ME 475: Mechatronics

- 3.00 credit hours
- **Course content**
  Introduction: organisation structure; System concept; mechanical, electrical and software components; process; software based tools: virtual instrumentation; CAD; CAM; Computer integrated systems; Computer interfacing; Manipulator; Actuator types; Sensors and vision systems; Smart robots; Artificial intelligence; Factory, Office and Home automation; Future trend.

- **Course teacher**
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ME 475: Mechatronics

- **Reference book**
  1. Introduction to Mechatronics and Measurement Systems,
     by M.B. Histand and D.G. Alciatore, publishing company: McGraw-Hill.
  2. Mechatronics: electronic control systems in mechanical engineering,
     by W. Bolton, publishing company: Longman
  3. Mechatronics
     by Dan Necsulescu, publishing company: Pearson

- **ACADEMIC OFFENCES**
  Students must write their assignments in their own words.
  If students take an idea, or a passage of text from book, journal, web etc, they must acknowledge this by proper referencing such as footnotes or citations.
  Plagiarism is a major academic offence.

Mechatronics: Introduction

- The word “mechatronics” was probably first coined by a Japanese engineer in 1969.
- The word ‘Mechatronics’ composed of MECHAnics and elecTRONICS.
- The definition of mechatronics has evolved since the original definition by the Yasakawa Electric Company in 1969.
- Yasakawa defined mechatronics in this way

  The word, mechatronics, is composed of “mecha” from mechanism and the “tronics” from electronics.
  In other words, technologies and developed products will be incorporating electronics more and more into mechanisms, intimately and organically, and making it impossible to tell where one ends and the other begins.

Mechatronics: Introduction

- The definition of mechatronics continued to evolve after Yasakawa suggested the original definition.
- One oft quoted definition of mechatronics was presented by Harashima, Tomizuka, and Fukada in 1996. In their words, mechatronics 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.

- More recently, we find the suggestion by W. Bolton:

  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: Key Elements

- 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

- The key elements of mechatronics are illustrated in Figure 1.1.

- As the field of mechatronics continues to mature, the list of relevant topics associated with the area will most certainly expand and evolve.

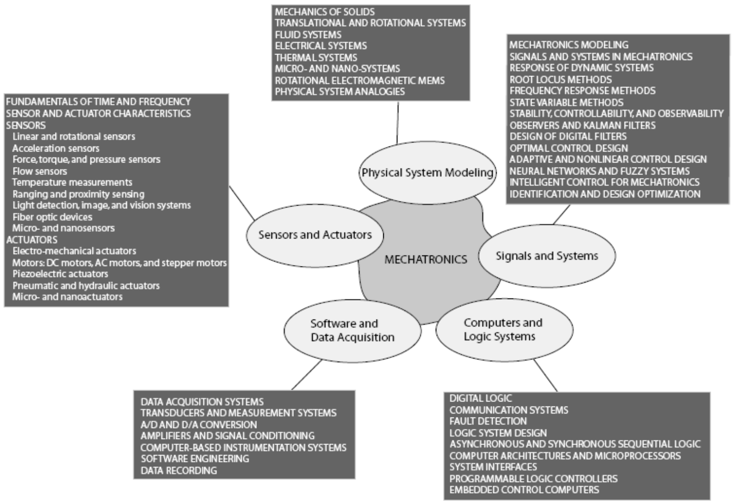

FIGURE 1.1 The key elements of mechatronics.

Mechatronics: Historical Perspective

- Early application of automatic control systems appeared in Greece from 300 to 1 BC with the development of float mechanism.
- Two important examples are
    - 1. water clock that used a float regulator.
    - 2. oil lamp, also used a float regulator to maintain a constant fuel level.

- Water-level float regulator:
    - The first historical feedback system
    - claimed by Russia, developed by Polzunov in 1765.
    - employs a float that rises and lowers in relation to the water level, thereby controlling the valve that covers the water inlet in the boiler.

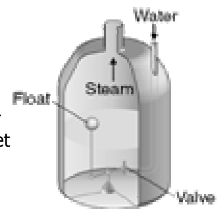

FIGURE 1.2 Water level float regulator

Mechatronics: Historical Perspective

- Watt's flyball governor:
    - Used to control the speed of a steam engine
    - measures the speed of the output shaft
    - utilizes the motion of the flyball to control the the valve
    - the amount of steam entering the engine is controlled
    - As the speed of the engine increases, the metal spheres on the governor apparatus rise and extend away from the shaft axis, thereby closing the valve.

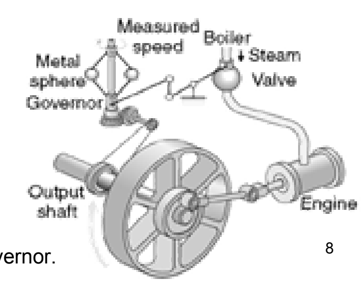

FIGURE 1.3 Watt's flyball governor.

Mechatronics: Historical Perspective

- Initially, mechatronics referred to systems with only mechanical systems and electrical components—no computation was involved.
- Examples of such systems include
  - the automatic sliding door, vending machines, and garage door openers.
- In the late 1970s, the Japan Society for the Promotion of Machine Industry (JSPMI) classified mechatronics products into four categories:

1. *Class I:* Primarily mechanical products with electronics incorporated to enhance functionality.
   - Examples include numerically controlled machine tools and variable speed drives in manufacturing machines.
   - Enabled by servo technology, power electronics, and control theory

Mechatronics: Historical Perspective

2. *Class II:* Traditional mechanical systems with significantly updated internal devices incorporating electronics. The external user interfaces are unaltered.
   - Examples include the modern sewing machine and automated manufacturing systems.
   - Enabled by computational and memory devices, and custom circuit design
3. *Class III:* Systems that retain the functionality of the traditional mechanical system, but the internal mechanisms are replaced by electronics.
   - An example is the digital watch.
   - Relied on heavily on microprocessor and IC to replace mechanical systems
4. *Class IV:* Products designed with mechanical and electronic technologies through synergistic integration.
   - Examples include photocopiers, intelligent washers and dryers, rice cookers, and automatic ovens.
   - true Mechatronics systems, integrate mechanical systems with electronics

The Development of the Automobile as a Mechatronic System

- The evolution of modern mechatronics can be illustrated with the example of the automobile.
- Until the 1960s, the radio was the only significant electronics in an automobile.
- All other functions were entirely mechanical or electrical, such as the starter motor and the battery charging systems.
- All engine systems were controlled by the driver and/or other mechanical control systems.
- For instance, a mechanical distributor was used to select the specific spark plug to fire when the fuel–air mixture was compressed. The timing of the ignition was the control variable. The mechanically controlled combustion process was not optimal in terms of fuel efficiency. Modeling of the combustion process showed that, for increased fuel efficiency, there existed an optimal time when the fuel should be ignited. The timing depends on load, speed, and other measurable quantities.

The Development of the Automobile as a Mechatronic System

- **Electronic ignition system**
  - one of the first mechatronic systems to be introduced in the automobile in the late 1970s.
  - The electronic ignition system consists of a crankshaft position sensor, camshaft position sensor, airflow rate, throttle position, rate of throttle position change sensors, and a dedicated microcontroller determining the timing of the spark plug firings.
  - Early implementations involved only a Hall effect sensor to sense the position of the rotor in the distributor accurately.
  - Subsequently eliminated the distributor completely and directly controlled the firings utilizing a microprocessor.
- **Antilock Brake System (ABS)**
  - was also introduced in the late 1970s in automobiles.
  - ABS works by sensing lockup of any of the wheels and then modulating the hydraulic pressure as needed to minimize or eliminate sliding.

The Development of the Automobile as a Mechatronic System

- **Traction Control System (TCS)**
  - introduced in automobiles in the mid-1990s.
  - TCS works by sensing slippage during acceleration and then modulating the power to the slipping wheel.
  - This process ensures that the vehicle is accelerating at the maximum possible rate under given road and vehicle conditions.

- **Vehicle Dynamics Control (VDC) system**
  - introduced in automobiles in the late 1990s.
  - The VDC works similar to the TCS with the addition of a yaw rate sensor and a lateral accelerometer.
  - The driver intention is determined by the steering wheel position and then compared with the actual direction of motion. The TCS system is then activated to control the power to the wheels and to control the vehicle velocity and minimize the difference between the steering wheel direction and the direction of the vehicle motion.
  - In some cases, the ABS is used to slow down the vehicle to achieve desired control.

The Development of the Automobile as a Mechatronic System

- New applications of mechatronic systems in the automotive world include
  - semi-autonomous to fully autonomous automobiles,
  - safety enhancements,
  - emission reduction, and
  - other features including intelligent cruise control, and brake by wire systems eliminating the hydraulics.

- Another significant growth area that would benefit from a mechatronics design approach is wireless networking of automobiles to ground stations and vehicle-to-vehicle communication.

- **Telematics**
  - combines audio, hands-free cell phone, navigation, Internet connectivity, e-mail, and voice recognition,
  - perhaps the largest potential automotive growth area.

- The use of electronics in automobiles is expected to increase at an annual rate of 6% per year over the next five years, and the electronics functionality will double over the next five years.

The Development of the Automobile as a Mechatronic System

- **Millimeter wave radar technology**
  - has recently found applications in automobiles.
  - detects the location of objects (other vehicles) in the scenery and the distance to the obstacle and the velocity in real-time.
  - Figure 1.4 shows an illustration of the vehicle-sensing capability with a millimeter-waver radar.
  - This technology provides the capability to control the distance between the vehicle and an obstacle (or another vehicle) by integrating the sensor with the cruise control and ABS systems.
  - The driver is able to set the speed and the desired distance between the cars ahead of him. The ABS system and the cruise control system are coupled together to safely achieve this remarkable capability.

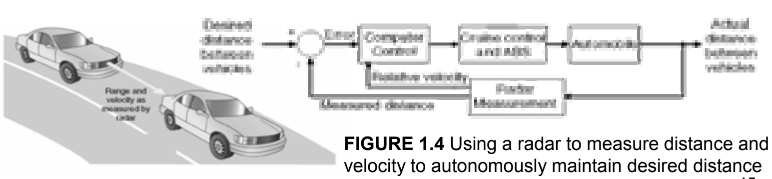

FIGURE 1.4 Using a radar to measure distance and velocity to autonomously maintain desired distance between vehicles.

The Development of the Automobile as a Mechatronic System

- Future mechatronic systems on automobiles may include
  - a fog-free windshield based on humidity and temperature sensing and climate control,
  - self-parallel parking,
  - rear parking aid,
  - lane change assistance,
  - fluidless electronic brake-by-wire, and
  - replacement of hydraulic systems with electromechanical servo systems.

- **Vehicle Emmision**
  - As the number of automobiles in the world increases, tougher emission standards are inevitable.
  - Mechatronic products will in all likelihood contribute to meet the challenges in emission control and engine efficiency by providing substantial reduction in CO, NO, and HC emissions and increase in vehicle efficiency.

The Development of the Automobile as a Mechatronic System

- Clearly, an automobile with
  - 30–60 microcontrollers,
  - up to 100 electric motors,
  - about 200 pounds of wiring,
  - a multitude of sensors, and
  - thousands of lines of software code can hardly be classified as a strictly mechanical system.

- The automobile is being transformed into a comprehensive mechatronic system.

Reference: "What is Mechatronics?" by Robert H. Bishop and M. K. Ramasubramanian, in MECHATRONICS: AN INTRODUCTION, 2006.