturing, while *a heating bed* is recommended for the *FLM process*.

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Collaborative Manufacturing Processes

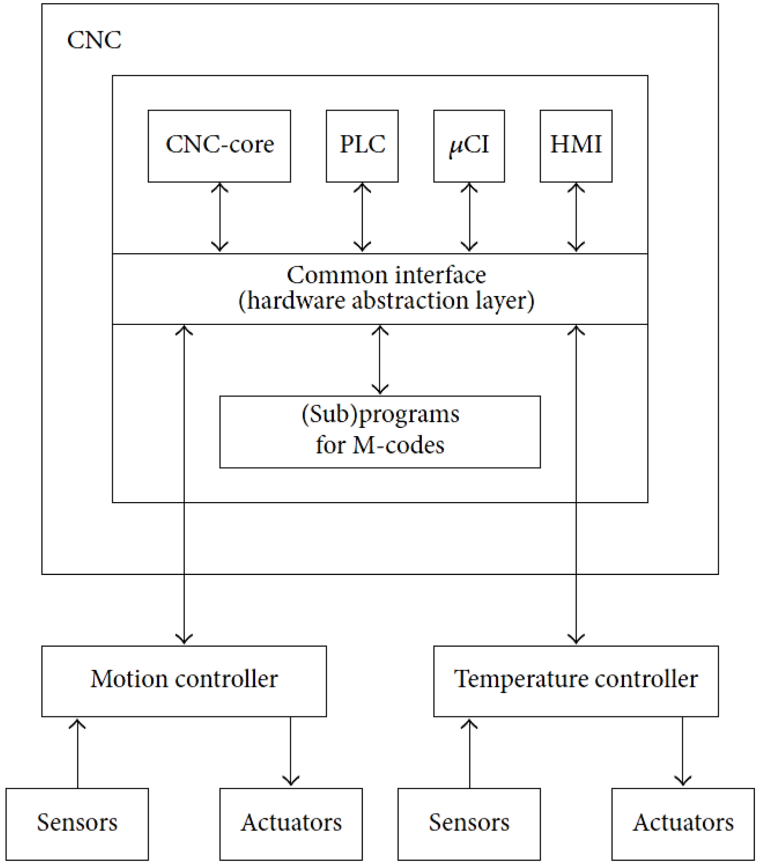
Hybrid Manufacturing

Architecture for hybrid manufacturing combining 3D printing and CNC machining (Müller and Wing, 2016))

Case study: Additive part manufactured by FLM and Subtractive post processed by drilling

Several components are integrated into the previously existing CNC architecture for enabling FLM:

- The CNC core, the PLC, and the human machine interface are standard components of a CNC
- The motion controller with its sensors and actuators for three axes are used for positioning the FLM tool. A further axis is required for filament transport.
- The integration of the temperature controller with its sensors and actuators is required during the additive/subtractive processes.



The extended CNC architecture for fused layer modeling

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Hybrid Manufacturing

Milling, Inspection and Laser Cladding

https://www.youtube.com/watch?v=4kZOE6KP8U8&ab_channel=AutodeskAdvancedManufacturing

Hybrid Manufacturing Inconel impeller

https://www.youtube.com/watch?v=70Nn5_HNmxc&ab_channel=CAMdivisionGmbH

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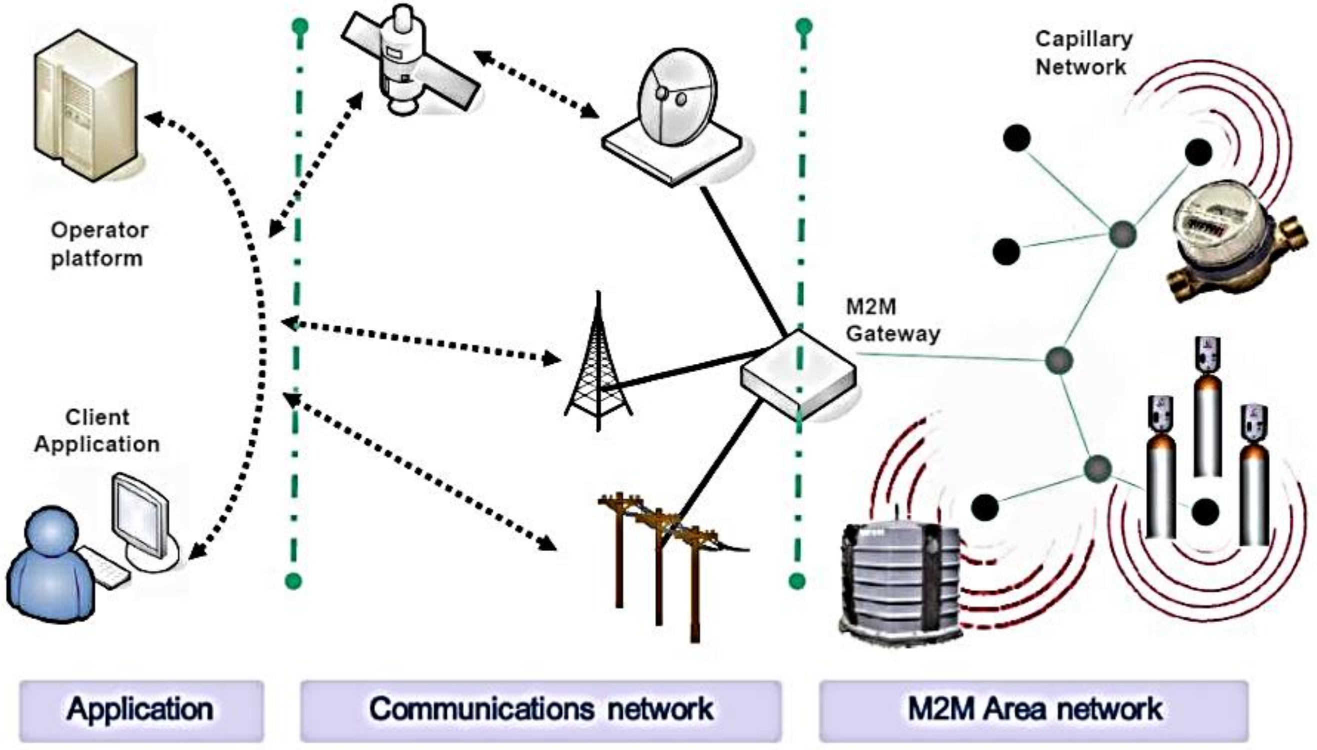
Machines Collaboration on a Shop Floor

Machine-to-Machine (M2M) Communications

- ***M2M*** communications refers to *communication between* computers, embedded processors, smart sensors, actuators and mobile devices without, or with only human intervention.
- ***M2M*** is based on very common used technologies – wireless sensors, mobile networks and the Internet.
- ***M2M*** devices reply to requests for data contained within them or transmit the data automatically



https://www.pantechsolutions.net/blog/machine-to-machine-architecture/

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Machines Collaboration on a Shop Floor

M2M Communications

Basic stages to most M2M based applications:

- Collection of data
- Transmission of data through a communication network
- Assessment of data
- Response to the available information

Enter the World of Machine to Machine

https://www.youtube.com/watch?v=UTTv9wesbao&ab_channel=VodafoneBusiness

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Machines Collaboration on a Shop Floor

M2M communication of a mobile robotic platform in machine tending applications

M2M communication utilizes general *information and communication technologies* as well as *Big Data*. Regarding ***Big Data in M2M***, five main requirements are demanded: *real-time-processing, scalability, ubiquity, reliability and heterogeneity*

- The automated workpiece exchange (machine tending) using a mobile robot platform The process can be subdivided into the following procedures:
  - Machine Door Status Check & Door Opening
  - Workpiece Status and Weight Check
  - Workpiece Space Status Check
  - Fixture Decomposition
  - Pick workpiece within the machine
  - Next Workpiece Identification
  - Workpiece gripping and handling
  - Place workpiece into the machine
  - Applying fixture specifications
  - Closing the machine door

Use Case of Machine Tending with a mobile robotic platform (YASKAWA graphic)

(Schneide et al., 2019)

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Machines Collaboration on a Shop Floor

M2M communication of a mobile robotic platform in machine tending applications

Exchange information analysis

- ***High data amount & Strict time target:***

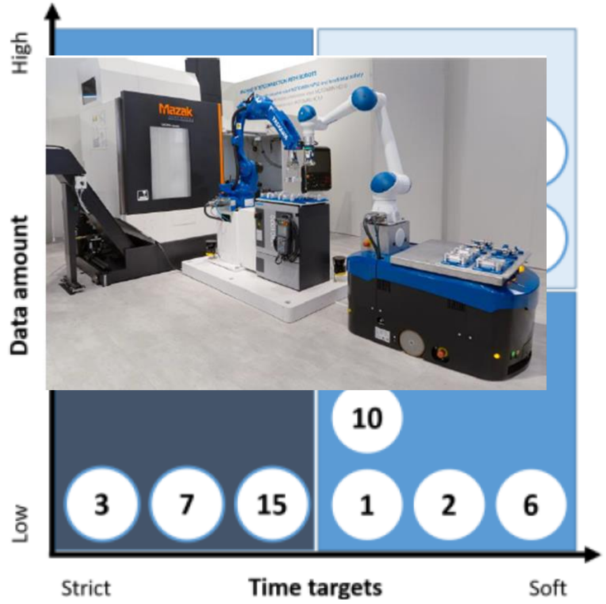
Changes in the drive process, such as speed limits or safety specifications, can be delivered in real-time at the respective spots.

- ***Low data amount & Soft time target:***

Position data, the positions are indicated as incremental values and relations. This information must be transmitted in real-time in order to enable the robot to converge to other objects precisely.

Before a trip start, the mobile platform needs information about <u>*driving parameters*</u>, such as acceleration, velocity, reaction time and respective braking.
These parameters are usually requested, *buffered and applied before the trip starts*, therefore, <u>*real-time transmission*</u> is *not important*.

Data amount and real-time requirements of the information in the use case of machine tending with a mobile robotic platform



1 Identifiers	10 Position data
2 Status data and job states	11 Map data
3 Battery status	12 Relational position data
4 ERP request	13 Routing data
5 Command data	14 Driving parameters
6 Description data (except timer)	15 Speed limit data
7 Timer	16 Safety specifications
8 Robot arm data	17 Sensor data
9 Technical motion execution details	18 Complex visual data

(Schneide et al., 2019)

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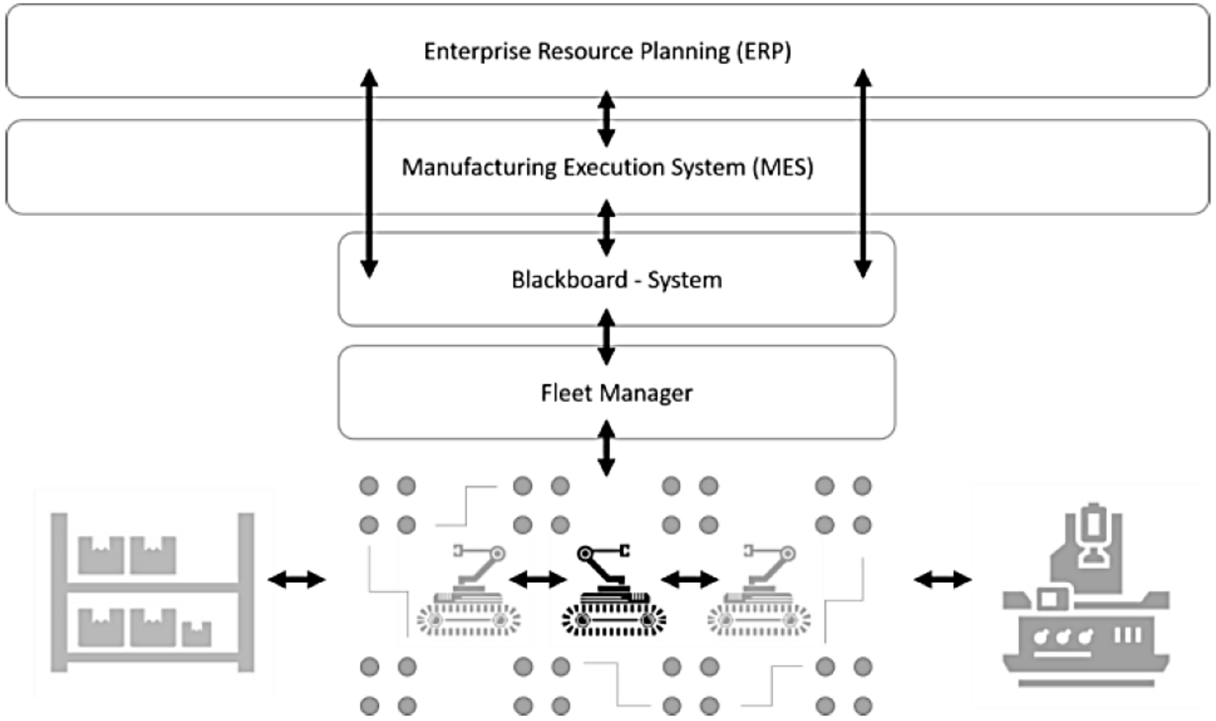
Machines Collaboration on a Shop Floor

M2M communication of a mobile robotic platform in machine tending applications

Eight requirements for communication systems for mobile robots in general need are:

- Allocation of information
- Wireless communication technology
- Communication in real-time under consideration of latencies
- Interoperability including open standards
- Coexistence with other communication systems
- Self-regulation regarding signal strength and package failure rate
- Network security and energy supply via a battery

Exemplary communication architecture of use case-tailored system



(Schneide et al., 2019)

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Machines Collaboration on a Shop Floor

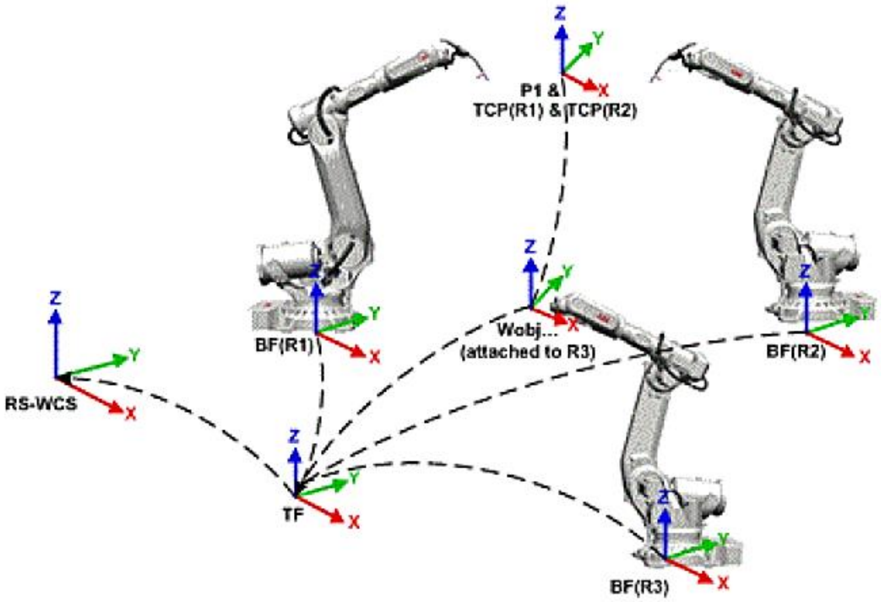
Collaborating robots

Multi agent systems *integrate* autonomous systems which are endowed by artificial intelligence, this concept aims to apply intelligent machines collaborating together to build a flexible environment

In the industry, agents represent ***robots***, sensors, controllers which can apply a common language that structures the rules of *cohabitation and collective work*.

Agents are between *reactive and cognitive* agents: the *reactive agents* are those that have just *reflexes* while the *cognitive agents* are those that can *form plans for their behaviors*

Communication between agents plays a vital role in this area which can show two forms: *Implicit and Explicit communication*



Collaborating manipulator arms in industry

(Benotsmane et al., 2018)

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Machines Collaboration on a Shop Floor

Collaborating robots

Artificial Intelligence (AI) of cooperation between several manipulator robots

A virtual simulation model of an assembly line includes a *few robot manipulators* equipped with sensors, cameras and intelligent controllers.

The ***robots*** are members of ***a multi-agent system*** that can *help each other and cooperate to finalize the tasks* defined in this line.

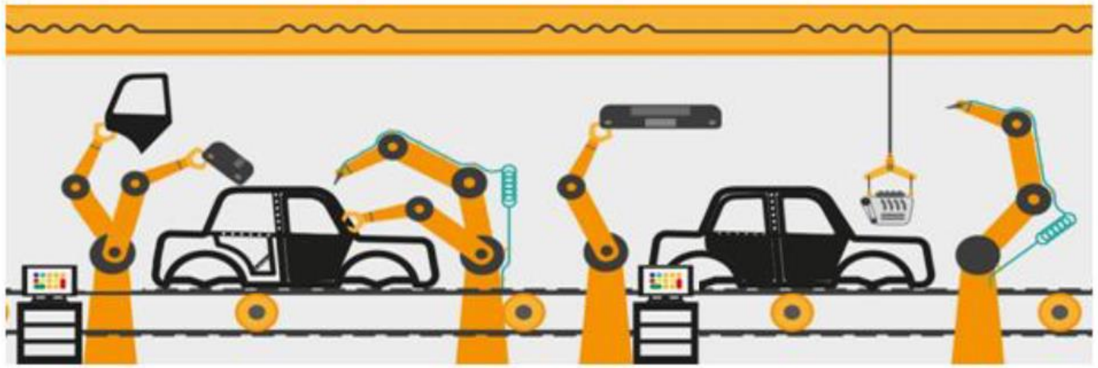
If some *malfunction* occurs in the production line, the *robots can reconfigure themselves* and *reorganize* the steps of the same task.

Two scenarios of collaborating robots :

1st scenario: ***the normal process,*** the *planning methods* of ***AI*** are used for creating the optimal scheduling for the tasks taking into the parallel work of the robots

2nd scenario: ***the disturbed process*** including some problems, random happenings, errors, etc. The ***AI*** is intended for *finding quasi-optimal strategies* for continuing the work after the random happening.

Cooperating manipulator arms in an assembly line



(Benotsmane et al., 2018)

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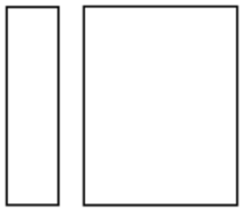
Machines Collaboration on a Shop Floor

Collaborating robots

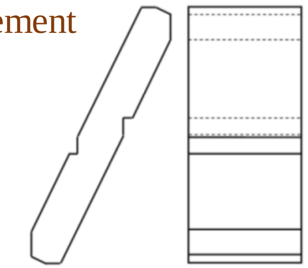
Two robots have to build up a house of cards:

- A shape from the two cards needs two hands, thus needs two robots.
- If one of the robots fails then the other has to use the supporting element.
- For supporting a card and removing a supporting element , an extra time opposite to cooperating robots

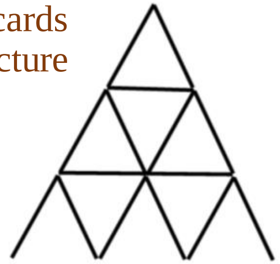


A supporting element

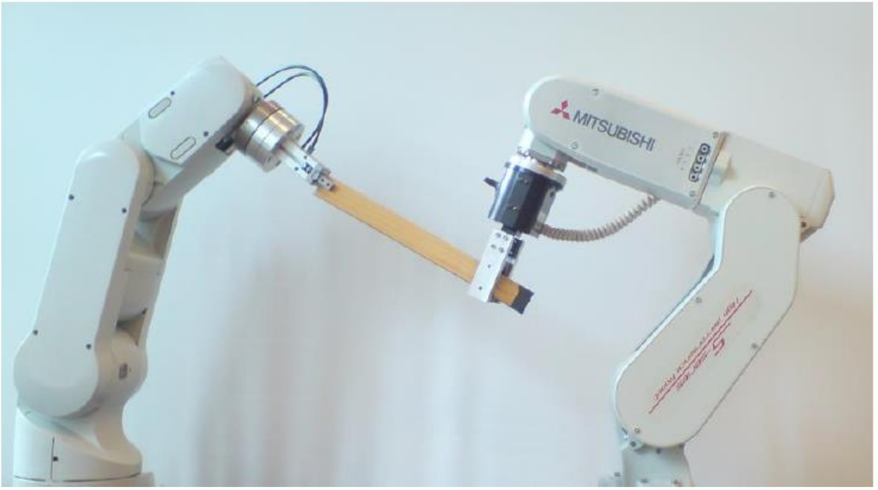
A card element



A house of cards structure



Cooperating of two manipulator arms to build up a house of cards.



(Benotsmane et al., 2018)

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Omron TM collaborative robot with CNC Machine tending application

https://www.youtube.com/watch?v=NaQMfkmQIno&ab_channel=OmronAutomation-Americas

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Activity: Self Study (Collaborative Design)

After reading the article: *"A Collaboration-Oriented M2M Messaging Mechanism for the Collaborative Automation between Machines in Future Industrial Networks" (Meng et.al, 2017)*

Discussion:

- What is Technical Solutions for Collaborative Automations between Machines?
- For case study of PicknPack food packaging line, what is the architecture of machine collaboration?

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