What is Mechatronics?

■ Term understood in different ways by different people.
■ “Component Mechatronics” vs. “Systems-Oriented Mechatronics”.
■ A widely-accepted definition:

The term “mechatronics” refers to a synergistic combination of precision engineering, electronic control and systems thinking in the design of products and manufacturing processes. It is an interdisciplinary subject that both draws on the constituent disciplines and includes subjects not normally associated with one of the above.

■ Compare a mechatronic system with the human body: muscles (mechanism), nerves (electronics) and brain (control and computation).
Some devices designed and analyzed with Mechatronics

- Photocopy machines, CAT scanners
- Hard disk drives, robot manipulators, positioners (conventional and nanometric accuracies)
- Modern agricultural equipment (smart watering, weeding, fertilizing)
- Modern optical equipment: telescopes, antennas
- Microsurgical devices, artificial organs and limbs
- Smart materials and structures: vibration and noise cancellation, adaptive wing technologies
- Modern earth-moving and mining equipment, and
- anything mechanical beginning with the word *smart*
Example: Hydraulic boomer evolution

- All-hydraulic, manual operation
- Electronic enhancement with local loops (constant drill rate, etc.)
- Semi-autonomous operation (program drill pattern and let it go)
- Fully autonomous (robotic) operation: machine decides where to drill and how according to knowledge base (models) and environmental information (real-time sensing, artificial vision).

Mathematical Modeling

- Present day engineering and science relies on mathematical modeling.
- NASA Mars Rover mission was heavily based on model-based simulations (no other choice).
- Models can be empirical (phenomenological), physics-based, or a mix.
- Empirical examples: heat transfer correlations, laminar/turbulent flow according to Reynolds number.
- Physical example: differential equation for forced pendulum:

\[ \ddot{\theta} + \frac{g}{l} \sin \theta = T \]
Uses of mathematical models: Device design

- Rough prediction in the pre-design stage: low accuracy, simple models.
- Prediction in the final design stage.
- Simulation studies to determine performance characteristics prior to building device: accurate, complex models.
- Empirical refinement of physics-based models using built device: high-fidelity model to be taken as “true”.
- Model used to predict behavior of device under a variety of conditions.
- Model useful for modifications and redesign.

Dynamic System Modeling

**Static**: Dependencies of variables upon one another are fixed (independent of time).

Example:

\[ V = iR \]

and even

\[ V(t) = i(t)R \]

that is, the fact that current must be multiplied by resistance to give voltage (the dependency) is independent of time. It also holds pointwise-in-time.

**Dynamic**: Dependencies of variables upon one another change with time. Pendulum example: Take \( g = 1 \) and suppose \( \sin \theta \approx \theta \), for simplicity. Assume the initial conditions to be \( \theta_{t=0} = \pi/4 \), \( \dot{\theta}_{t=0} = 0 \). Suppose that the external torque is given by \( T(t) = -1 \).

The solution to this equation is

\[ \theta(t) = (\frac{\pi}{4} + 1) \cos(t) - 1 = (\frac{\pi}{4} + 1) \cos(t) + T(t) \]

Is the dependency of \( \theta \) upon \( T \) independent of time? Is it given by simple proportionality?
A (loose) classification of dynamic models

A mechatronic design challenge: Robo-Hockey / Table Tennis

- Skeleton: air table, guides, transmission
- Muscle power: motors and power supplies, compressed air source
- Nerve system: Power and control electronics, wiring
- Senses: cameras (puck position and velocity), linear position sensors (slides)
- Also possible: play against machine over a network.
Required: KMR 5th ed, chapter 1. *Available through Electronic Course Reserves*

Required: ME magazine article on mechatronics:
See course website

Recommended: Browse through the WWW and learn about mechatronics applications.