Automated Systems and Control (Part 7)
Computer Integrated Manufacturing (CIM) 
Major Components

• CIM technologies include computer aided design (CAD)
• Computer aided engineering (CAE)
• Computer aided process planning (CAP)
• Computer aided manufacturing (CAM)
• Computer numerical control (CNC)
• Distributed numerical control (DNC)
• Flexible manufacturing systems (FMS)
• Robotics, automatic guided vehicle systems (AGVS)
• Automatic storage and retrieval systems (AS/RS)
CIM Benefits

• Reduction in engineering design costs
• Reduction in overall lead time
• Increased product quality
• Increased capability of engineers
• Increased productivity of production operations
• Reduction of work-in-process, and
• Reduction of personnel costs
Manufacturing Networks

• Provides the infrastructure to transmit manufacturing and management data used to define and control computer-integrated manufacturing systems or components of computer-aided design (CAD) and computer-aided manufacturing (CAM)
Manufacturing Networks

• Consist of primarily local area networks (LAN)

• LAN’s can be joined to form enterprise wide computing (EWC) or corporate networks
Network Specifications

• Bandwidth architecture
• Access protocol
• Cable
• Distance
• Cost
Network Components

- Servers (file, client, and web) most common
- Transmission medium (cable or wireless)
- Network interface card (NIC), and
- Network operating system
Servers

• *File Server*: stores the network operating system, program, and data files for shared use

• *Client server or (database server)*: used for real-time access by multiple users to any file  E.G. Databases and CAD documents
Transmission Medium

- Coaxial Cable: Still the most common medium
- Unshielded twisted pair cable (UTP): used in LAN’s that are relatively free of electromagnetic interference (EMI)
- Shielded twisted cable (STP): used in areas with high EMI
- Fiber Optics: most secure medium, since the light does not have the electromagnetic fields inherent with wire or wireless communications
Network Interface Card (NIC)

- Connects the computer motherboard to the cabling

- Internal network interface cards are used with desktop computers

- Laptops use a NIC that connects to the laptop by the PCMCIA port
Data Transmission

- Traditional telephone system (POTS) lines and modems, least expensive but low bandwidth and performance
- Integrated services digital network lines (ISDN) a faster system; however, not universally available with high line and supporting equipment costs
- Digital subscriber lines (DSL) use conventional four-wire telephone lines in a digital mode DSL support speeds of 64 Kbps to 1.544 Mbps depending on the distance between the user and the vendor
Data Transmission

• T1 lines are used by companies for their enterprise-wide computing needs

• A T1 line is copper wire consisting of 24 channels that can transmit at 1.544 Mbps

• T3 line is fiber-optic cable and can support a transmission rate of 44.736 Mbps
Data Transmission Continued

• Data transmission issues will remain constant, regardless of the technology

• How to transmit data reliably over a distance at the highest appropriate speed and at an economical cost

• Communicating remotely with networks between networks and the Internet
Network Operating System

• The software that interfaces the user with the network and its components

• Examples: Novell Netware, Windows NT, and Unix
Open-Systems interconnect (OSI) Seven Layer Model

1. Physical
2. Data Link
3. Network
4. Transport
5. Session
6. Presentation
7. Application
Open-Systems interconnect (OSI) Seven Layer Model

1. The physical layer processes digital information into a form transmitted by the physical medium (wires, radio waves, or fibers)
2. The data-link layer arranges the raw data bits of physical layer into frames
3. The network layer identifies the destination address of the frames and requests network facilities and priorities
4. The transport layer verifies that data are sent and received correctly and in the correct order
Open-Systems interconnect (OSI) Seven Layer Model

5. The session layer determines how two networks communicate, establishes communication and monitors that communication

6. The presentation layer is the interface between the application layer and the session layer

7. The applications layer, the level seen by users, exchanges information between the programs and the user interface
Repeaters, Bridges, Routers, and Gateways

- Work at different levels of the OSI model to add capability to local area networks
Repeaters

- Operate at level 1, the physical level, by receiving a signal and transmitting the same signal (repeating it).
- Used to increase the overall transmission distance for the different conductors in a given network
- Do not do error control, flow control, or address correction
- Reasonably fast because they do not process the signal
Bridges

- Enable computers on two similar but different networks to communicate with each other.
- Transmit similar data from one network to another and filter out information that is not addressed for the other network.
- Used to link identical LANs to increase the range of user access.
- Store and forward frames at the data-link level (layer 2) of the OSI model.
Routers

- Protocol-sensitive units that support communication between dissimilar LANs using the same protocol
- Operate at the third level of the OSI model and communicate in packets
- Capable of modifying the network-specific information so that they can route a message from one type of network to another, if both are based on a common network operating system
- A router is capable of selecting an appropriate path
Gateways

- Connect networks of different network operating systems, architectures, and protocols by translating the protocol from one to another

- Process bits at the physical layer all through error detection, framing, routing, flow control, etc., at the appropriate level from the physical through the application layers
Fundamental Network Topologies

(a) Star

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Common Hybrid Topologies
Protocols

- Protocols regulate the data format for moving data between levels of the open-systems interconnect (OSI) model

- Carrier-sense multiple access/collision (CSMA/CD) detection is used by Ethernet

- Transmission-control protocol/internet protocol (TCP/IP) used for internet and intranet transmission
Protocols

- Protocols - the internet protocol (IP) addresses the data and directs it to the appropriate destination

- Token passing - token passing allows a workstation to transmit data when the workstation holds the token

- Polling – is most frequency used with host or mainframe-based systems, however least common

- Hypertext transfer protocol (HTTP) – is used to transfer information from web servers to web browsers
Computer Numerical Control Machining

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Computer Numerical Control (CNC)

- CNC machines machine parts by moving a tool along a programmed path based on the work piece geometry by a coordinate and axis identification system.
- Tool path and part geometry require a coordinate and axis identification system.
Computer Numerical Control (CNC)

- Computer instructions – software
- Machine control unit
- Processing machine
Three-Axis Vertical Milling Machine
Two-Axis Lathe Coordinate System
The Right-Hand Rule
Numerical Control (NC) Languages

• Earliest automatic programming of tools (APT) doing 4 or 5 axes CNC operations

• Still used by airframe and machine tool building industries

• Current 3-D graphical CAM programs are currently used for constructing complex surfaces
Linear and Circular CNC Interpolations

• Linear interpolations as small as .0001 inches

• Circular interpolation most common higher order, used to approximate circles in (2D)

• Parabolic interpolation is a second higher order interpolation used primarily with curve geometry
Elements of a CNC Machine Control Unit

- Operator interface
- Machine control unit
- Machine interface
CNC Motion Control

• Open-loop stepping motor

• Closed-loop servo control
Open-Loop Control System

- Generates commands based on time
- Discrete on and off control
- Receives no feedback
- E.G. Early garage doors, printers, and stepper motor drives
Closed-Loop Control System

- Used with discrete and servo systems
- Generates feedback
- E.G. CNC equipment, robots, cruise control
- PLC systems use closed-loop feedback to insure that specific motions are accomplished prior to energizing the next output
Programmable Logic Controllers (PLCs)

- Used to control manufacturing cells in islands of programmable automation, flexible manufacturing, and computer integrated manufacturing
Advantages of PLCs

- Designed as programmable replacements of hardwired relays
- Easy program modification
- Collecting data capability
- Communication with other equipment at the (I/O) level
- Troubleshooting the control system
PLC Applications

- Primary function is still discrete (On-Off) control
- Can also perform relay replacement, Boolean algebra, count programmed actions, execute time delays, perform sequence operations, manipulate data, and communicate with other PLCs or computers via networks
PLC Components

- Input modules
- CPU
- Memory
- Output modules
PLC Component Information

- Designed to operate in a harsh electrical environment and execute a single program

- Safety considerations mandate local control for startup, emergency shut down and lockout
PLC Component Information

- Sized according to the number of inputs and outputs
  - Micro: up to 32 I/O
  - Small: 32 to 128 I/O
  - Medium: 64 to 1024 I/O
  - Large: 512 to 4096 I/O
  - Very Large: 2048 to 8092 I/O
Relay Ladder Logic (RLL)
Programming Language for PLCs

- *Rails* are vertical lines serving as the voltage source for relay circuits and logic
- *Rungs* are horizontal lines and contains the branches, inputs, and outputs
- *Branch* starts and ends an OR function
- (RLL) language is used because electricians know the language from relay controls
Basic Ladder Logic

(a) AND

(b) OR

(c) NOT
Robotics

- Robots are programmable multifunctional tools
- Robot subsystems
  - Power system
  - Control system
  - Mechanical system
  - Mechanical world interface system
Power Systems

- Electrical used with closed-loop servo control with high accuracy, repeatability and speed

- Hydraulic power used for large heavy loads

- Pneumatics used for small, fast, non servo controlled robot arms
Control Systems Categories

- Type of control (servo vs. non servo)
- Type of feedback (open or closed loop)
- Resolution and accuracy
- Communication capability
Three Common Coordinate Systems

- **World coordinate system** – an X, Y, Z system with 0,0,0 located at the center of the base of the robot, used for programming with a teach pendant or a computer.

- **Tool coordinate system** – center on the tool flange, X and Y are parallel to the tool flange and Z is perpendicular to the flange, used to program a robot arm to pick parts out of fixtures.

- **Part coordinate system** – has the coordinate center oriented according to the dimensions of the part, used to program welding and paint spraying guns.
Robot Mechanical Systems

• Links – solid members (multiple shapes)
• Joints – provides for movement between the links
• 4 types of joints
  – Linear transverse
  – Linear telescoping
  – Rotary hinge
  – Rotary pivot
Mechanical Links and Joints

(d) Linear Transverse Joint

(c) Rotary Pin Joint
Robot Arm/World Interface
(Grasping Devices)

- Two, three or four mechanical fingers most common
- Hooks, magnets and vacuum suckers
- Process tooling, spray guns and welding guns
Automated Material Handling and Identification

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Material Handling Equipment

- *Unit loads*: large single pieces or parts or products grouped on a pallet or in a tote

- *Bulk loads*: liquids or semi-solids moved by conveyor or pipeline and stored in bins or solids
Automated Material Handling Systems

- Automated guided vehicle (AGV)
- Automated storage and retrieval systems (AS/RS)
Automated Guided Vehicle (AGV) Configurations

- **Train**: used to move carts of parts from storage to retrieval
- **Fork lift**: used to move pallets and totes on manufacturing floor
- **Unit load**: also used to move pallets and totes on manufacturing floor
- **Assembly**: moves a part being assembled or a part to the assembly process
Automated Storage and Retrieval Systems (AS/RS)

- Storage (work-in-progress or assembly to order inventory)
- AS/RS classed by the size of the unit load: micro, mini, or unit
- Advantages: provide high-bay storage with a smaller footprint than conventional storage
Automatic Identification Systems

- Provides accuracy and speed of data entry for inventory, work in progress and final products
- Types: Bar code, radio frequency data transmission, radio frequency identification, magnetic stripe, voice recognition, and machine vision
Bar Coding

- Most robust and reliable forms of automatic identification
- Bar codes come in multiple symbols and densities and available in linear, two dimensional, and three dimensional formats
Most Common Linear Bar Codes

• Universal product code (UPC): Numeric
• Code 39: Alphanumeric
• Interleaved 3 of 5
• Code 128
Bar Code Characteristics

- The narrower the bar the higher the density
- Widths are uniform throughout the code
- Nine-segment stop on each end
- Plain (quiet) zone on each end
- Read starting at either end
Radio Frequency Data Transmission

- Allows mobile real-time input of bar code data to a host computer
- Advantages: direct, real-time transmission of data from receiving, manufacturing and shipping is readily accessible for resource planning, shipping, accounting, etc
- Disadvantage: limited to approximately one mile range
Radio Frequency Identification (RFI)

- Utilizes an electronic battery powered unit, transponder (TAG) attached to a pallet or part
- A responder (antenna) receives the data and sends it to the host computer
- Tags are hardened to withstand vibration liquids and temperature extremes
- Used in applications where a process or routing might cover or destroy a bar code
- RFI more expensive than bar codes
Magnetic Stripes

• May be attached to pallets or parts
• Disadvantages
  – Cannot be read remotely
  – More expensive than bar codes
Voice Recognition

• Types: dictation and computer voice

• Justification to use voice recognition to control factory automation is a function of demand and cost benefits to the user
Machine Vision Applications

- Inspection
- Identification
- Machine guidance
Machine Vision Systems Capabilities

- Forming an image and converting the image into appropriate electrical signals
- Organizing the signals into a form that may be processed by a computer
- Analyzing and measuring various features and characteristics of the signals generated by the image
- Interpreting the data so that useful decisions can be made about the image
Machine Vision System
Components

- One or more cameras
- Camera controller
- Camera vision processing unit interface
- Vision system CPU
- Monitor
Software Application

• The software processes the image from the cameras and performs image recognition by template matching or feature weighting