A. JAMES CLARK
SCHOOL OF ENGINEERING

ENPM 692
MANUFACTURING AND AUTOMATION

Instructor: Dr. Mahesh Mani, PhD
Email: mmani@umd.edu

Time: Wednesdays 7:00pm - 9:40pm
Location: JMP 2222

Course Coverage

- Manufacturing Automation
- Industrial Robotics
- Additive Manufacturing
- Sustainable Manufacturing
- Digital Factories
- Network-Centric and Smart Manufacturing

Plan

- 15 Sessions
  - 13 Sessions for Lectures
  - 2 Sessions for Final Project Presentations
- Assignments & Quizzes

Lectures

Lecture 1	1/29/2025	Introduction Lecture
Lecture 2	2/5/2025	Industrial Robotics
Lecture 3	2/12/2025	Additive Manufacturing- technologies
Lecture 4	2/19/2025	Additive Manufacturing- capabilities and applications
Lecture 5	2/26/2025	Sustainable Manufacturing –Overview
Lecture 6	3/5/2025	Sustainable Manufacturing – Practicality
Lecture 7	3/12/2025	Manufacturing Simulation
Spring Break	3/19/2025	No Lecture-Spring Break
Lecture 8	3/26/2025	Digital Manufacturing
Lecture 9	4/2/2025	Network Centric Manufacturing
Lecture 10	4/8/2025	Guest Lecture
Lecture 11	4/16/2025	Network Centric Manufacturing
Lecture 12	4/23/2025	Guest Lecture
Lecture 13	4/30/2025	Smart Manufacturing Platforms
Lecture 14	5/7/2025	Final - Project Presentations
Lecture 15	5/14/2025	Final - Project Presentations

Grading- What to Expect

- **Assignments** (**30%** of the overall grade)
  - Technical assignments such as summarizing related literature, comparison studies or a similar exercise
- **In class quizzes** (**20%** of the overall grade)
  - In class quizzes covers all areas in the course.
- **Final project** (**50%** of the overall grade) – includes final report, group presentation, Q/A
  - Final technical report and presentation very important

Final Project

- Technical report presenting proposals for making production more efficient.
  - Choose any relevant manufacturing scenario
  - Technical report summarizes
    - problem definition, goal and scope of the production scenario
    - research and analysis
    - smart manufacturing recommendations
  - Oral presentation with clear illustrations, within allotted time
  - Review peer presentations and provide feedback.

50% of the overall grade

Reference Books

- Groover, Mikell P. Automation, production systems, and computer-integrated manufacturing. Fourth Edition, Pearson, 2015.
- Gibson, Ian, David W. Rosen, and Brent Stucker. Additive manufacturing technologies. New York: Springer, 2015.
- …

Introduction to Manufacturing Automation

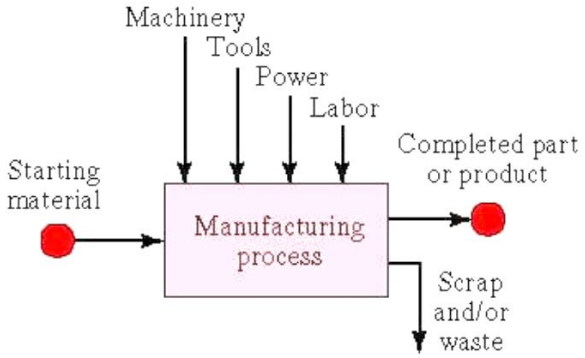
Manufacturing and Automation

manufacturing
noun
1. the making of goods by manual labor and/or by machinery, especially on a large scale: the manufacture of computers.
2. the making or producing of anything; generation: the manufacture of body cells.
3. the thing or material manufactured; product
verb (used with object), manufactured, manufacturing.
4. to make or produce by hand or machinery, especially on a large scale.
5. to work up (material) into form for use: to manufacture cotton.

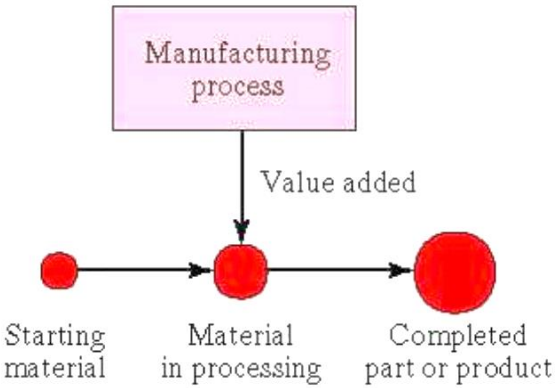
automation
noun
1. the technique, method, or system of operating or controlling a process by highly automatic means, as by electronic devices, reducing human intervention to a minimum.
2. a mechanical device, operated electronically, that functions automatically, without continuous input from an operator.
3. act or process of automating.
4. the state of being automated.

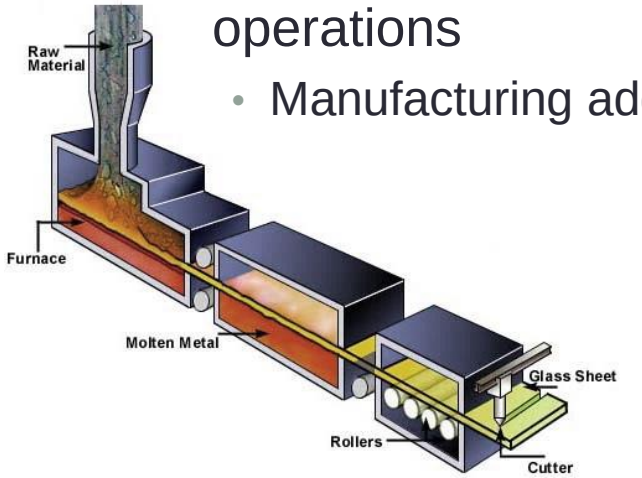
Manufacturing Definition

- **Technical** – The application of physical and chemical processes to alter the geometry, properties, and/or appearance of a given starting material to make parts or products



- **Economic-** Transformation of materials into items of greater value by means of one or more processing and/or assembly operations
  - Manufacturing adds value to the material





Definitions (Source: Groover)

Classifications

Hierarchy

- **Section: D - Manufacturing**

Breakdown:

This Section is divided into the following Divisions:

- 15 - Manufacture of food products and beverages
- 16 - Manufacture of tobacco products
- 17 - Manufacture of textiles
- 18 - Manufacture of wearing apparel; dressing and dyeing of fur
- 19 - Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
- 20 - Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
- 21 - Manufacture of paper and paper products
- 22 - Publishing, printing and reproduction of recorded media
- 23 - Manufacture of coke, refined petroleum products and nuclear fuel
- 24 - Manufacture of chemicals and chemical products
- 25 - Manufacture of rubber and plastics products
- 26 - Manufacture of other non-metallic mineral products
- 27 - Manufacture of basic metals
- 28 - Manufacture of fabricated metal products, except machinery and equipment
- 29 - Manufacture of machinery and equipment n.e.c.
- 30 - Manufacture of office, accounting and computing machinery
- 31 - Manufacture of electrical machinery and apparatus n.e.c.
- 32 - Manufacture of radio, television and communication equipment and apparatus
- 33 - Manufacture of medical, precision and optical instruments, watches and clocks
- 34 - Manufacture of motor vehicles, trailers and semi-trailers
- 35 - Manufacture of other transport equipment
- 36 - Manufacture of furniture; manufacturing n.e.c.
- 37 - Recycling

ISIC classifications https://unstats.un.org/UNSDWebsite/

Classifications

-- Industry Classifications

- **Process industries**, e.g., chemicals, petroleum, basic metals, foods and beverages, power generation
  - Continuous production
  - Batch production
- **Discrete product (and part) industries**, e.g., cars, aircraft, appliances, machinery, and their component parts
  - Continuous production
  - Batch production

Process and Discrete Manufacturing Industries

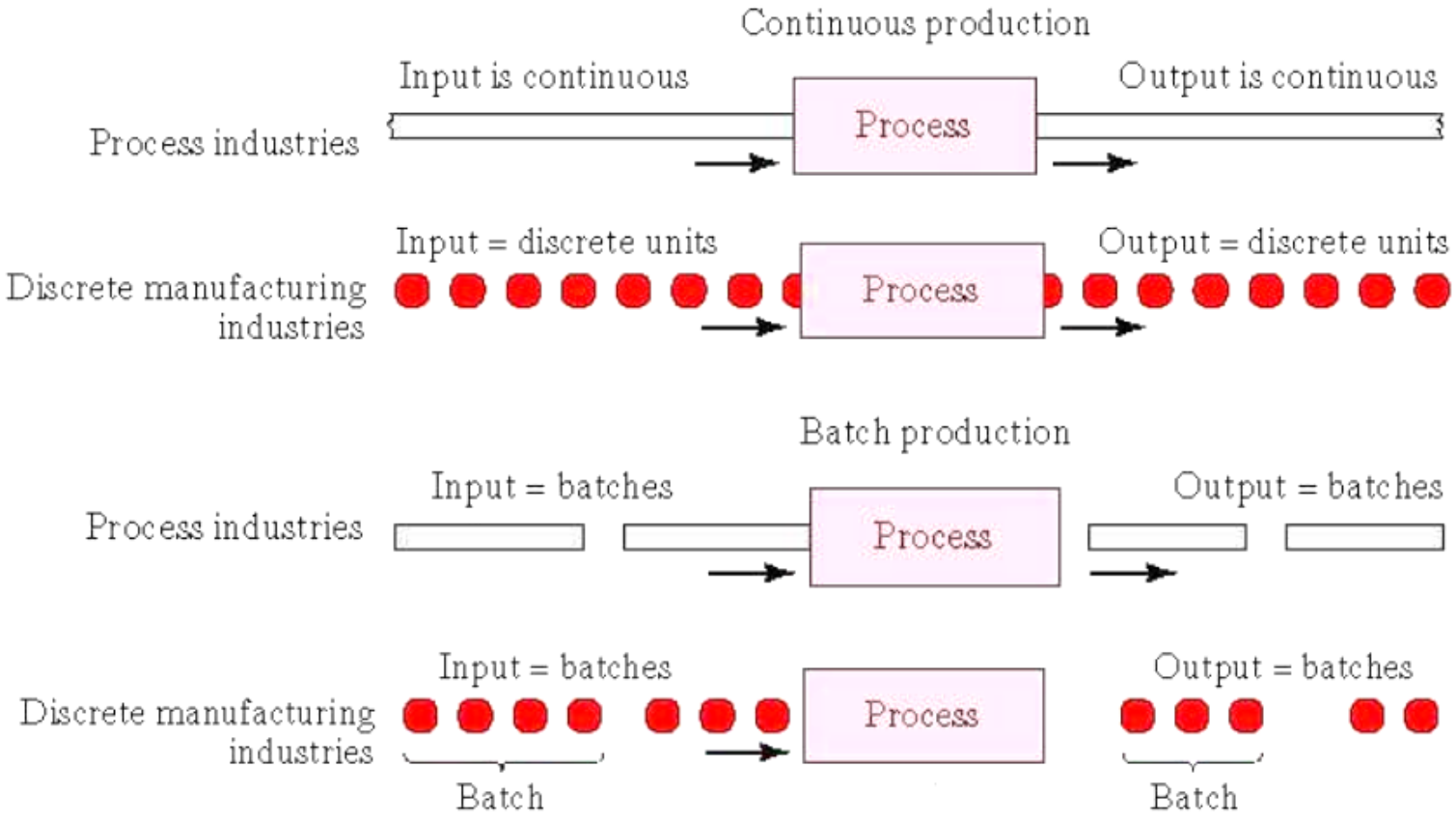


Figure. Continuous and Batch Production (Ref. Groover)

Classification of Manufacturing Processes

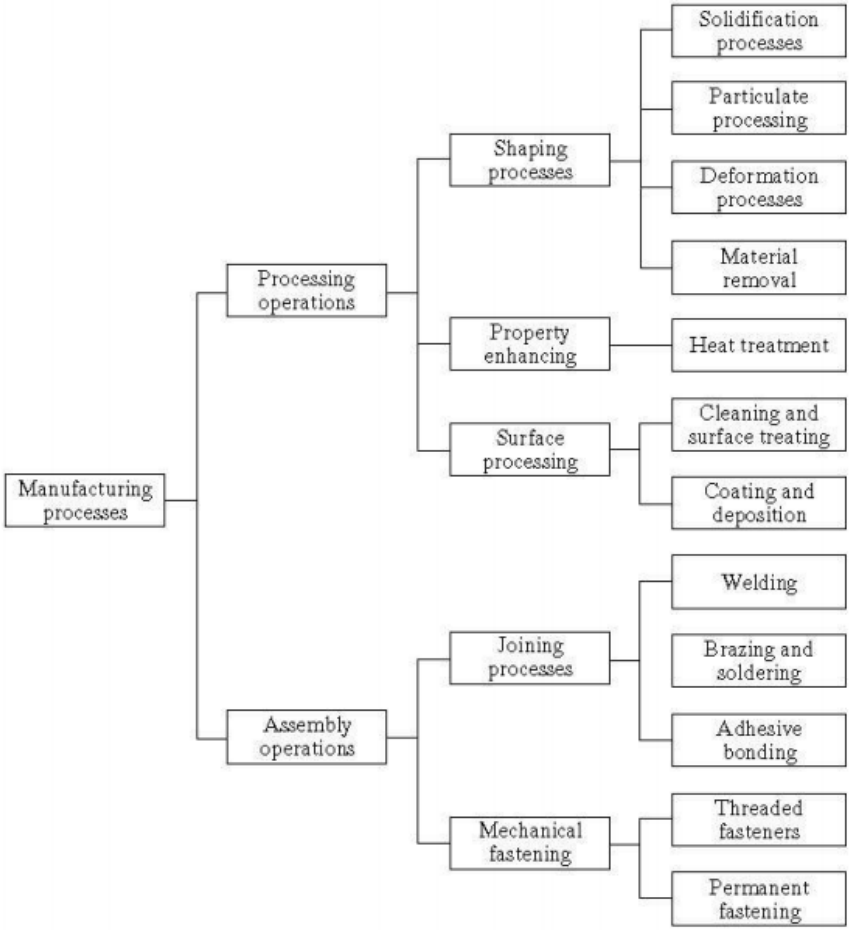
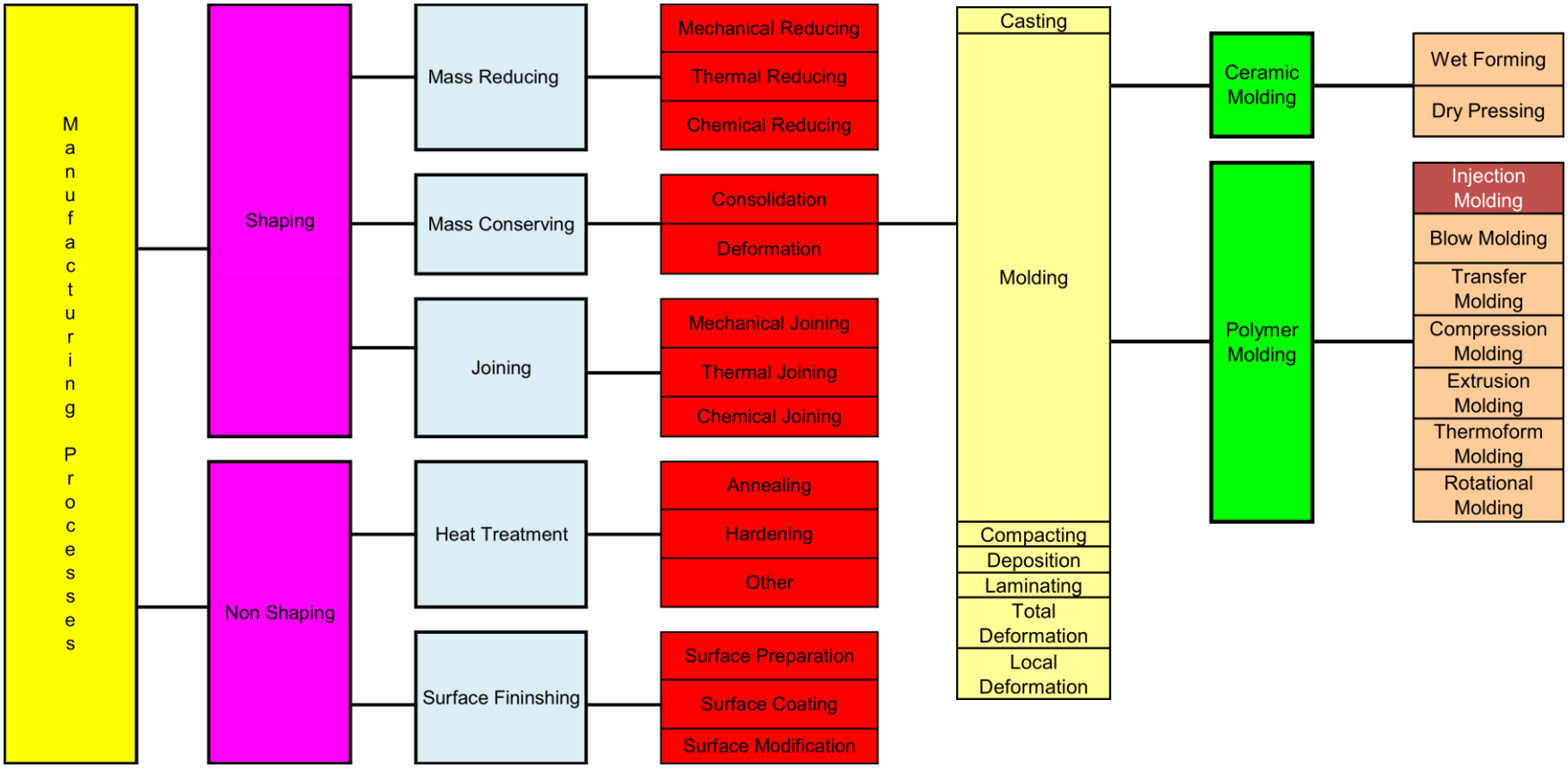


Figure. Classification of Manufacturing Process (Source: Groover)

Classifications Cont.



Reference: Todd, H.R., Alen, K.D., (1994) Manufacturing Processes Reference Guide, Industrial Press Inc.

Efforts by Wichita State University: uplci

Manufacturing Operations

Convert raw materials into finished products

For discrete products:

- 1. Processing and assembly operations
- 2. Material handling
- 3. Inspection and testing
- 4. Coordination and control

Processing Operations

A ***processing operation*** transforms a work material from one state of completion to a more advanced state using energy to alter its shape, properties or appearance to add value to the material.

- Shaping operations
  - Solidification processes
  - Particulate processing
  - Deformation processes
  - Material removal processes
- Property-enhancing operations
  - Heat Treating
- Surface processing operations
  - Cleaning and surface treatments
  - Coating and thin-film deposition

Assembly Operations

*An **assembly operation** joins two or more components to create a new entity which is called an assembly, subassembly, etc.*

- Joining processes
  - Welding
  - Brazing and soldering
  - Adhesive bonding
- Mechanical assembly
  - Threaded fasteners (e.g., bolts and nuts, screws)
  - Rivets
  - Interference fits (e.g., press fitting, shrink fits)

Material Handling

- A means of moving and storing materials between processing and/or assembly operations
  - Material transport
  - Vehicles, e.g., forklift trucks, AGVs, monorails
  - Conveyors
  - Hoists and cranes
- Storage systems
- Unitizing equipment
- Automatic identification and data capture (AIDC)
  - Bar codes
  - Radio-frequency identification (RFID)
  - Other AIDC equipment

Material Handling-Time

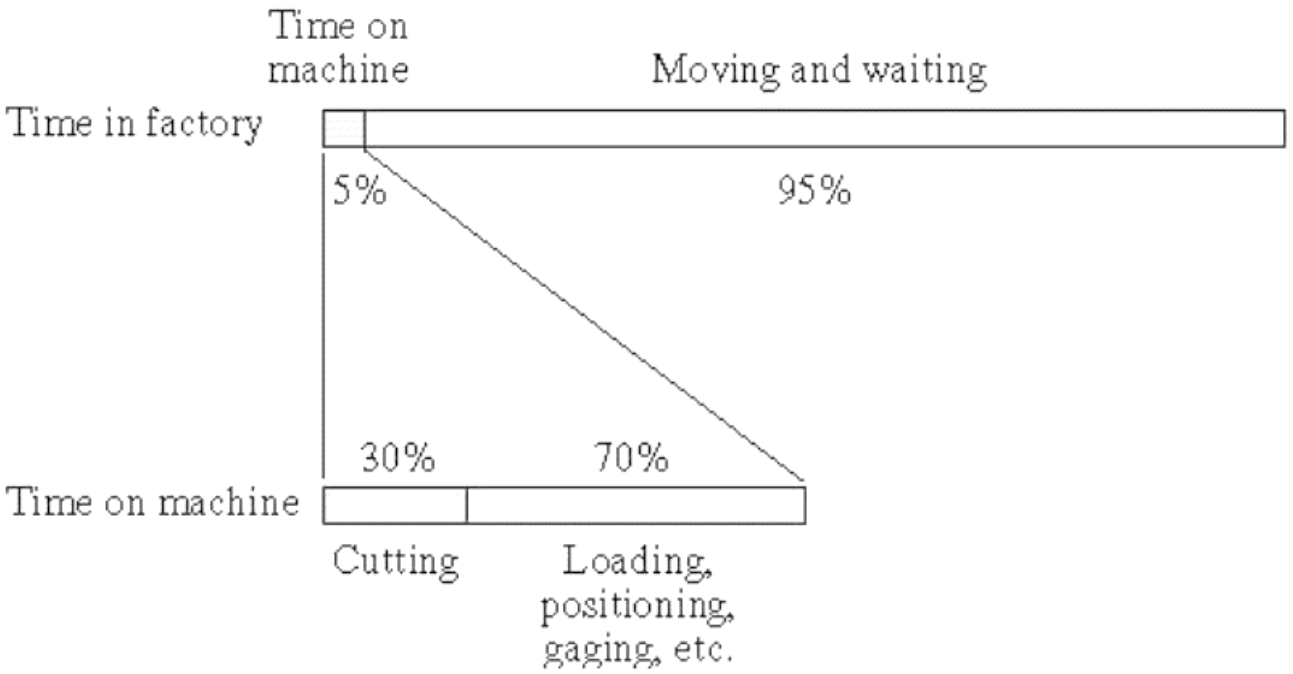


Figure. Time spent in materials handling (Source: Groover)

Inspection and Testing

- ***Inspection*** – examination of the product and its components to determine whether they conform to design specifications

- ***Testing*** – observing the product (or part, material, subassembly) during actual operation or under conditions that might occur during operation

Coordination and Control

- Regulation of the individual processing and assembly operations
  - Process control
  - Quality control
- Management of plant level activities
  - Production planning and control
  - Quality control

What is Industrial Automation?

Automated manufacturing:
https://www.youtube.com/watch?v=8WW_WbYVlU0

Realities of Manufacturing Today

- Outsourcing- Contract manufacturing
  - Local and international
- Globalization- Decentralized Manufacturing
- Competition
  - Increased expectations in quality
  - Increased operational efficiency- economic

Automation in production systems

- *automation* can be defined as a technology concerned with the application of mechanical, electronic, and computer-based systems to operate and control production.

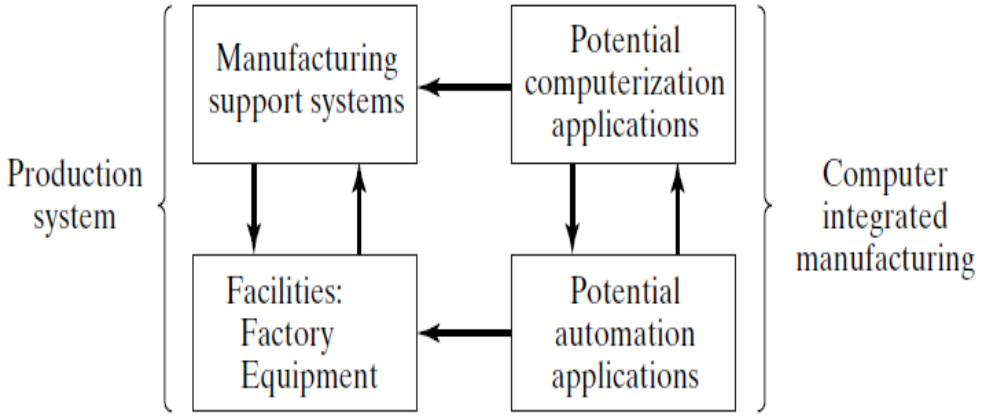


Figure. Opportunities for automation (Source Groover)

Manufacturing systems

In terms of the human participation in the processes performed by the manufacturing system:

- Manual work systems - a worker performing one or more tasks without the aid of powered tools, but sometimes using hand tools
- Worker-machine systems - a worker operating powered equipment
- Automated systems - a process performed by a machine without direct participation of a human

Manufacturing Support Systems

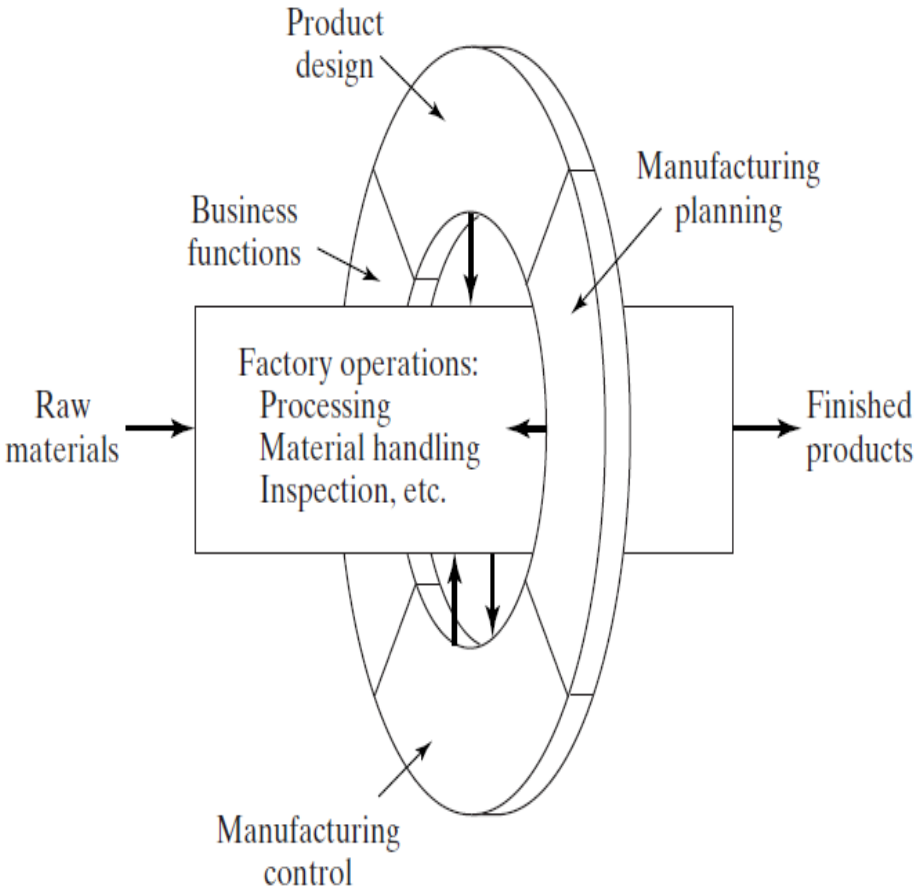


Figure. Manufacturing information-processing activities (Source Groover)

Manufacturing Approaches and Technologies

- Automation - automated equipment
- Material handling technologies - manufacturing usually involves a sequence of activities
- Manufacturing systems - integration and coordination of multiple automated or manual workstations
- Flexible manufacturing - to compete in the low volume/high-mix product categories
- Quality programs - to achieve the high quality expected by today's customers
- CIM - to integrate design, production, and logistics
- Lean production - more work with fewer resources

Examples

- Automated machine tools
- Transfer lines
- Automated assembly systems
- Industrial robots that perform processing or assembly operations
- Automated material handling and storage systems to integrate manufacturing operations
- Automatic inspection systems for quality control

Automated Manufacturing Systems

- Fixed automation
  - A manufacturing system in which the sequence of processing (or assembly) operations is fixed by the equipment configuration
- Programmable automation:
  - A manufacturing system designed with the capability to change the sequence of operations to accommodate different product configurations
- Flexible automation
  - An extension of programmable automation in which the system is capable of changing over from one job to the next with no lost time between jobs

Automated Manufacturing Systems

- Fixed automation
  - high initial investment for custom-engineered equipment
  - high production rates
  - relatively inflexible in accommodating product variety
- Programmable automation:
  - high investment in general purpose equipment
  - lower production rates than fixed automation
  - flexibility to deal with variations and changes in product configuration
  - most suitable for batch production
- Flexible automation
  - high investment for a custom-engineered system
  - continuous production of variable mixtures of products
  - medium production rates
  - flexibility to deal with product design variations

Automated Manufacturing Systems

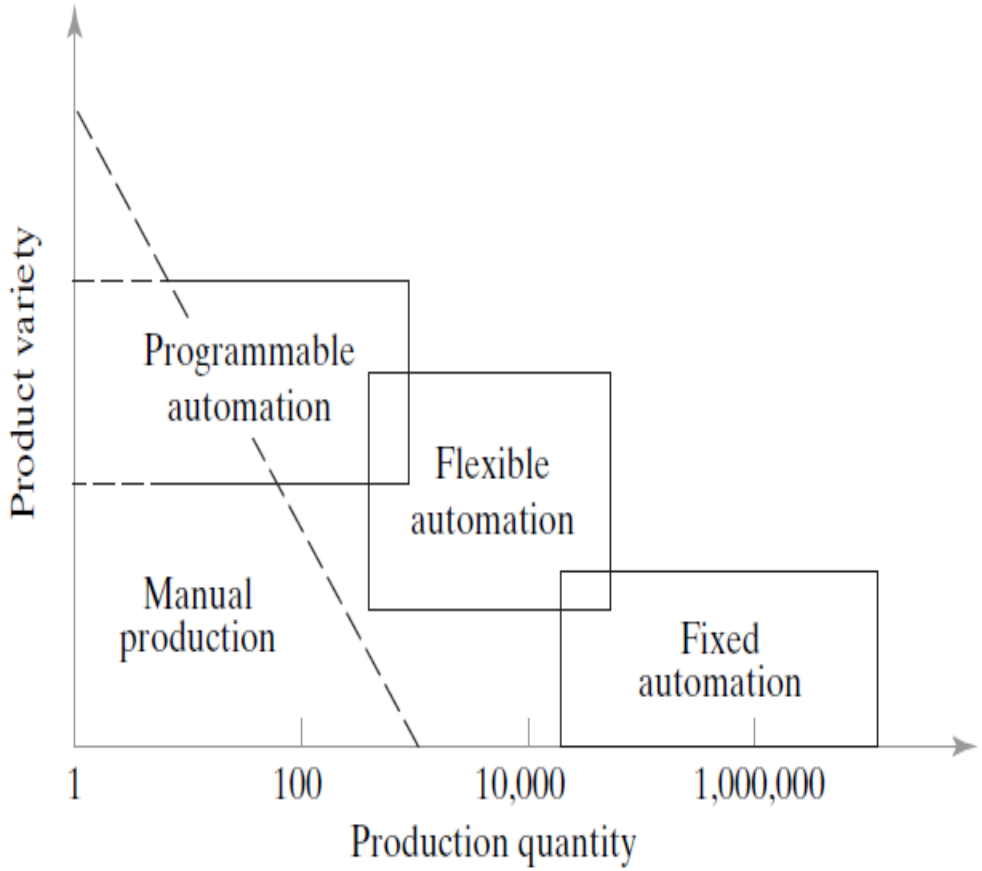


Figure. Types of automation relative to production quantity and part variety (Source: Groover)

Manufacturing Capability

Manufacturing capability - the technical and physical limitations of a manufacturing firm and each of its plants

Three dimensions of manufacturing capability:

- Technological processing capability - the available set of manufacturing processes
- Physical size and weight of product
- Production capacity (plant capacity) – max production quantity that can be made in a given time under assumed operating conditions

- Lean Production-*Operating the factory with the minimum possible resources and yet maximizing the amount of work accomplished*

Production performance metrics

- Production rate *Rp*
- Cycle time Tc
- Production capacity *PC*
- Utilization *U*
- Availability *A*
- Manufacturing lead time *MLT*
- Work-in-progress *WIP*

More information in Chapter 3
Manufacturing Models and Metrics

Elements of an automated system

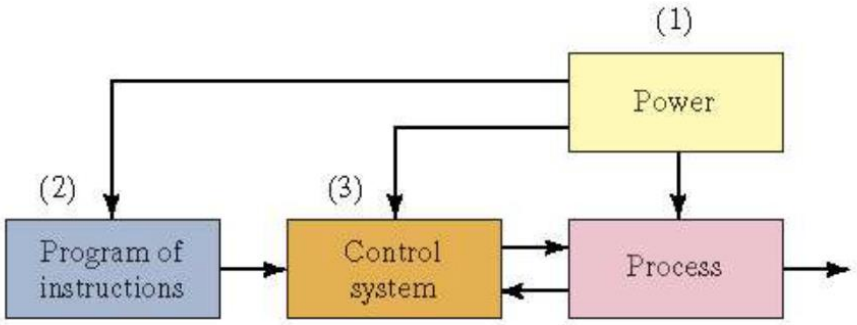


Figure. Elements of an automated system (Source: Groover)

1. Power - to accomplish the process and operate the automated system
2. Program of instructions – to direct the process
3. Control system – to actuate the instructions.

Implemented using a Program of Instructions combined with a Control System that executes the instructions.

Components of a control system

- *Input Parameter* (set point) represents the desired value of the output
- The *process* is the operation or function being controlled (output value)
- A *sensor* is used to measure the output variable and close the loop between input and output.
- The *controller* compares the output with the input and makes the required adjustment in the process to reduce the difference between them.
- The *adjustment* is accomplished using one or more *actuators* which are the hardware devices that physically carry out the control actions.

Control system types

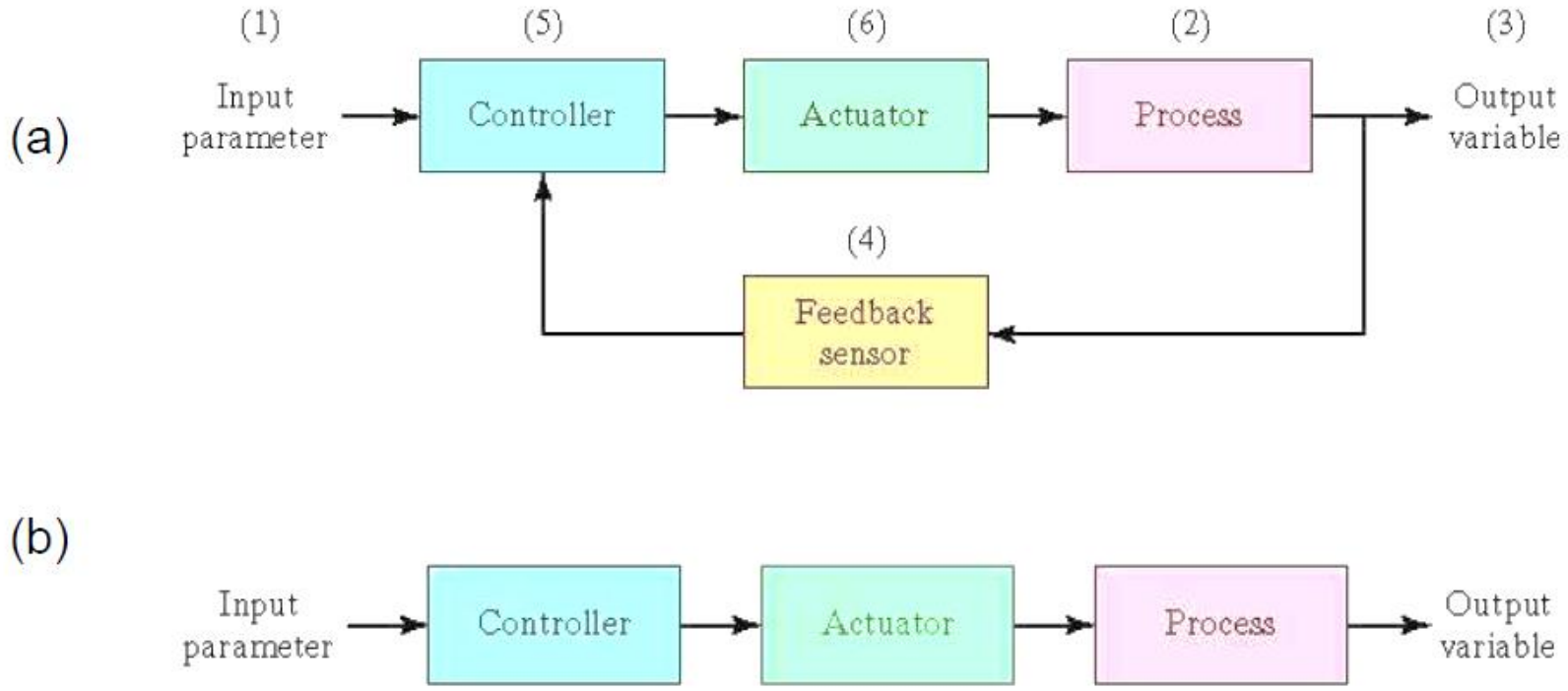


Figure. Closed-loop and open-loop control system (Source. Groover)

Reasons for Automating- Advanced Automation Functions

- Safety monitoring
  - To protect workers and equipment
  - Possible responses to hazards:
  - Complete stoppage of the system
  - Sounding an alarm
  - Reducing operating speed of process
  - Taking corrective action to recover from the safety violation
- Maintenance and repair diagnostics
  - Status monitoring
  - Failure diagnostics
  - Recommendation of repair procedure
- Error detection and recovery

Levels of Automation

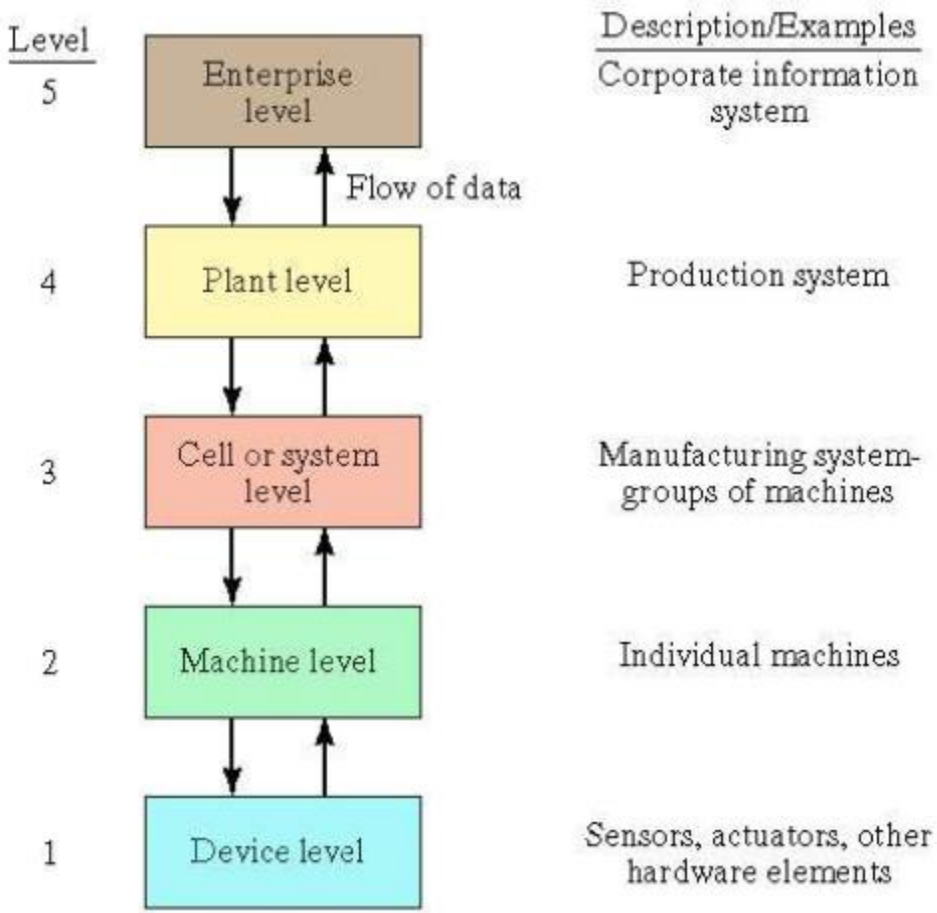


Figure. Levels of automation (Source: Groover)

Automation principles and strategies

- USA principle
  - *Understand* the existing process
  - *Simplify* the process
  - *Automate* the process.
- Ten Strategies for Automation and Production Systems
  - *Specialization of operations*.
  - *Combined operations*.
  - *Simultaneous operations*.
  - *Integration of operations*.
  - *Increased flexibility*.
  - *Improved material handling and storage*.
  - *On-line inspection*.
  - *Process control and optimization*.
  - *Plant operations control*.
  - *Computer-integrated manufacturing* (CIM).
- Automation Migration Strategy
  - Phase 1: *Manual production*
  - Phase 2: *Automated production*
  - Phase 3: *Automated integrated production*

The Future of Factory Automation

Disruptive Technologies

Do some research- explore some of the articles available on the Factories of the Future

Economically disruptive technologies

Mobile Internet

Increasingly inexpensive and capable mobile computing devices and Internet connectivity

Automation of knowledge work

Intelligent software systems that can perform knowledge work tasks involving unstructured commands and subtle judgments

The Internet of Things

Networks of low-cost sensors and actuators for data collection, monitoring, decision making, and process optimization

Cloud technology

Use of computer hardware and software resources delivered over a network or the Internet, often as a service

Advanced robotics

Increasingly capable robots with enhanced senses, dexterity, and intelligence used to automate tasks or augment humans

Autonomous and near-autonomous vehicles

Vehicles that can navigate and operate with reduced or no human intervention

Next-generation genomics

Fast, low-cost gene sequencing, advanced big data analytics, and synthetic biology ("writing" DNA)

Energy storage

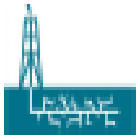
Devices or systems that store energy for later use, including batteries

3D printing

Additive manufacturing techniques to create objects by printing layers of material based on digital models

Advanced materials

Materials designed to have superior characteristics (e.g., strength, weight, conductivity) or functionality



Advanced oil and gas exploration and recovery

Exploration and recovery techniques that make extraction of unconventional oil and gas economical

Renewable energy

Generation of electricity from renewable sources with reduced harmful climate impact

Source: http://www.mckinsey.com/insights/business_technology/disruptive_technologies