Module 1

Introduction to Mechatronics

Fundamentals of Mechatronics (MH501)

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Module Objectives

After this module you will be able to

- Explain the meaning of Mechatronics and its relevance in engineering design
- Know about various applications of mechatronics
- Explain what is a system
- Describe open loop and closed loop systems
- Compare between traditional and mechatronics based design approach
History

• “Mechatronics” term coined by engineer Tetsura Mori in 1969 at Yasakawa Electric Corp.
• Upto 1980 mechatronics meant only combination of electronics and mechanical engineering
  • Computing technology added later with development of computers
Bird’s Eye View of Mechatronics

- Multidisciplinary
  - Electronics
  - Mechanical
  - Software
  - Control
  - Systems Design

- Examples include, modern automobiles, spacecrafts, marine vessels, robots, factory automated systems, etc.

Fig. Ref.: Rensselaer Polytechnic Institute
Examples of Mechatronics Systems
A Document Scanner

- Quiz: List the components of a document scanner and describe how that works using neat sketches
Scanner Types

- Flatbed scanner
- Sheetfed scanner
- Drum scanner
- Handheld scanner
Flatbed Scanner
Components of Scanner

- Scanner head
  - Fluorescent lamp
  - Transformer
  - CCD sensor
  - Mirror
  - Lens
  - Filters
- Drive system
  - Stepper motor
  - Belt
- Control circuitry
- Interface ports
Components of Scanner – Contd.
Components of Scanner – Contd.

Charge Coupled Device (CCD)

- Photons are converted into electrons
- Array of p-doped MOS capacitors (pixels) sense light
  - High intensity leads to more charge
- Distribution of charge represents image

CCD Array
Components of Scanner - Contd.

Stepper Motor and belt drive
Components of Scanner - Contd.

- ADF
- Transparency Adapter
- USB
- SCSI
- Interface Controller
Overall Working of Flatbed Scanner

http://www.xbitlabs.com
Parts of a Mechatronics System

- Mechanical System
  - Moving parts like drives, pulleys, gears, mechanisms, etc.
- Electronic and Electrical System
  - Microcontroller, analog-digital and digital-analog converters, sensors, actuators, etc.
- Information System
  - Software
- User Interface
Typical Components of Mechatronics System

- Drive Circuits
- Actuators
- Mechanical System
- Sensors
- Signal Conditioning
- Analog-Digital Convertor
- Controller
- User Interface
Some Other Examples of Mechatronic Systems

- Digital Camera
Autofocus

(a) IR pulses
    Shutter button pressed
        IR pulse sent out
            Return IR pulse
                Microprocessor
                    Signal conditioning
                        Motor
                            Lens position

(b) IR pulses
    IR pulse sent out
        Microprocessor
            Signal conditioning
                Motor
                    Masked IR detector
                        Lens and mask
Engine Management System
Engine Management System

Valve opens for air-fuel intake

Cam-shaft

Intake stroke

Air-fuel mixture

Compression stroke
Spark for ignition

Hot gases expand

Power stroke

Valve opens to vent exhaust gases

Exhaust stroke
Parts of a Mechatronics System

- **Mechanical System**
  - Moving parts like drives, pulleys, gears, mechanisms, etc.

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- **Information System**
  - Software
Typical Components of Mechatronics System

- Drive Circuits
  - Digital-Analog Convertor
  - Controller
    - Analog-Digital Convertor
    - User Interface
  - Signal Conditioning
  - Mechanical System
    - Sensors
  - Actuators
A system can be thought of as a box or block diagram.

- Having an input and corresponding output.
- Inputs and outputs of the system are important, not what goes inside the system.

**Spring Mass System**

- Input Displacement
- Output Force

Output force = Spring Stiffness × Input Displacement

We don’t care about internal physics such as grain structure of spring material or molecular phenomenon.
System: Room Illumination

Input
Switch position ON or OFF

Illumination System

Output
Glow or Darkness
Physical Components of Illumination System

- Rocker Switch
- Light bulb with inert gas
- Power System

Components:
- Rocker
- Pivot
- Spring
- Contact
- Power
- Load
- Terminal
Subsystems of Illumination System

Input
Switch position
Force

Output
Illumination

Switch
Spring
Contacts

Power Source
Wire

Light Bulb
Filament
Chamber

Illumination System
Mechatronics System Example

Scanner Example Revisited

Input
Hard Copy

Scanner

Output
Soft Copy
Subsystems of Scanner System

- Drive System
- Scanning Head
- Character Recognition
- Interface Device
- Illumination System

Input: Hard Copy → Scanner
Output: Soft Copy
Drive System (Mechanical)

Pulse -> Stepper Motor -> Gearing System -> Belt Drive -> Linear Displacement of Scanning Head
Scanning Head (Electronic and Electrical)

- Transformer
- LED Array
- CCD Sensor
- Controller
- Interface Device

Inputs:
- Hard copy
- Power

Outputs:
- Image Data
- Pulse sequence for moving Drive System
Control System

Image data \rightarrow \text{Microcontroller} \rightarrow \text{Pulse}
Components of Mechatronics Systems

- Mechanical System
- Electrical System
- Information System
Mechanical Systems and Analysis

Types of Systems

- Rigid – Rigid Multibody Simulation
- Deformable – Failure analysis, Finite Element Method (FEM)
- Fluid – Computational Fluid Dynamics (CFD)

Some mechanical components used

- Rigid - Gears, drives, cams, bearings, etc.
- Flexible – Electroactive polymers, Shape memory alloys, fiber reinforced material
- Fluid - Hydraulic cylinder, pneumatic cylinder, etc.
Electrical Systems

- Motors and generators
- Sensors and actuators
- Solid state devices
- Circuits – signal conditioning, amplifiers, etc.
- Contact devices – relays, switches. Circuit breakers, fuses, etc.
Information System

Information System consist of four parts

- Communication Systems
- Signal Processing
- Control System
- Numerical Solvers for Optimization

- Under Information System following activities are performed
  - Modeling
  - Simulation
  - Automatic Control
  - Optimization
Traditional Vs Mechatronics Based Design

- In traditional design individual subsystems were designed sequentially:
  - Mechanical design
  - After mechanical design, control systems were designed
- In mechatronics, all subsystems are designed concurrently as there is tight interaction between the subsystems.

- Concurrent design in mechatronics:
  - More compact and easily reprogrammable
  - Electronics and mechanical parts complement each other
  - Most design and error checking completed using Simulation

Traditional bimetallic strip based design
Closed-Loop and Open Loop Systems

- Open loop system look only it its input to determine what it should do

- Closed loop system looks both at its input as well as output to determine what to do
Examples

Open Loop System

- Control system of a microwave turns it off after set time
  - Does not look at temperature of food to “decide” turning off microwave
  - No feedback
- Regulator of Ceiling Fan depends on electrical resistance in the circuit
  - No feedback RPM is received by the regulator

Closed Loop System

- Temperature control system looks at the sensor readings of surrounding temperature
  - If different than desired temperature takes action
Summary

- *System* is an abstraction represented using box or block diagram which has an input and corresponding output/s
- Mechatronics system has following subsystems
  - Electrical System
  - Mechanical System
  - Information System
- Traditional design is sequential while mechatronics based design is concurrent

Next Class

- Electronics and electrical engineering fundamentals
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Homework 1

• Identify a mechatronics system in Mechanical Engineering Workshop/Labs.
  • Discuss why it is mechatronics based
  • Make a system diagram and break it down to as many subsystems as you can
  • Identify sensors and actuators and determine its technical specifications

• Use internet, lab manuals, and reference books to find information about components
• Date of submission August 10\textsuperscript{th}, 2017 (during class)