Automated Manufacturing Systems

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The aim of this presentation

• Introduce the basics of Automated Manufacturing Systems (AMSs)

• Provide a general picture of the organization of these systems

• Show how AMSs integrate multiple kinds of subsystems and therefore require multiple kinds of techniques for their design

• Introduce the different levels of control present in AMSs

• Make evident the importance of the communication subsystems for this kind of system
Presentation Outline

1. Introduction
2. Components
3. Organization
   1. General aspects
   2. Types of Control
4. Reference Models. The CIM model
5. Design Approaches (centralized vs. distributed system)
6. Control Networks in AMSs
   1. The OSI model point of view
   2. The control hierarchy point of view
   3. The device hierarchy point of view
   4. Communication network architecture
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Introduction (1)

• **Competition** among manufacturing companies together with the availability of adequate **computing and communication technology** has caused dramatic changes in the manufacturing environment.

• From **manual** operation to **semiautomatic** operation (machines able to perform several steps of an automated sequence) and from there to **fully automated** facilities.

• Other terms used to denote these systems are:
  - FMS: Flexible Manufacturing Systems
  - FOF: Factory of the Future
  - CIM: Computer Integrated Manufacturing (comprising also the other company’s activities such as marketing, finances, etc.)
Introduction (2)

• **Definition of AMS:** A system consisting of a set of interconnected stations for material processing that are capable of automatically processing a wide variety of types of pieces simultaneously and controlled by computers.

• **Characteristics of the automated manufacturing:**
  - High degree of automation
  - High degree of integration
  - High degree of flexibility
    - Flexibility in the production volume
    - Flexibility in the routing
    - Flexibility at the product level
• **Advantages of automated manufacturing** when compared with traditional manufacturing:
  – Productivity increase
  – Reduced **lead times**
  – Reduced labour costs
  – More efficient use of equipment
  – Improved product quality
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Components (1)

- We are going to focus on the elements that are directly involved in the **physical manufacturing** (since AMSs are usually considered to take care also of other aspects such as marketing, finances, etc.)
  - Sensors
    - Sensors of pressure, temperature, position, speed, etc.
    - **Limit switches**
  - Actuators
    - E.g. Electro-valves, relays, etc.
    - Actuated equipment
      - Pneumatic
      - Hydraulic
      - Electro-mechanic
Components (2)

- Industrial robots: programmable mechanical manipulator (arm) capable of moving along several directions describing complex trajectories with its end-effector (the device that is attached to the end of the arm). It is designed to carry out factory work usually performed by human workers.
  - Complex manipulation of pieces
  - Spray painting
  - Inspection
  - Assembly

- Computerized Numerical Control (CNC) equipment: Computerized **machine tool** whose actions are controlled by directly inserting numerical data
  - Drill
  - Milling Machine
  - Lathe
Components (3)

- Programmable Logic Controllers (PLCs): Solid state devices used for controlling the operation of machines or processes by means of a stored program and the feedback of the I/O devices
  - Implementation of **sequential** processes.
  - **GRAFCETs** are used to specify the processes.
  - **Ladder diagrams** are used as programming language
  - **Scan**: periodic cycle in which inputs are read, new state is computed and outputs are updated.
  - **Choice of a PLC**: scan time, number of I/O both digital and analog, communication interface, memory size, supply voltage, programming language, etc.

- Transfer systems
  - Automated Guided Vehicles (AGVs)
  - Towline Systems
  - Roller Conveyor Systems
  - Belt Conveyor Systems
Components (4)

- Automated Warehouses: systems that control the movement of materials and send the corresponding information to the adequate computers within the factory
  - Functions and advantages:
    - Status and location of materials is controlled by computers
    - Inventory is simplified
    - Security and safety are improved
    - Unnecessary movements of materials are eliminated

- Bar code readers (as those used in supermarkets)
  - Uses (mainly identification and thereby...):
    - Tracking of components in an assembly
    - Correct assembly verification
  - Advantages:
    - Easy installation and interface with a computer (COTS comp. available)
    - Low cost
Components (5)

- **Vision Systems:**
  - **Uses (generally test and inspection):**
    - Localization of objects and their absence
    - Identification of objects
    - Dimensional gauging
  - **Types of output information:**
    - Logical data (resulting from image processing)
    - Video information (e.g. in security applications)

- **Microcontrollers:**
  - Play similar roles as the PLCs
  - **Differences:**
    - (initially) They are faster and have better capacity for data manipulation
    - Less I/O ports
    - More programming languages
    - Easier interface with other computers

- **Computers:** (higher-level control and database management)
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Organization (1)

- Let us discuss how these elements are organized
- An illustrative concept is the manufacturing cell
Organization (2)

• A **factory** can be seen as a set of manufacturing cells

• Many **technological areas** are involved in an AMS:
  – Mechanical Engineering
  – Computing and Communications
  – Control
  – Robotics
  – Vision & Perception Systems
  – Computer Aided Design (CAD)
  – Computer Aided Manufacturing (CAM)
  – Computer Aided Test (CAT), etc.

• We are going to focus now on those directly involved in the physical manufacturing process
Organization (3)

- One of those technologies is **Control**:
  - The methodology used to alter the behaviour or the performance of a system according to a predetermined goal.

- In an AMS there are several **types of control** (depending on the abstraction level)
  - Dynamic Control:
    - Lowest level
    - Directly controls the process variables
    - E.g. position of a robotic arm
  - Sequential Control
    - A process is sequenced as a series of steps (binary actuation or DC)
    - Typically performed by PLCs
  - Supervisory Control
  - System-wide Control
Organization (4)

- In an AMS there are several types of control (depending on the abstraction level)
  - **Dynamic Control**:
    - Lowest level
    - Directly controls the process variables
    - E.g. position of a robotic arm

![Control System Diagram]
Organization (5)

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Reference Models (1)

- Different approaches are possible
- From the point of view of materials & information flow

Materials flow

Information flow

Diagram:

- Central database
- Design station
- CAD, CAM
- CAM, CAP
- Test data
- Raw materials
- Flexible manufacturing
- Assembly station
- Inspection station
- Finished product
Reference Models (2)

- From the point of view of the databases

- Factory information management system
  - Order processing
  - Cost accounting
  - Purchasing
  - Overall production planning and scheduling

- Common database

- Links to the “outside world”

- Computer aided design
  - Design scheduling
  - Simulation
  - Functional analysis

- Materials handling and storage
  - Warehouse automation
  - Vendor parts inspection
  - Product and in-process inventory

- Flexible manufacturing inspection and assembly
  - Production planning and control
  - Part programming and machining
  - Materials handling and in-process storage
The (hierarchical) CIM Model

- The model ISO-RM-FA covers the company as a whole

Company: Corporate management
Factory: Manufacturing planning
Shop: Assignment and Supervision of Materials and Resources
Cell Pool: Coordination of Machines and Operations. Alarms & Monitoring
Cell: Machine Control. Execution of manufacturing commands
Machine: Activation of sequences and movements. Physical manufacture
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Design Approaches

• Two approaches could be considered (only one is possible)

• Centralized approach:

• Distributed approach:
Design Approaches

• Two approaches could be considered (only one is possible)

• Centralized approach:
  – Pros:
    • Effective for small systems
    • Easy programming and maintenance
  – Cons:
    • Reduced capacity and flexibility
    • Single point of failure
    • Not adequate for real (complex) AMSs

• Distributed approach:
Design Approaches

• Two approaches could be considered (only one is possible)

• Centralized approach:

• Distributed approach:
  – Pros:
    • Many nodes working simultaneously dramatically increases capacity
    • Nodes are placed where they are required for the local control
    • Easier automation, integration and flexibility
    • Independent (easier) debugging and maintenance of each part
    • Allows gradual expansion of the system
  – Cons:
    • Harsh environment
    • Need for communication standards and interoperability
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Control Networks in AMSs (1)

• In a **distributed control system** the **network is the backbone** and provides fundamental services

• The **use of networks in AMSs** can be seen from many different **points of view**:
  – The OSI model point of view
  – The control hierarchy point of view
  – The device hierarchy point of view

• All these points of view lead together to a typical **communication network architecture**
Control Networks in AMSs (2)

- The OSI model point of view:
  - Each layer provides specific services to the one above
  - Each layer adds some control information to the message

<table>
<thead>
<tr>
<th>Layer</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>Common services for classes of applications</td>
</tr>
<tr>
<td>Presentation</td>
<td>Data semantics</td>
</tr>
<tr>
<td>Session</td>
<td>Remote actions</td>
</tr>
<tr>
<td>Transport</td>
<td>End-to-end communication control</td>
</tr>
<tr>
<td>Network</td>
<td>Routing, logical addressing</td>
</tr>
<tr>
<td>Data Link</td>
<td>Physical addressing, MAC, LLC</td>
</tr>
<tr>
<td>Physical</td>
<td>Topology, medium, bit-encoding</td>
</tr>
</tbody>
</table>

Physical interconnection medium
Control Networks in AMSs (3)

- The OSI model point of view:
  - Each layer provides specific services to the one above
  - Each layer adds some control information to the message

- This approach causes large computation and communication overheads

- Depending on the nodes involved the communication has different requirements.
  - Low cost
  - Real-time
  - High bandwidth
  - Small vs large data

- For some requirements the stack should be reduced

- The application layer is always important
The control hierarchy point of view:
- Intra-level & inter-level comms
Control Networks in AMSs (5)

• The device hierarchy point of view:
  – In the CIM model presented before there was a device hierarchy that was implicit in the pyramid
  – At each level of this hierarchy a different kind of control is carried out
  – Moreover, at each level, the communication requirements are different
    • Real-time comms at the lowest levels vs. high bandwidth at the highest ones
    • Smaller data at the lowest levels (sensor and actuator info)
    • Lower cost at the lowest levels (more and longer wires)
  – Furthermore, the different device levels must be connected among them
  – Thus it is natural to have an architecture based on subnetworks
References

Source for these slides