MCE503: Modeling and Simulation of Mechatronic Systems

Lecture 1: Introduction

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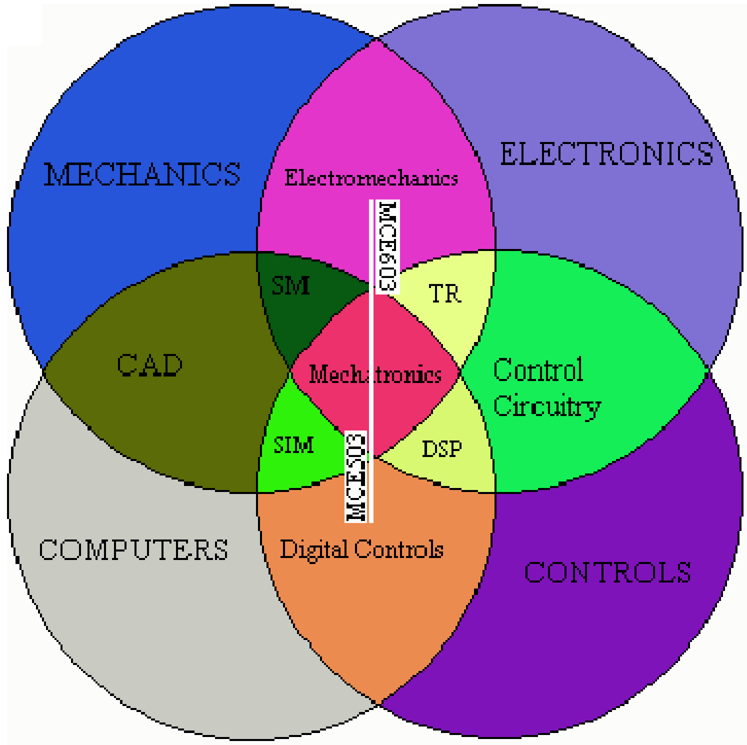
What is Mechatronics?

- Term understood in different ways by different people.
- Common perception: sensors and actuators, control technology.
- 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).

Mechatronics: An interdisciplinary subject



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, artifical 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:

$$\ddot{\theta} + \frac{g}{l}\sin\theta = T$$

Student input: Uses of mathematical models: Device desig

Dynamic System Modeling

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

$$V = iR$$

and even

$$V(t) = i(t)R$$

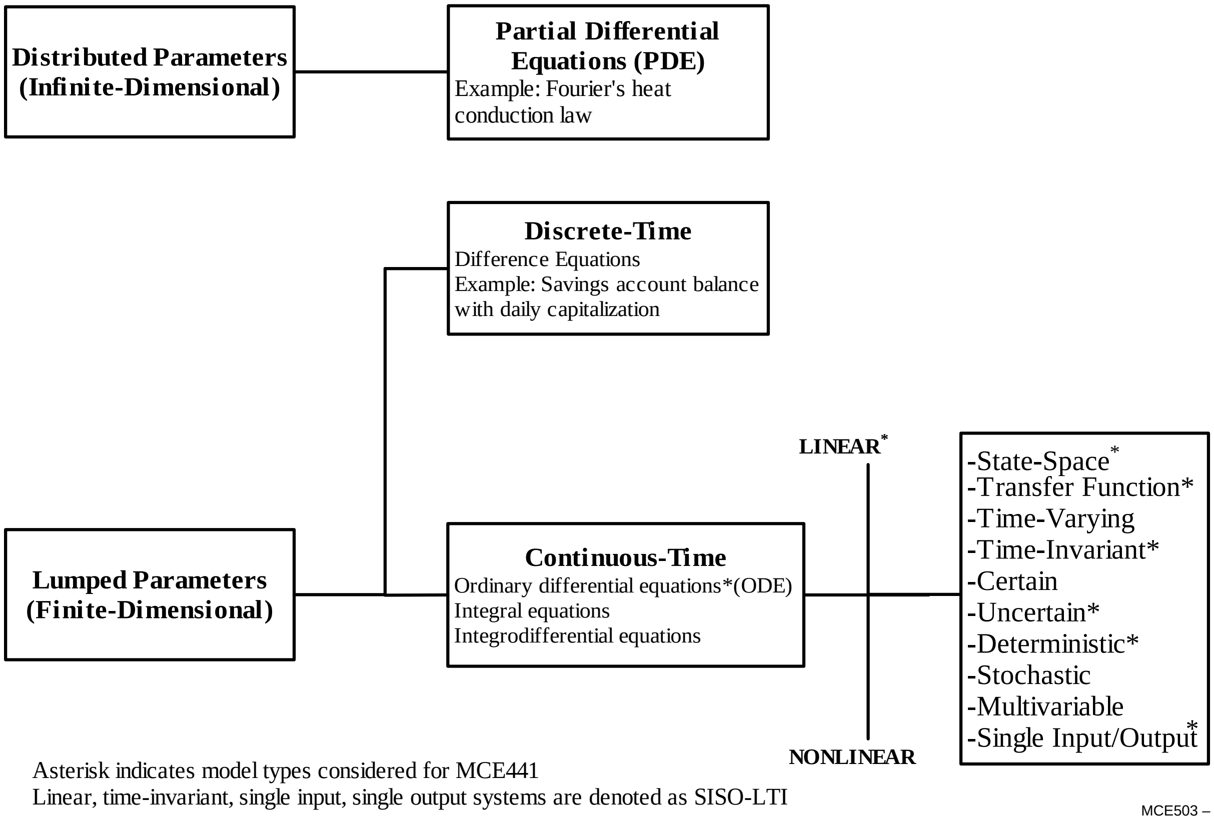
that is, the fact that current must be multiplied by resistance to give voltage (the dependency) is independent of time. It also holds pointwise-in-time.

Dynamic: Dependencies of variables upon one another change with time. Pendulum example: Take $\frac{g}{l} = 1$ 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

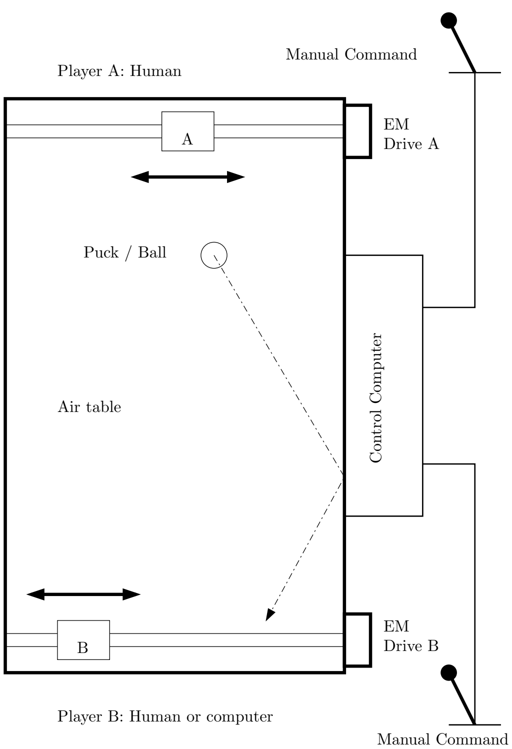
$$\theta(t) = (\frac{\pi}{4} + 1)\cos(t) - 1 = (\frac{\pi}{4} + 1)\cos(t) + T(t)$$

Is the dependency of θ upon T independent of time? Is it given by simple proportionality?

A (loose) classification of dynamic models



A mechatronic design challenge: Robo-Hockey / Table Ter



- 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)
- Brains: model-based machine strategy for beating human.
- Also possible: play against machine over a network.

Required and recommended reading

Required: KMR chapter 1.
Required: ME magazine article on mechatronics:
See course website
Required: Check out *any* issue of IEEE/ASME Transactions on Mechatronics (available online through OhioLink). Pick an article of your choice and read it. Email the instructor the complete citation, for example:

Yano, K. and Terashima, K., Sloshing suppression control of liquid transfer systems considering a 3-D transfer path, *IEEE ASME Transactions on Mechatronics*, Vol 10, Issue 1, Feb. 2005.

together with your own version of the abstract.

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