Mechatronic Design

TOPIC:

Mechatronic Systems Components

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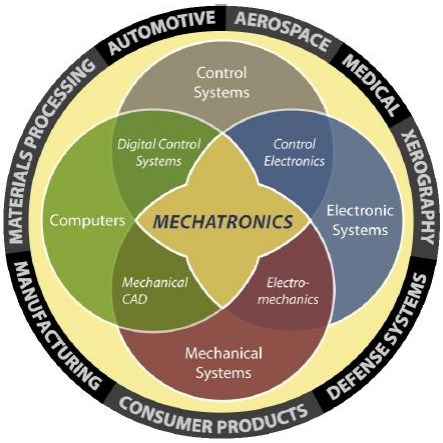
Outline

- Mechatronic Systems Overview
  - Definitions
  - Historical development
  - Applications & examples
- Mechatronic Design Approach
  - Traditional Design vs Mechatronic Design
  - Mechatronic Desing Process
  - Advantages
  - Key Elements



Mechatronics Definition

- The word, ***mechatronics***, is composed of "mecha" from mechanism and the "tronics" from electronics
- The name [mechatronics] was first coined by Ko Kikuchi at Yasakawa Electric Co. (Japan)
- It is defined as: ***"The synergistic integration of mechanical engineering, with electronics and intelligent computer control in the design and manufacturing of industrial products and processes"***

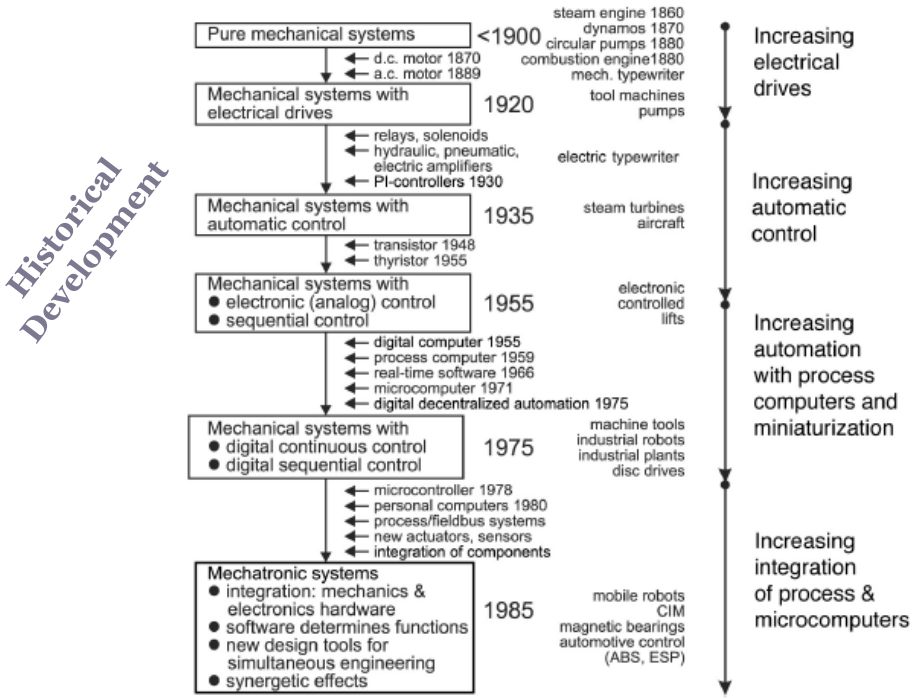
Harashima, Tomizuka, and Fukada, 1996

Mechatronics Application Areas

Automation and robotics	Machine vision
Automotive engineering	Mechatronics systems
Computer aided and integrated manufacturing systems	Medical systems
Computer Numerically Controlled machines	Packaging
Consumer products	Sensing and control systems
Diagnostic, reliability, and control system techniques	Servo-mechanics
Engineering design	Structural dynamic systems
Engineering and manufacturing systems	Systems engineering
Expert systems	Transportation and vehicular systems
Industrial goods	

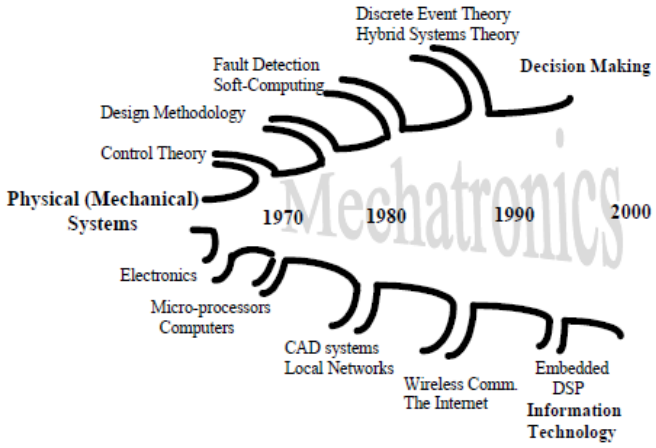
Mechatronic Products Examples

- *Smart consumer products*: home security, camera, microwave oven, toaster, dish washer, laundry washer-dryer, climate control units, etc.
- *Medical*: implant-devices, assisted surgery, haptic, etc.
- *Defense*: unmanned air, ground, and underwater vehicles, smart munitions, jet engines, etc.
- *Manufacturing*: robotics, machines, processes, etc.
- *Automotive*: climate control, antilock brake, active suspension, cruise control, air bags, engine management, safety, etc.
- *Network-centric, distributed systems*: distributed robotics, tele-robotics, intelligent highways, etc.



Mechatronics Evolution

- *Mechatronics is an evolutionary process, not a revolutionary one.*

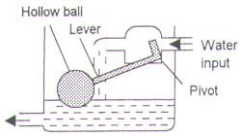


Some History

- *Mechanical Engineering experienced an exponential growth in the early 19th century because of the industrial revolution*
- *The development of semiconductors in the 1950s and computers in the 1980s revolutionized all engineering products and processes*
- *Technological advances in design, manufacturing, and operation of engineered products/devices/processes can be traced through:*
  - *Industrial revolution*
  - *Semiconductor revolution*
  - *Information revolution*

Industrial Revolution

- Design of products and processes for energy conversion and transmission
  - Energy to do useful work
- Engineering designs of this era were largely mechanical
  - Motion transmission, sensing, actuation, and control were performed using mechanical components such as cams, gears, levers, and linkages
- Purely mechanical systems suffer from
  - Power amplification inability
  - Energy losses due to tolerances, inertia, and friction



Float Valve

Semiconductor Revolution

- Creation of integrated circuit (IC) technology.
- Signal conditioning electronics could filter and encode sensor data in analog/digital format
- Effective, miniaturized, power electronics could amplify and deliver the required amount of power to actuators
- Discrete and analog/digital ICs provided computational intelligence for the control of mechanical devices


Integrated Circuit


Operational Amplifier

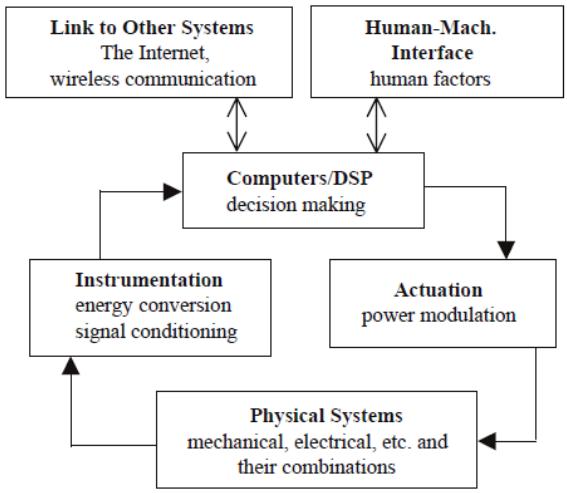
A/D Converter

Information Revolution

- Development of Very Large Scale Integration (VLSI) technology allowed the introduction of microprocessor, microcomputer, and microcontroller
  - Computing hardware became ubiquitous, cheap, and small
- Computing hardware can be interfaced with electromechanical systems to control them
  - Programmability of microcontrollers is providing a versatile and flexible alternative to implement control techniques
- Computing hardware can can be embedded in engineered products/processes
  - Integrated computer-electrical-mechanical devices are now capable of converting, transmitting, and processing the *physical energy* and the *information*

Modern Mechatronic System

- *Today, many mechanical systems use some form of electronics and computers to control its functionality*

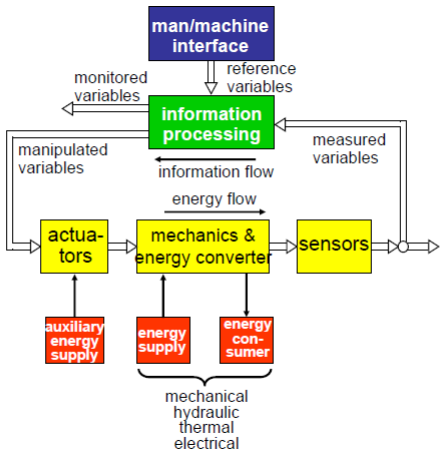


Modern Mechatronic System

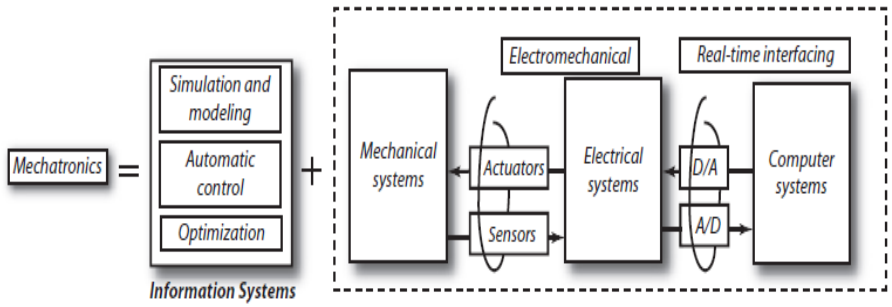
- Highly efficient products and processes are now being developed by proper selection and integration of:
  - Sensors
  - Actuators
  - Signal conditioning
  - Power electronics
  - Decision and control algorithms, and
  - Computer hardware and software

Mechatronics: Improves the Mechanical and Information Processing

- *Information is sometimes referred as "Virtual Energy"*

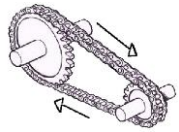


Mechatronic Key Elements



Mechanical Elements

- Mechanical elements refer to
  - Mechanical structure and mechanisms
  - Thermo-fluid and hydraulic systems
- Mechanical elements may include static/dynamic characteristics
- A mechanical element is designed to interact with its environment
- Mechanical elements require physical power to produce motion, force, heat, etc.



Chain and sprocket

Gear, rack, pinion, etc.

Electromechanical Elements

- Electromechanical elements refer to:
  - Sensors
    - A variety of physical variables can be measured using sensors, e.g., light using photo-resistor, level and displacement using potentiometer, direction/tilt using magnetic sensor, sound using microphone, stress and pressure using strain gauge, touch using micro-switch, temperature using thermistor, and humidity using conductivity sensor
  - Actuators
    - AC and DC motors and servomotors, stepper motor, relay, solenoid, electromagnet, pumps, hydraulic and pneumatic valves and cylinders apply commanded action on the physical process

Pneumatic Cylinder

DC Motor

Electrical/Electronic Elements

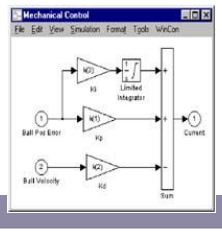
- The electrical/electronic elements are used to interface electro-mechanical sensors and actuators to the control interface/computing hardware elements
- Electrical elements refer to:
  - Electrical components (e.g., resistor (R), capacitor (C), inductor (L), transformer, etc.), circuits, and analog signals
- Electronic elements refer to:
  - Analog/Digital electronics, transistors, thyristors, opto-isolators, operational amplifiers, power electronics, and signal conditioning

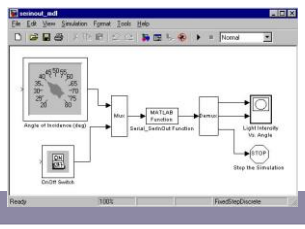
Control Interface & Computing Hardware

- Control Interface & Computing Hardware elements refer to:
  - Analog-to-digital converter (ADC) and digital-to-analog converter (DAC)
  - Digital input/output (I/O), counters, timers and data acquisition
  - Control boards, microprocessors, microcontrollers and digital signal processor (DSP).
- Control Interface Hardware (analog/digital interfacing) allows the Communication of sensor signal to the control computer and communication of control signal from the control computer to the actuator
- Control Computing Hardware implements a control algorithm, which uses sensor measurements, to compute control actions to be applied by the actuator.

Computer & Information Systems

- Computer & Information systems refer to hardware and software utilized to perform:
  - Computer-aided system analysis, optimization, design, and simulation
  - Virtual instrumentation
  - Rapid control prototyping
  - Hardware-in-the-loop simulation
  - PC-based data acquisition and control





Required Expertise for Mechatronic Design

- Typical knowledge base for optimal design of a mechatronic systems comprises of:
  - Dynamic system modeling and analysis
    - Thermo-fluid, structural, hydraulic, electrical, chemical, biological, etc.
  - Decision and control theory
  - Sensors and signal conditioning
  - Actuators and power electronics
  - Data acquisition
    - ADC, DAC, Digital I/O, counters, timers, etc.
  - Hardware interfacing
  - Embedded computing

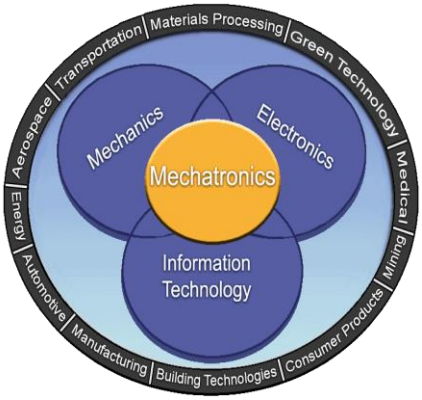
Summary

- Mechatronics is the application of complex decision making (***computational intelligence***) to the operation of physical systems
- A mechatronic system is not just a marriage of electrical and mechanical systems and is more than just a control system; it is a ***complete integration*** of all of them
- Mechatronics is a ***methodology*** used for the optimal design of electromechanical products

Mechatronics Engineering

- *Mechatronics Engineering is the*
  - *Analysis*
  - *Design*
  - *Manufacturing*
  - *Integration*
  - *and maintenance*

  of mechanics with electronics through intelligent computer control.



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