INTRODUCTION TO MECHATRONICS

PRASHANT AMBADEKAR

WHAT IS CONTROL?

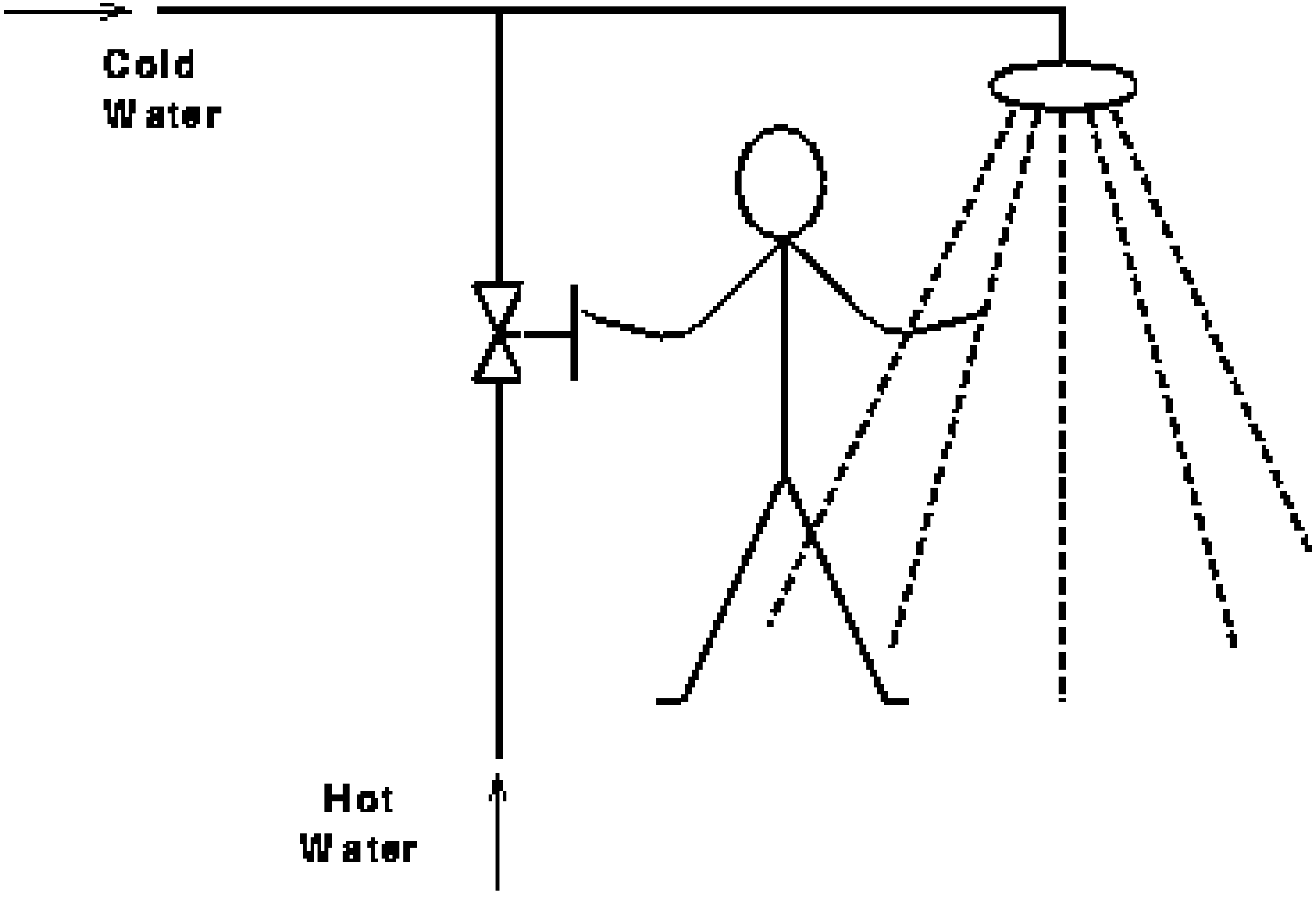
Control is the process of altering, manually or automatically, the performance of a system to a desired one.

WHY CONTROL?

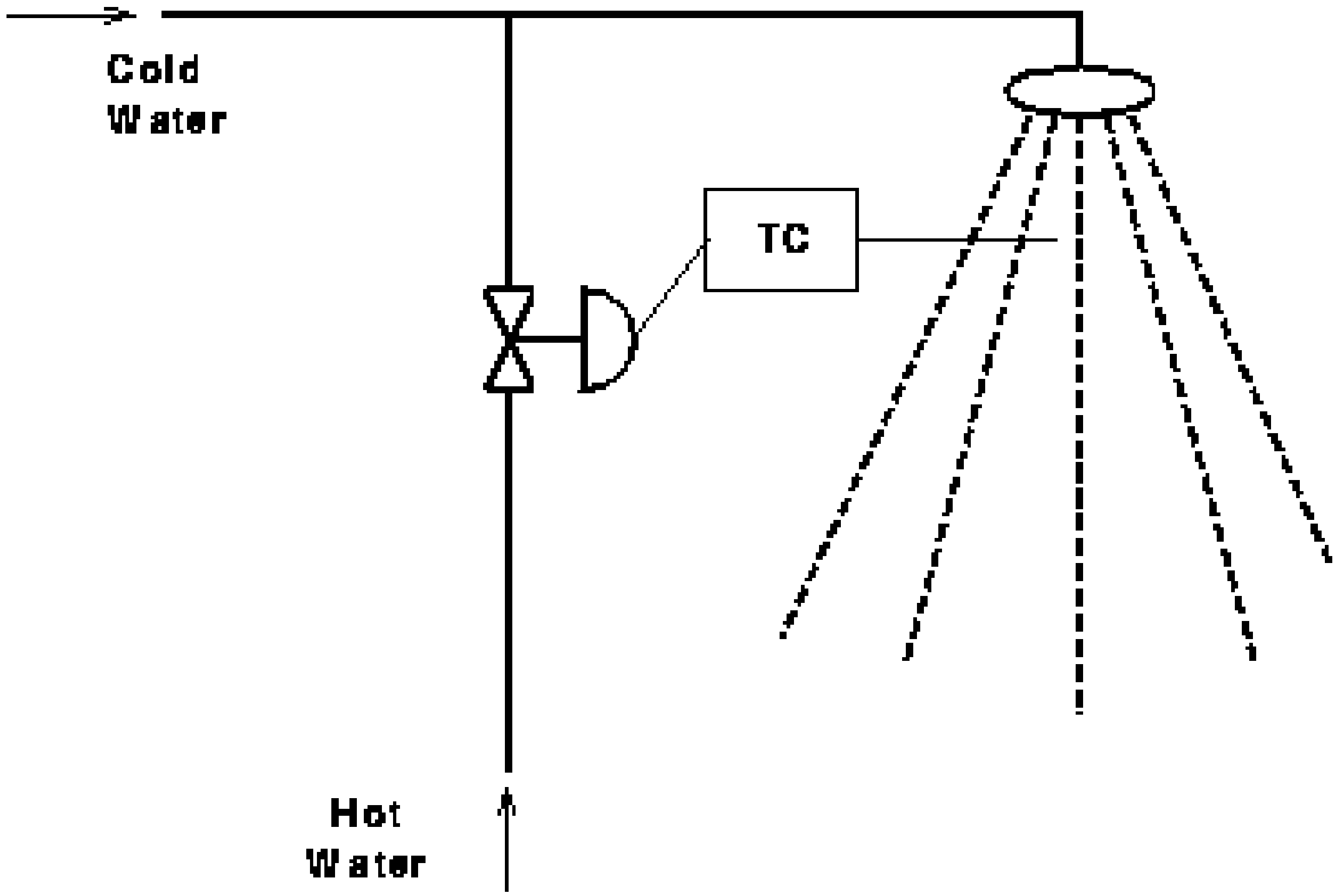
Because systems by themselves usually do not behave the way we would like them to

Manual Control System

Consider a simple manual control system shown below.

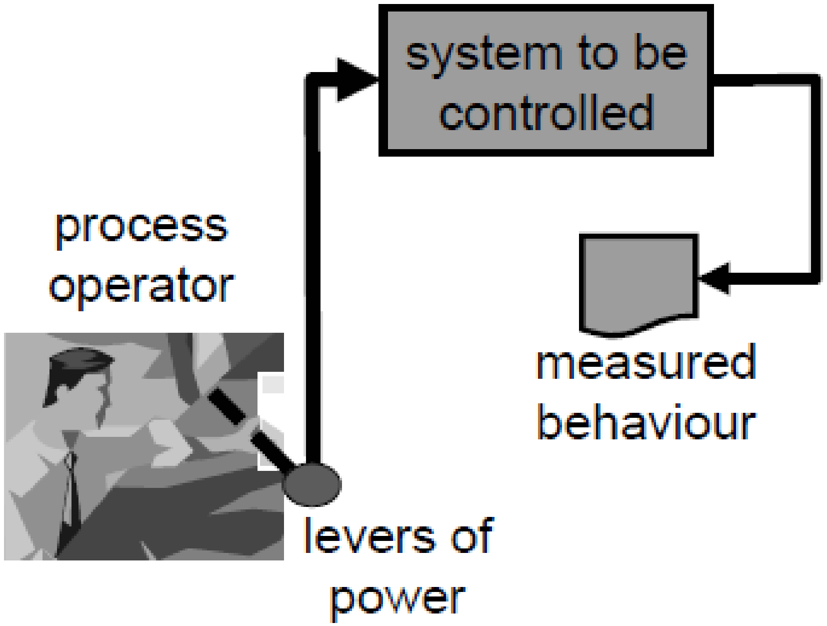


Automatic Control System

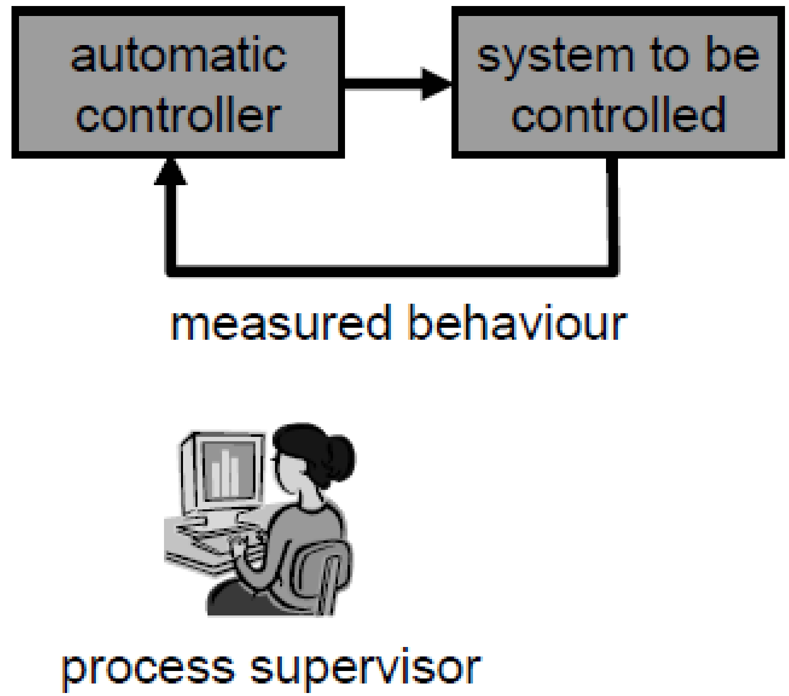


Manual/Automatic Control System

Manual Control



Automatic Control

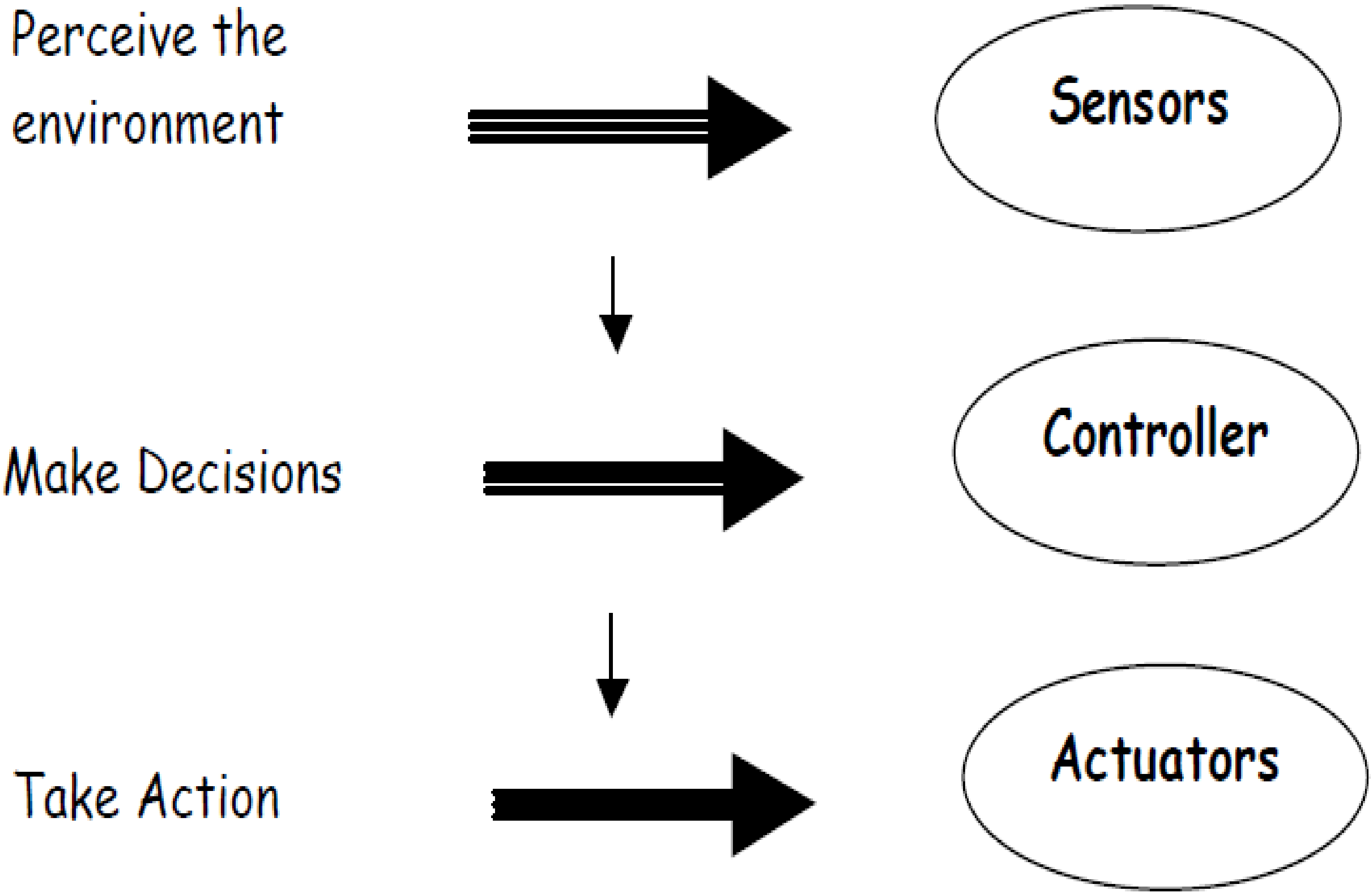


Automatic control describes the situation in which a machine is controlled by another machine.

Activity - TPS

What do these devices have in common?

Essentials in Mechatronics System



Toaster – A Mechatronics Application

1 Plug in the toaster to an electric plug so that it can work.

Toaster – A Mechatronics Application

3 Select the darkness of food in toaster using the adjustment knob.

Toaster – A Mechatronics Application

4 Lower the lever to start the toasting cycle.

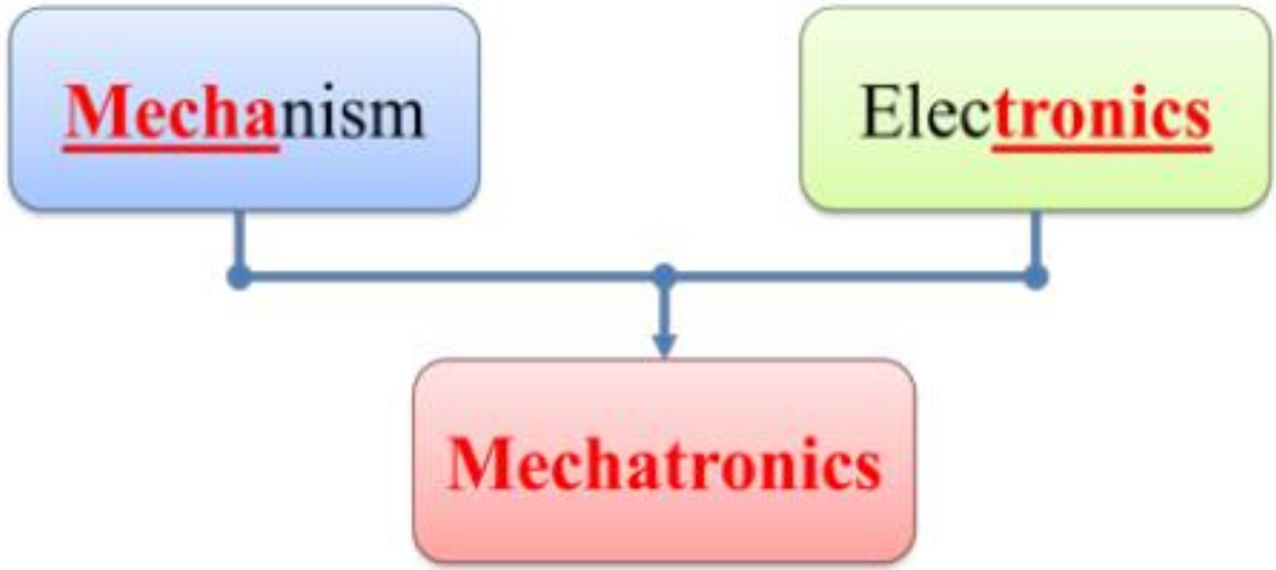
Toaster – A Mechatronics Application

5 Depending on how dark you selected the food in the toaster to be, it will take a minute or two,

Toaster – A Mechatronics Application

6 Take food out of toaster and put jam, honey, or anything else you may want to add onto it.

DEFINITION OF MECHATRONICS



Mechatronics is a concept of *Japanese* origin (1970's) and can be defined as the application of electronics and computer technology to control the motions of mechanical systems.

The **term 'mechatronics'** was coined by Yasakawa Electric Company to refer to the use of electronics in mechanical control

DEFINITION OF MECHATRONICS

Integration of electronics, control engineering, and mechanical engineering.

W. Bolton

Application of complex decision making to the operation of physical systems.

D. M. Auslander and C. J. Kempf

Synergistic integration of mechanical engineering with electronics and intelligent computer control in the design and manufacturing of industrial products and processes.

F. Harshama, M. Tomizuka

DEFINITION OF MECHATRONICS

Synergistic use of precision engineering, control theory, computer science, and sensor and actuator technology to design improved products and processes.

S. Ashley

Methodology used for the optimal design of electromechanical products.

D. Shetty and R. A Kolk

Field of study involving the analysis, design, synthesis, and selection of systems that combine electronics and mechanical components with modern controls and microprocessors.

D. G. Alciatore and M. B. Histand

DEFINITION OF MECHATRONICS

Mechatronics is defined as the interdisciplinary field of engineering that deals with the design of products whose function relies on the integration of mechanical, electrical, and electronic components connected by a control scheme.

Computer algorithm to modify the behavior of a mechanical system. **Electronics** are used to transduce information between the computer science and mechanical disciplines.

DEFINITION OF MECHATRONICS

Mechatronics: Working Definition

Mechatronics is the synergistic integration of sensors, actuators, signal conditioning, power electronics, decision and control algorithms, and computer hardware and software to manage complexity, uncertainty, and communication in engineered systems.

MECHATRONICS

Controller

is

mind of the mechatronic system

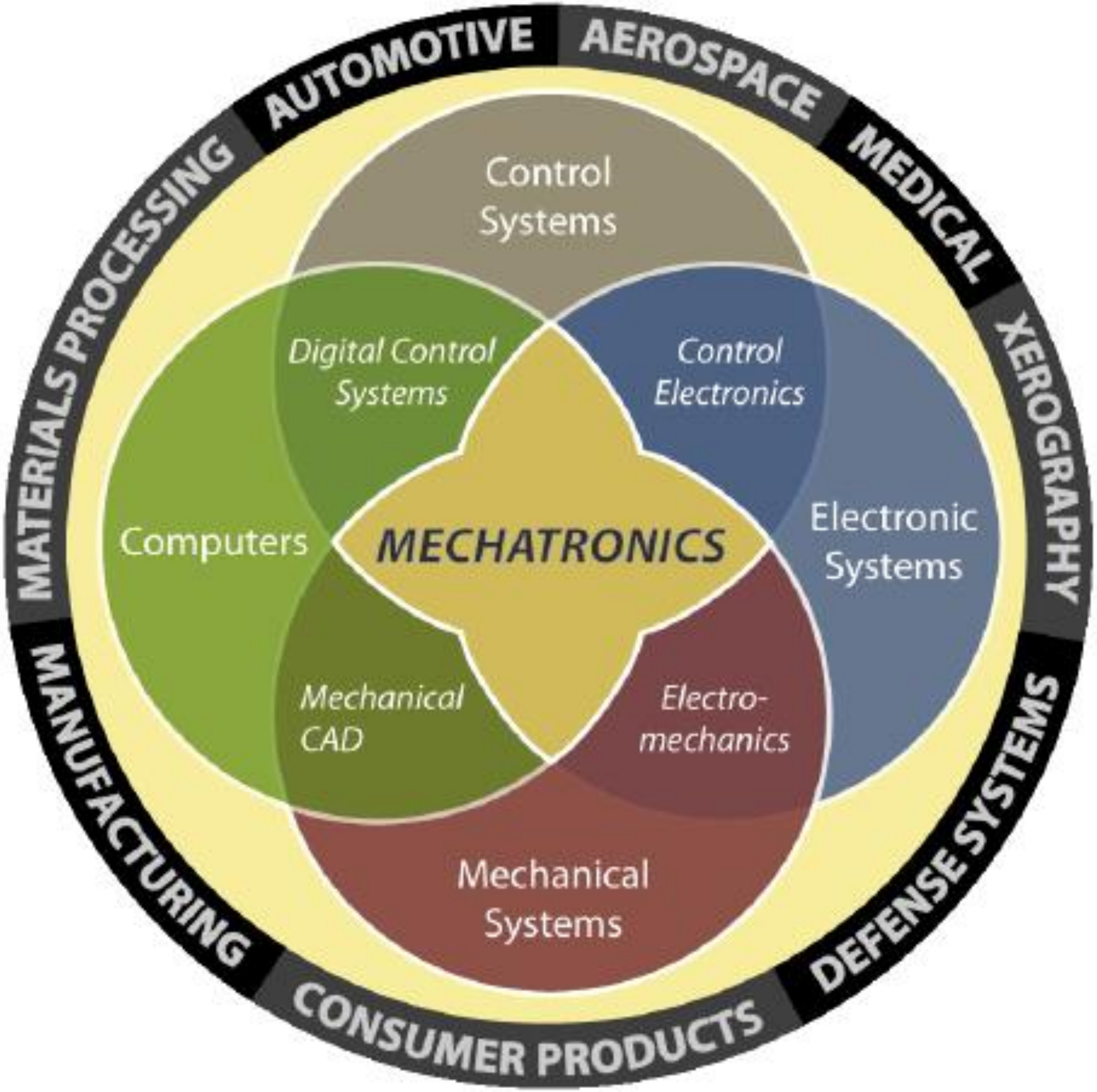
that processes

user commands and sensed signals

to generate command signals

to be sent to the actuators in the system.

MECHATRONICS



ADVANTAGES OF MECHATRONICS

- It has made easy to design products and processes.
- Mechatronics system helps in optimizing performance and quality.
- The products produced are cost effective and of good quality.
- Higher degree of flexibility.

DISADVANTAGES OF MECHATRONICS

- Knowledge of different engineering disciplines for design and implementation is imperative.
- It is expensive to incorporate mechatronics approach to an existing / old system.
- Specific problems for various systems will have to be addressed separately and properly.
- High initial cost of the system.

OBJECTIVES OF MECHATRONICS

- To improve products and processes.
- To develop novel mechanism.
- To design new products.
- To create new technology using novel concepts.

SENSOR

- Sensor is a device that responds to a change in the physical phenomenon.
- Sensors are required to monitor the performance of machines and processes.
- Transducer is a device that converts one form of energy into another form of energy.
- Some of the more common measurement variables in mechatronics systems are temperature, speed, position, force, torque, and acceleration.

VARIOUS SENSOR

- Proximity sensors
- Limit switches
- Potentiometer
- Digital optical encoder
- Strain gage
- Load cells
- Linear variable differential transformer
- Bimetallic strip
- Thermocouple
- Accelerometer
- Surface acoustic wave as sensor
- Hall effect sensor
- Resistance temperature detector

USE OF SENSORS / TRANSDUCERS

- To provide information of the measuring element.
  - Position, velocity or acceleration.
- To act as protective mechanism for the system.
- To help eliminate redundant devices.
  - Complex or expensive feeding or sorting devices.
- To provide real time information concerning nature of the task being performed.
- To provide identification and indication of the presence of different components.

ACTUATOR

- Kind of motor that controls / moves mechanisms / systems.
- Mechanism that converts electrical signals into useful mechanical motion or action.
- Actuation involves a physical acting on the process initiated by a sensor.
- It takes hydraulic fluid, electric current or other sources of power and converts the energy to facilitate the motion.
- Actuators produce either linear, rotary or oscillatory motion.

ACTUATOR

- Speed is vital in the case of motion control equipment.
- Process of converting sources of power into energy has been a great innovation to machinery.
- Efficiency brought about by actuators make them a cost effective alternative to human operation.
- There are four main types of actuators:
  - Hydraulic, Pneumatic, Electric and Mechanical.
  - Unconventional actuators

HYDRAULIC ACTUATOR

- It consist of a cylinder or motor that utilizes hydraulic power to facilitate mechanical process.
- Mechanical motion gives an output in terms of linear, rotary or oscillatory motion.
- LIMITATION:
  - Since liquids are nearly incompressible, they take longer to gain speed and power
- ADVANTAGE:
  - Can exert great force.
  - Precise control of the movement produced.

HYDRAULIC ACTUATOR

- MODE OF OPERATION:
  - Manually, such as a hydraulic **car jack**
  - Through a hydraulic pump, which can be seen in construction equipment such as cranes or excavators.
- WORKING:
  - Linear actuators consists of a hollow cylinder that contains fluid and a piston that is inserted in it.
  - When pressure is applied onto the piston, objects can be moved by the force produced.

PNEUMATIC ACTUATOR

- Pneumatic actuators work on the same concept as hydraulic actuators
- Fluid used is compressed gas instead of liquid.
- Energy is converted into linear or rotary motion
  - depending on the type of actuator.

PNEUMATIC ACTUATOR

- PREFERRED:
  - For quick operation.
  - Places where cleanliness is important
- LIMITATIONS:
  - Leakage
  - Less efficient compared to mechanical actuators.
  - Create noise
  - More space is needed

ELECTRIC ACTUATOR

- Devices powered by motors that convert electrical energy to mechanical torque.
- Electrical energy is used to create motion in equipment.
- Since no oil is involved, electrical actuators are considered to be one of the cleanest and readily available forms of actuators.
- Electric actuators are typically installed in engines, where they open and close different valves.

MECHANICAL ACTUATOR

- Mechanical actuators function through converting rotary motion to linear motion.
- It receives energy from various source.

VARIOUS ACTUATORS

- Solenoids
- Relays
- Electric motors
- Voice coil
- Piezoelectric
- Gear
- Cam
- Chain drive
- Harmonic drive
- Comb drive

EXAMPLES OF MECHATRONICS SYSTEM

EXAMPLES OF MECHATRONICS SYSTEM

Mechatronic systems are commonly found in homes, offices, schools, shops, and of course, in industrial applications.

Common mechatronic systems include:

Domestic appliances: Fridges and freezers, microwave ovens, washing machines, vacuum cleaners, dishwashers, mixers, blenders, stereos, televisions, telephones, lawn mowers, digital cameras, videos and CD players, camcorders, and many other similar modern devices.

Domestic systems: Air conditioning units, security systems, automatic gate control systems.

EXAMPLES OF MECHATRONICS SYSTEM

Office equipment: Laser printers, scanners, photocopiers, fax machines, as well as other computer peripherals.

Retail equipment: Bar-coding machines, and tills found in supermarkets.

Banking systems: Note counting machines, and automatic teller machines.

Manufacturing equipment: Numerically controlled (NC) tools, pick-and-place robots, welding robots, automated guided vehicles (AGVs), and other industrial robots.

EXAMPLES OF MECHATRONICS SYSTEM

Aviation systems: cockpit controls and instrumentation, flight control actuators, landing gear systems, and other aircraft subsystems.

Automobile system: ABS, air-bags, parking (proximity) sensors, anti-theft electronic keys, door lock system etc.

Elevators and escalators

Mobile robots and manipulator arms

Sorting and packaging systems in production lines

EXAMPLES OF MECHATRONICS SYSTEM

Computer Numerically Control (CNC) machines

Aeroplanes and helicopters

Tank fluid level and temperature control systems:

Temperature control system in an industrial oven

Heat-seeking missiles: These are complex systems that require extremely fast responses. A poor or slow controller could easily lead to the destruction of the missile. The orientation of the missile will be controlled based on the heat signal received from the target.

Coordinate Measuring Machines (CMM)

EXAMPLES OF MECHATRONICS SYSTEM

- Automatically stops when the door is opened.
- Software control with various programmes.
- Revolution and rotation may start synchronously during paint mixing.
- The revolution and rotation speed is controlled perfectly to make sure the machine will work steadily.

EXAMPLES OF MECHATRONICS SYSTEM

- Automatic clamping and opening setting
- Speed control to ensure stable operation.
- Self checking program runs automatically before operation.
- Controller activates alarm in case of abnormality.

- Digital display to show actual time and set time so that exact mixing is obtained.
- Automatic identification of the drum size to offer adequate clamping power and rotation speed.

EXAMPLES OF MECHATRONICS SYSTEM

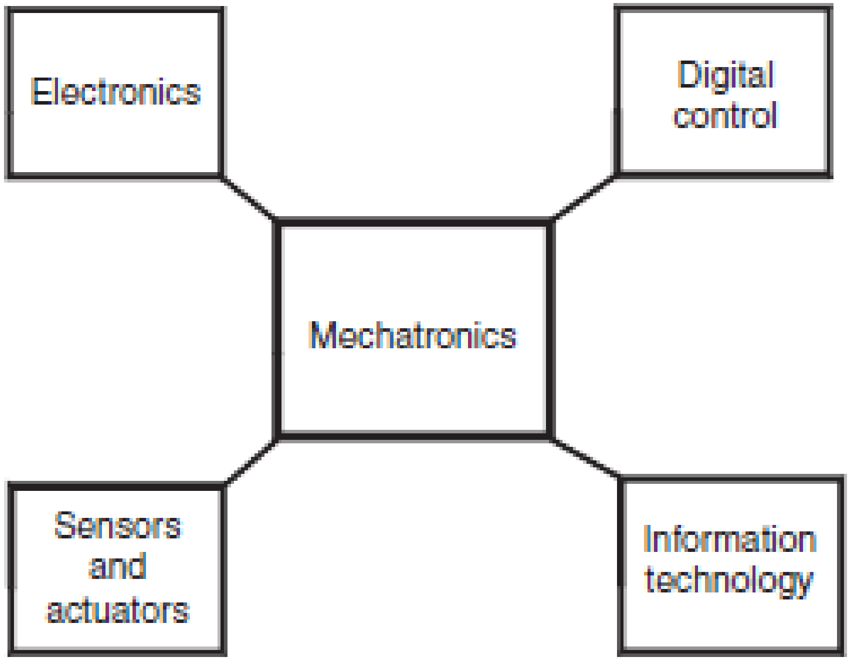
sensor		
Light sensor	Measures the brightness of ambient light	Controls screen brightness
Thermometer	measuring ambient temperature.	If component gets overheated, system shuts down by itself
Accelerometer	Measures acceleration that handset experiences	Portrait or landscape orientation. Screen facing upwards or downward
Barometer	Measure atmospheric pressure	Determines how high the device is above sea level, which in turn results in improved GPS accuracy
Proximity sensor	Measures the distance between phone and face	Deactivate display for saving power and prevent any unintentional inputs caused from touching face/ear to the screen.

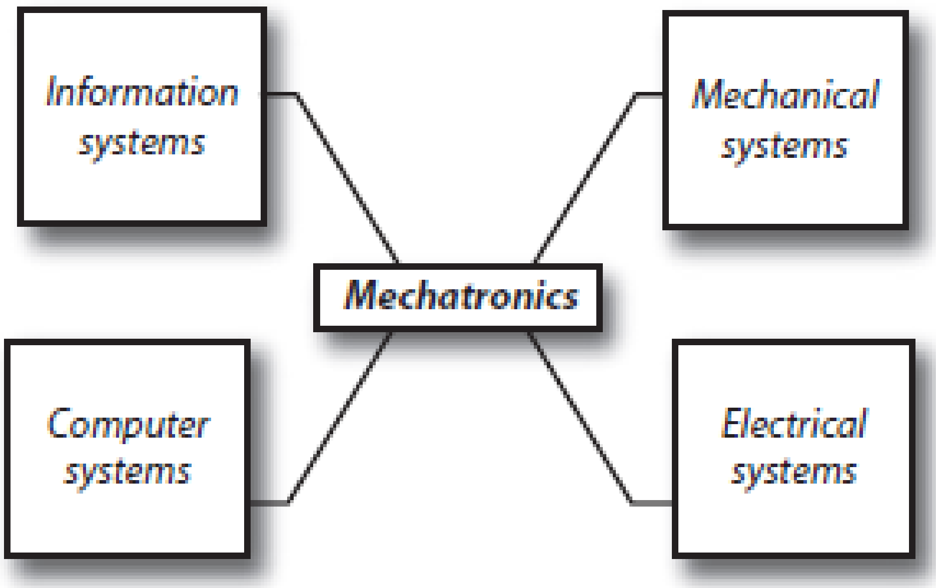
KEY ELEMENTS OF MECHATRONICS

The study of mechatronic systems can be divided into the following areas of specialty:

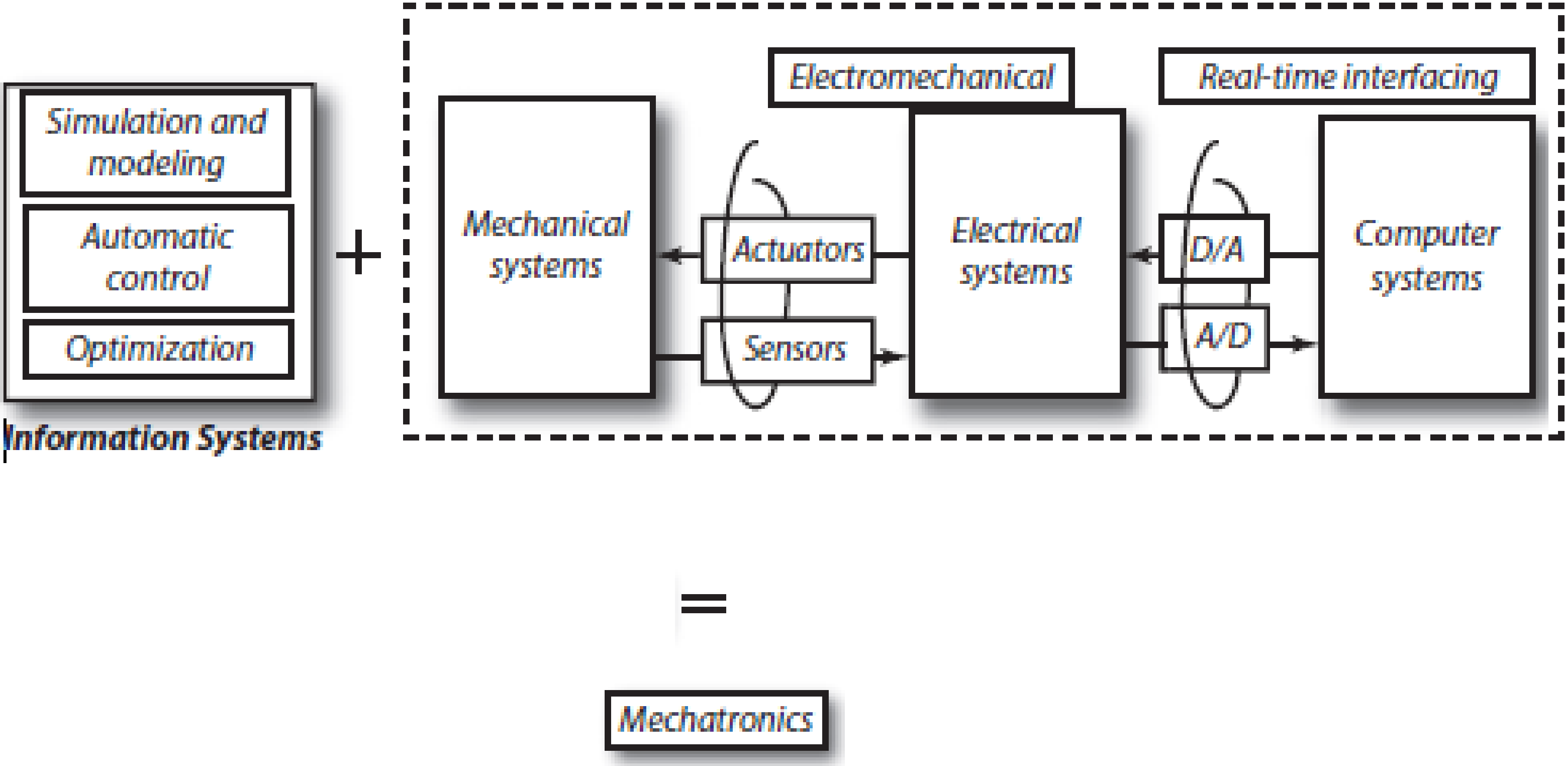
1. Physical Systems Modeling
2. Sensors and Actuators
3. Signals and Systems
4. Computers and Logic Systems
5. Software and Data Acquisition

KEY ELEMENTS OF MECHATRONICS





KEY ELEMENTS OF MECHATRONICS



KEY ELEMENTS OF MECHATRONICS

- Modeling is the process of representing the behavior of a real system by a collection of mathematical equations and logic.
- Models are collections of mathematical and logic expressions.
- Models can be either *static* or *dynamic.*
- Models are represented in block diagram.

KEY ELEMENTS OF MECHATRONICS

- Models accept external information and process it with their logic and equations to produce outputs.
- Externally produced information supplied to the model either can be fixed in value or changing.
- An external information is called an *input signal.*
- Model output information is assumed to be changing and is therefore referred to as output *signals.*

KEY ELEMENTS OF MECHATRONICS

- Block diagram consist of two fundamental objects: signal wires and blocks.
- Signal wire transmits a signal or a value from its point of origination to its point of termination.
- An arrowhead on the signal wire defines the direction in which the signal flows.
- Direction of flow is defined for a given signal wire.
- Signals may flow in forward or backward direction.
- A block gets input and produces output.

KEY ELEMENTS OF MECHATRONICS

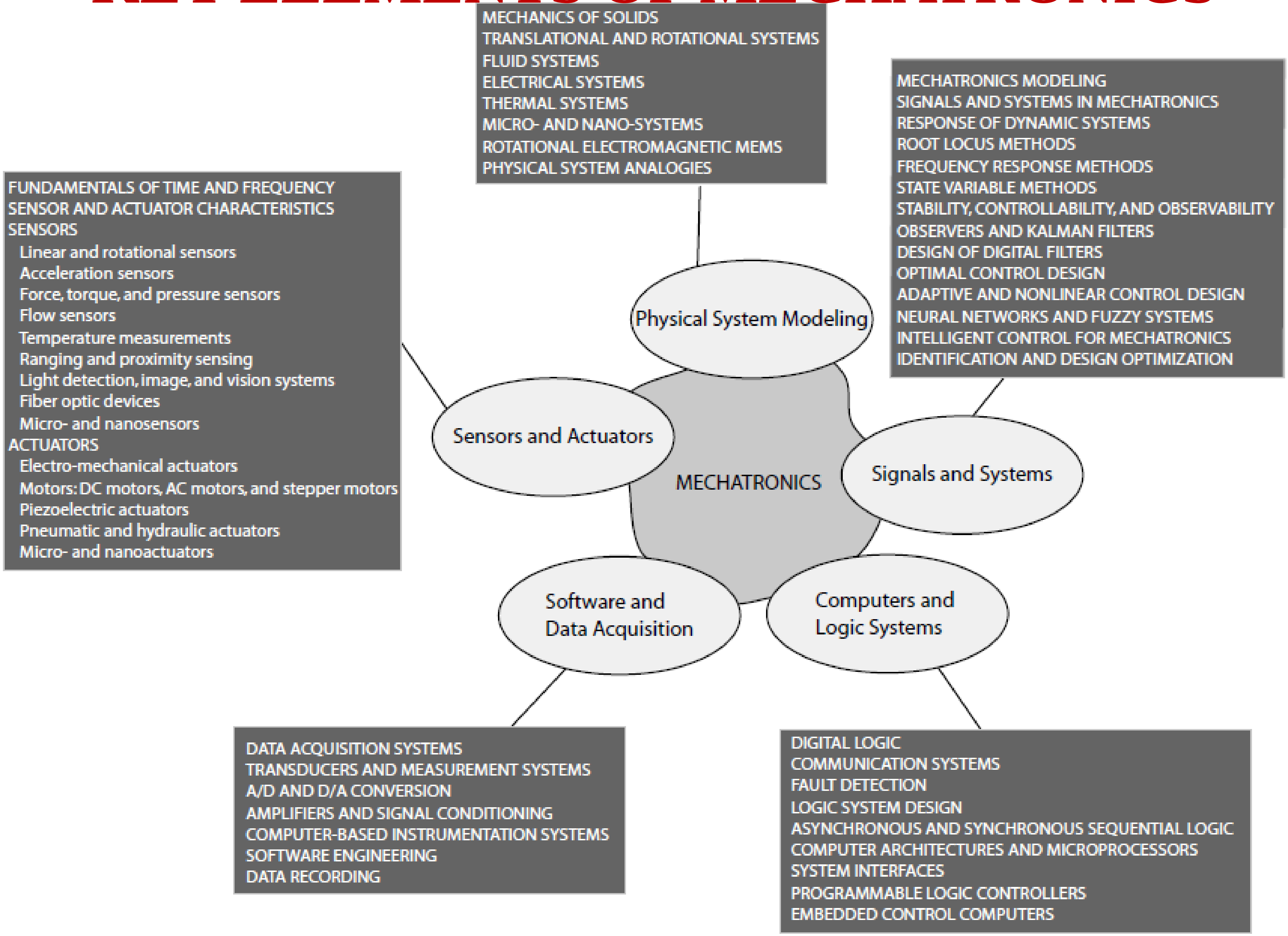
- Simulation is the process of solving the model and is performed on a computer.
- Simulation process can be divided into three sections: initialization, iteration, and termination.
- Initialization sort equations for each blocks according to the pattern in which the blocks are connected.
- The iteration section solves any DE present in the model using NT and/or differentiation.
- Display section of a simulation is used to present the output.
  - Reading, chart or animation.

KEY ELEMENTS OF MECHATRONICS

Optimization

- Optimization solves the problem of distributing limited resources throughout a system so that pre-specified aspects of its behavior are satisfied.
- In mechatronics, optimization is primarily used to establish the optimal system configuration.

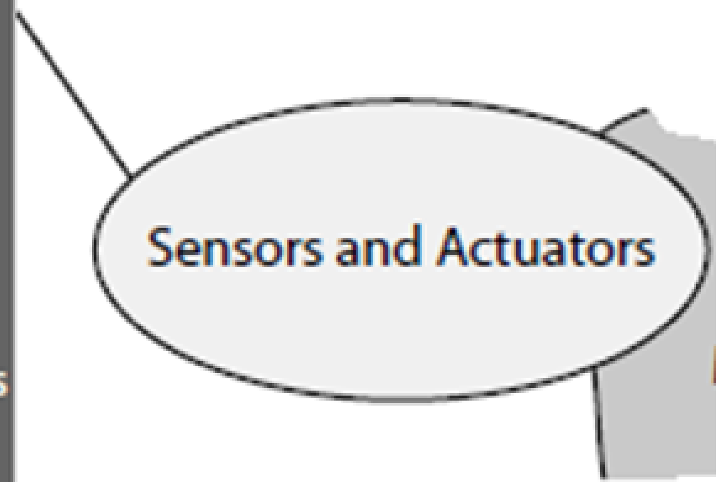
KEY ELEMENTS OF MECHATRONICS



KEY ELEMENTS OF MECHATRONICS

FUNDAMENTALS OF TIME AND FREQUENCY
SENSOR AND ACTUATOR CHARACTERISTICS
SENSORS
- Linear and rotational sensors
- Acceleration sensors
- Force, torque, and pressure sensors
- Flow sensors
- Temperature measurements
- Ranging and proximity sensing
- Light detection, image, and vision systems
- Fiber optic devices
- Micro- and nanosensors

ACTUATORS
- Electro-mechanical actuators
- Motors: DC motors, AC motors, and stepper motors
- Piezoelectric actuators
- Pneumatic and hydraulic actuators
- Micro- and nanoactuators



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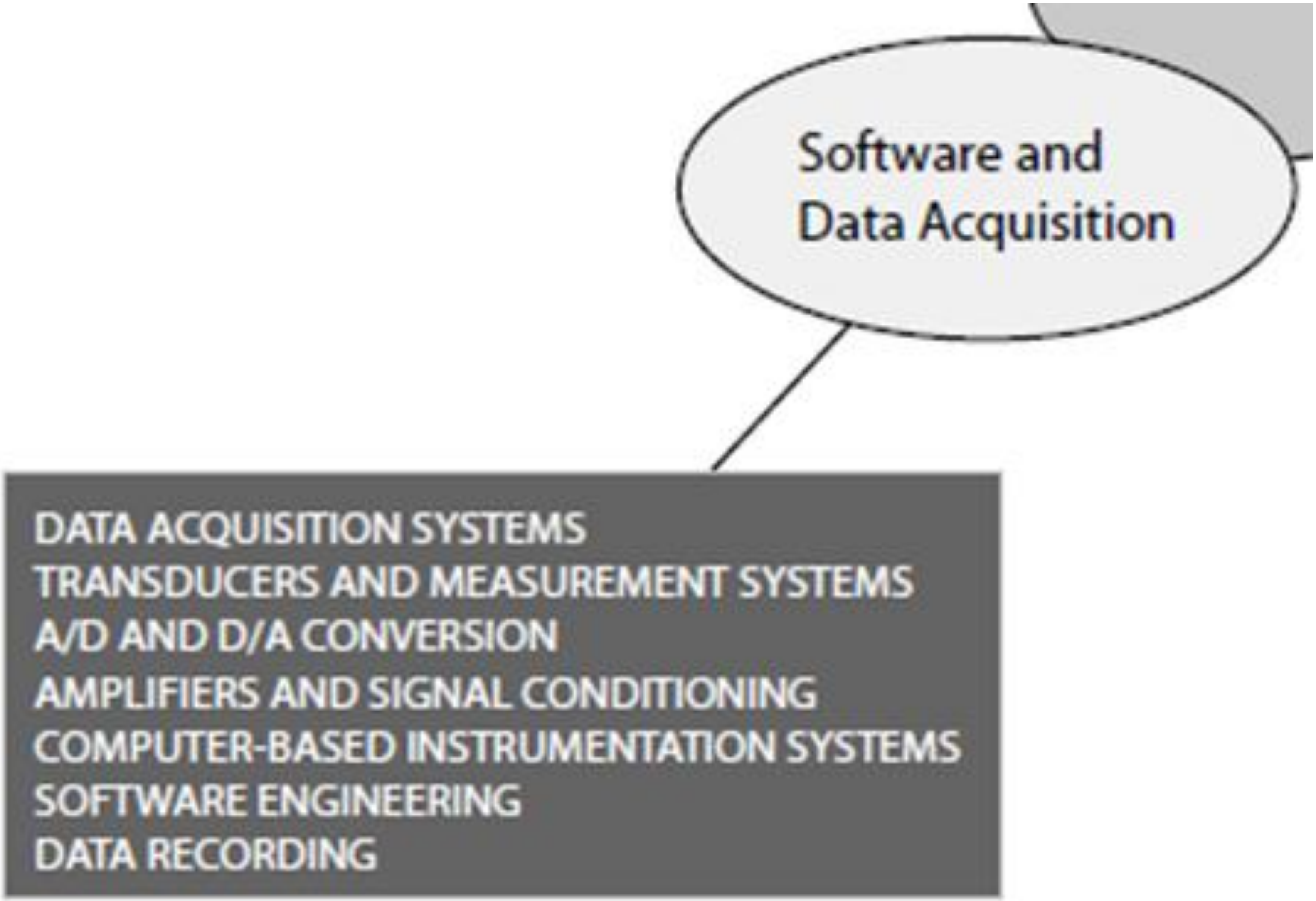
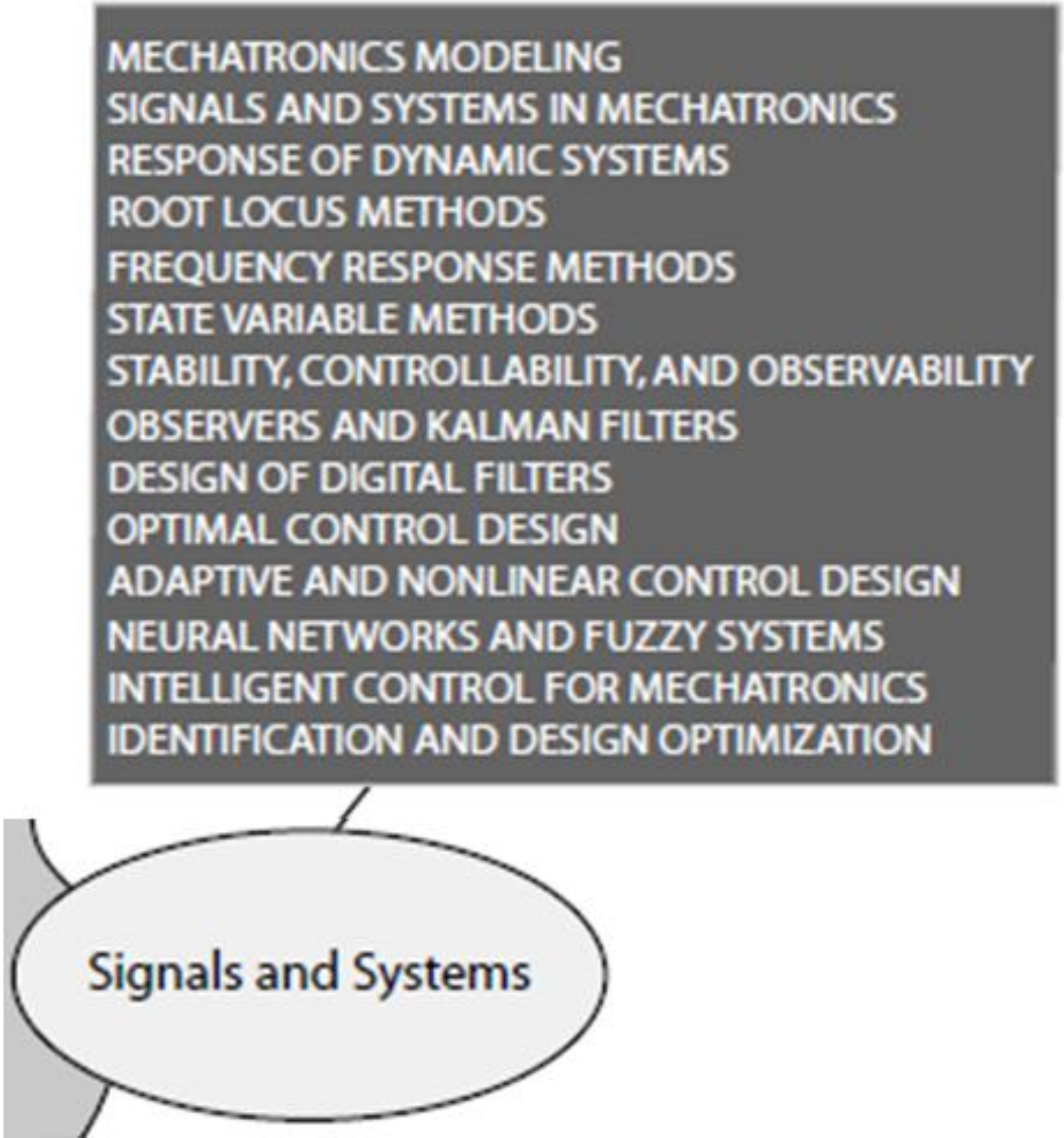


KEY ELEMENTS OF MECHATRONICS

Computers and Logic Systems

- DIGITAL LOGIC
- COMMUNICATION SYSTEMS
- FAULT DETECTION
- LOGIC SYSTEM DESIGN
- ASYNCHRONOUS AND SYNCHRONOUS SEQUENTIAL LOGIC
- COMPUTER ARCHITECTURES AND MICROPROCESSORS
- SYSTEM INTERFACES
- PROGRAMMABLE LOGIC CONTROLLERS
- EMBEDDED CONTROL COMPUTERS

KEY ELEMENTS OF MECHATRONICS



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