Introduction to Mechatronics

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Evolution of Mechatronics

- **Industrial Revolution [1760-1840]**

[Motion Transmission, Sensing, Actuation and Transmission using Mechanical Components]

- **Semiconductor Revolution [1960 - …**

[Integrated Circuit, Power Amplifier, Semi Conductor Technology] Solid State Sensors and Actuators - W Shockley, J Bardeen and W Brattain
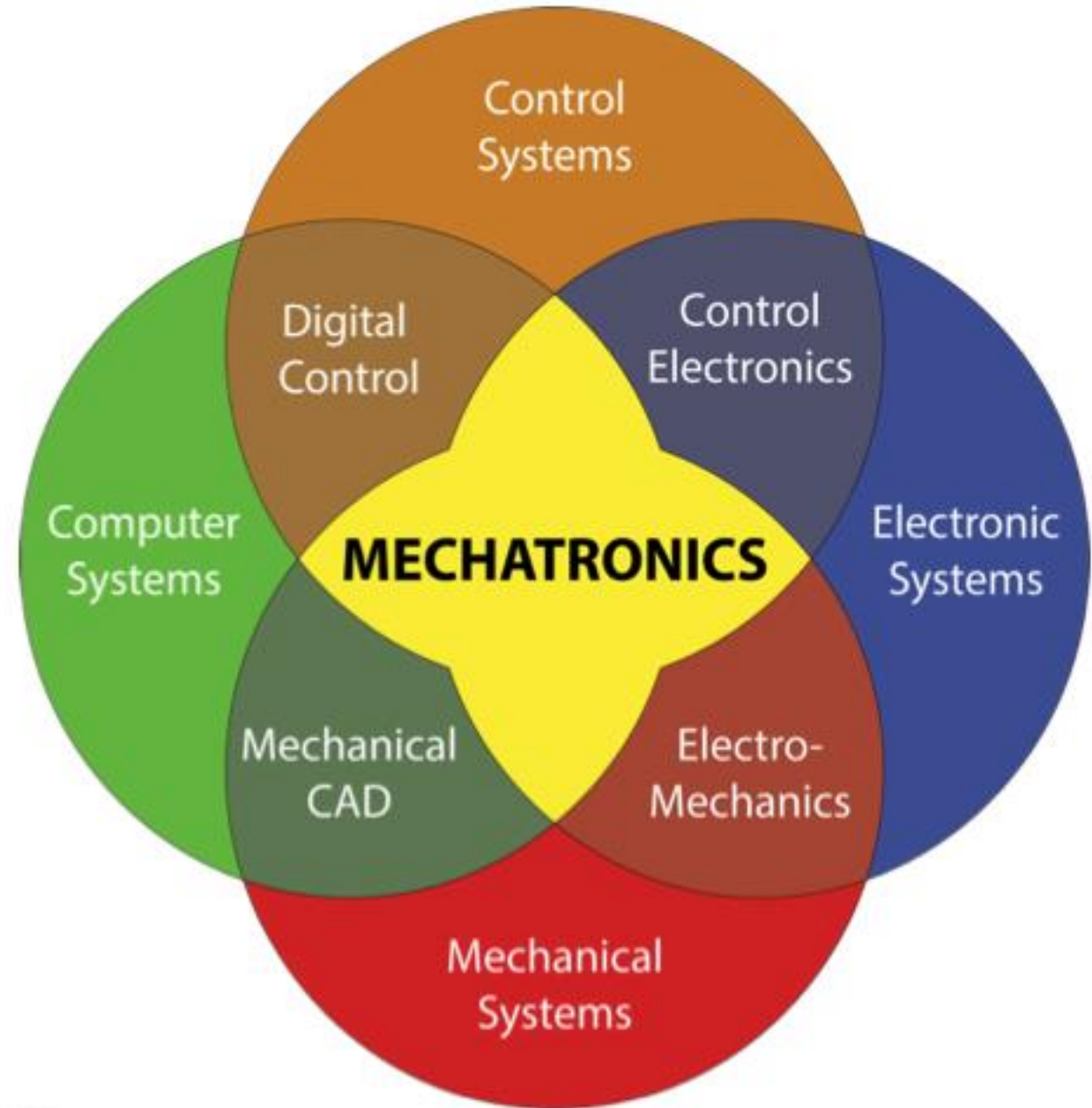
- **Information Revolution**

[Microprocessors, AD-DA Conversion, Microcontroller, Micro-progaming etc.] Obtaining, Processing, Storing and Transmission of Information.

What is Mechatronics?

It represents a synergistic integration of Mechanical, Electronics, Control and Computer Systems.

J L Shelton, Purdue University

A few Allied Areas of Mechatronics

- Cybernatics: Control + Communication
- Cyberphysical Systems: Control + Communication + Mechanism (Physical) – a subset of mechatronics
- Internet of Things (IOT): Network of Mechatronic Devices
- Artificial Intelligence (AI): Machine + Computer Intelligence (A Combination of Software and Hardware often involving an array of sensors)
- Robotics: Mechanical System + Control System + Sensors + Actuators + Intelligence (?)
- Biomechatronics: Biology + Mechanical System + Control System eg Medical Devices for therapeutic use
- Mechamatronics: Mechanical + Smart Material + Electronic System

Elements of Mechatronics

• **Mechanical Elements**:

Mechanism, Thermo-fluid, and Hydraulic aspects of a mechatronics system.

The mechanical element may include static/dynamic characteristics as it interacts with its environment purposefully – Anything that requires Physical Power for generating Motion, Heat, Temperature etc.

Elements of Mechatronics

- **Electro-mechanical Elements**:

Sensors and Actuators - 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 such as light emitting diode (LED), DC servomotor, stepper motor, relay, solenoid, speaker, shape memory alloy, electromagnet, and pump apply commanded action on the physical process.

In recent years, IC-based sensing and actuation solutions have also become ubiquitous (e.g., digital-compass, -potentiometer, etc.).

Elements of Mechatronics – cont..

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- **Electrical/Electronic Elements**:

Electrical components (e.g., resistor (R), capacitor (C), inductor (L), transformer, etc.), circuits, and analog signals.

Electronic elements refer to analog/digital electronics, transistors, thermistors, opto-isolators, operational amplifiers, power electronics, and signal conditioning.

The electrical/electronic elements are used to interface electro-mechanical sensors and actuators to the control interface hardware elements.

Elements of Mechatronics – cont..

- **Control Interface/Computing Hardware**:

Control interface/computing hardware elements refer to analog-to-digital (A2D) converter, digital-to-analog (D2A) converter, digital input/output (I/O), counters, timers, microprocessor, microcontroller, data acquisition and control (DAC) board, and digital signal processing (DSP) board.

The control interface hardware allows analog/digital interfacing, i.e., communication of sensor signal to the control computer and communication of control signal from the control computer to the actuator. The control computing hardware implements a control algorithm, which uses sensor measurements, to compute control actions to be applied by the actuator.

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Is that all?

- No! You need **Computing Elements**: Computer elements refer to hardware/software utilized to perform computer-aided dynamic system analysis, optimization, design, and simulation; virtual instrumentation; rapid control prototyping; hardware-in-the-loop simulation; and PC-based data acquisition and control.

Mechatronics Design Process

- Traditional Product Design involves sequential discipline specific design efforts

- E.g.. Mechanical – Electrical – Controls - Manufacturing

- Sequential Design Process may be inefficient and suboptimal

- Mechatronics focuses on concurrent design of all the systems. It attempts to make interdisciplinary synergies and take intelligent decision when the synergy is not present.

- Design Trade-off: More electronic complexity vs. more mechanical complexity

Important aspects of Mechatronic Design

- Compared to pure mechanical realizations the use of electrical energy in the form of actuators led to simplification of mechanical devices eg. Mechanical Clock vs Digital Clock

- Further integration of microcontrollers created decentralized electrical drives

- The design of light weight structures need to have more flexible material with inherent damping mechanism – electronic damping

- Addition of closed loop control helps to remove the constraints of linearization of mechanical system (large amplitude motion)

- Addition of New Functions (Consider Automobiles)

Various Levels of Mechatronics (JSPMI)

Class I: Primary Mechanical Products with Electronics incorporated for additional functionality eg. CNC Machine

Class II: Traditionally Mechanical System internally modified by electronics eg. Flexible Automated Manufacturing

Class III: Systems that retain only functions of mechanical system but completely substituted by electronics eg, digital watch

Class IV: Products designed through synergistic integration of mechanical and electronics system eg: washing machine, modern automobile

Industrial Applications

- [A Smart Support for the Elderly](#)
- [Pipe Health Monitoring Robot](#)
- [River Health Monitoring System](#)
- [Intubation Device with A CO2-Sensor for Facilitation Of Endoctracheal Intubation](#)

What are our Major Milestones in the Course?

- Introduction
- Sensors
- Actuators
- Basic System Models and Response Study
- Basic Control System
- Basic Electric Circuit Components and Semi-conductor Electronics
- Basic Signal Conditioning
- Microcontrollers and DSP

What are the Evaluation Criteria?

- **Assignments and Mini Projects: 4 [10%]**
- **Quizzes: 2   [20%]**
- **Mid-sem: 1 [30%]**
- **End-sem: 1 [40%]**
- **Course Policy:**
  - <u>Attendance</u>
  - **Students having more than 90% attendance will get bonus marks during Course Grading**

Reference Books

- W. Bolton, Mechatronics, Pearson Publishers., 4th edition.
- S. Graham Kelly, System Dynamics and Response
- David G. Alciatore and Michael B. Histand, Introduction to Mechatronics and Measurement systems, TMH Publications
- E O Doebelin, Measurement System Application and Design