MECH 420
Sensors and Actuators

Presentation Part 2

Clarence W. de Silva, Ph.D., P.Eng.
Professor of Mechanical Engineering
e-mail: desilva@mech.ubc.ca

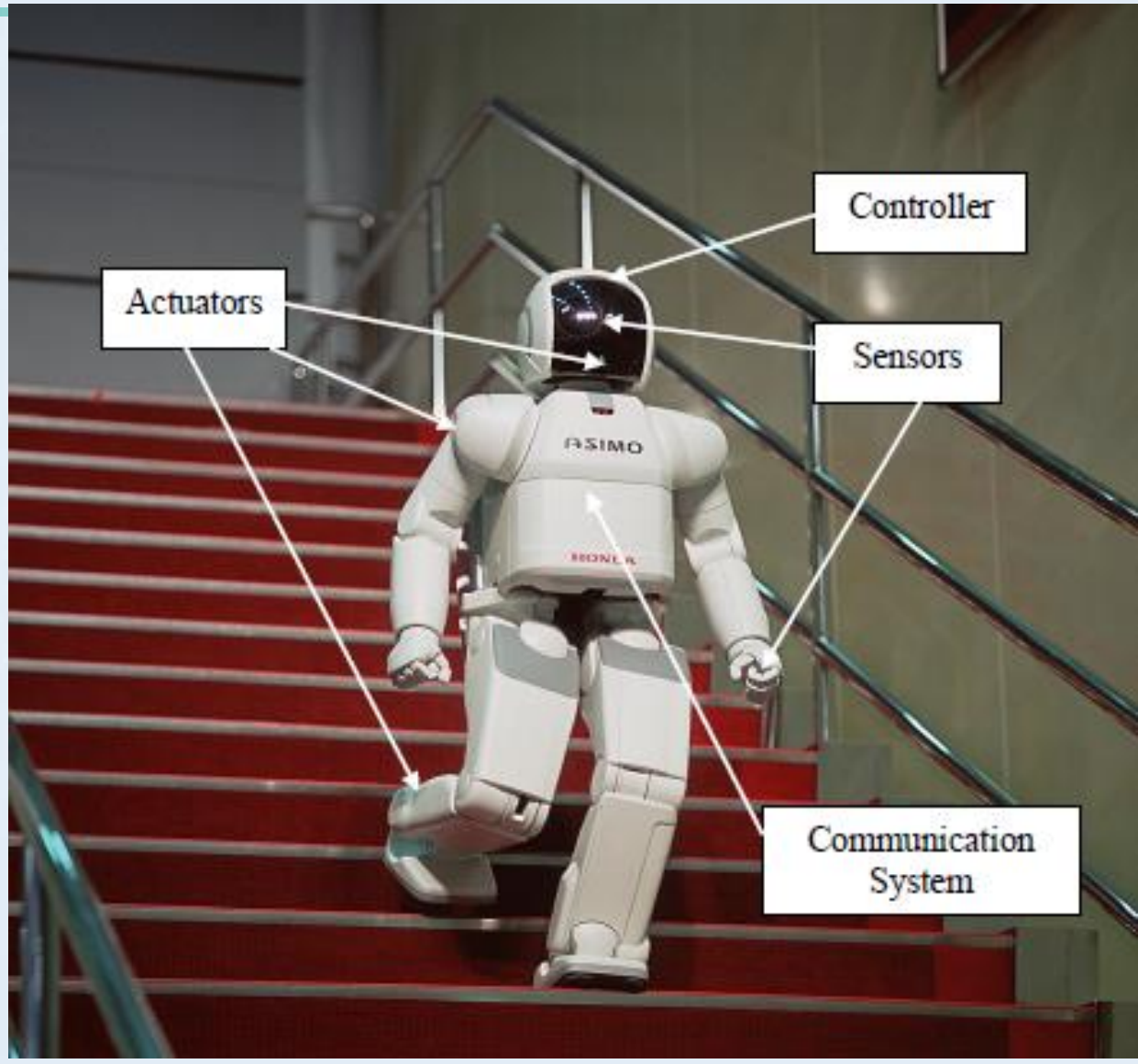
Part 2: Mechatronics & Instrumentation Process

- Mechatronics
- Instrumentation Process
- Examples

Mechatronics

Is this a mechatronic system?

Humanoid robot:



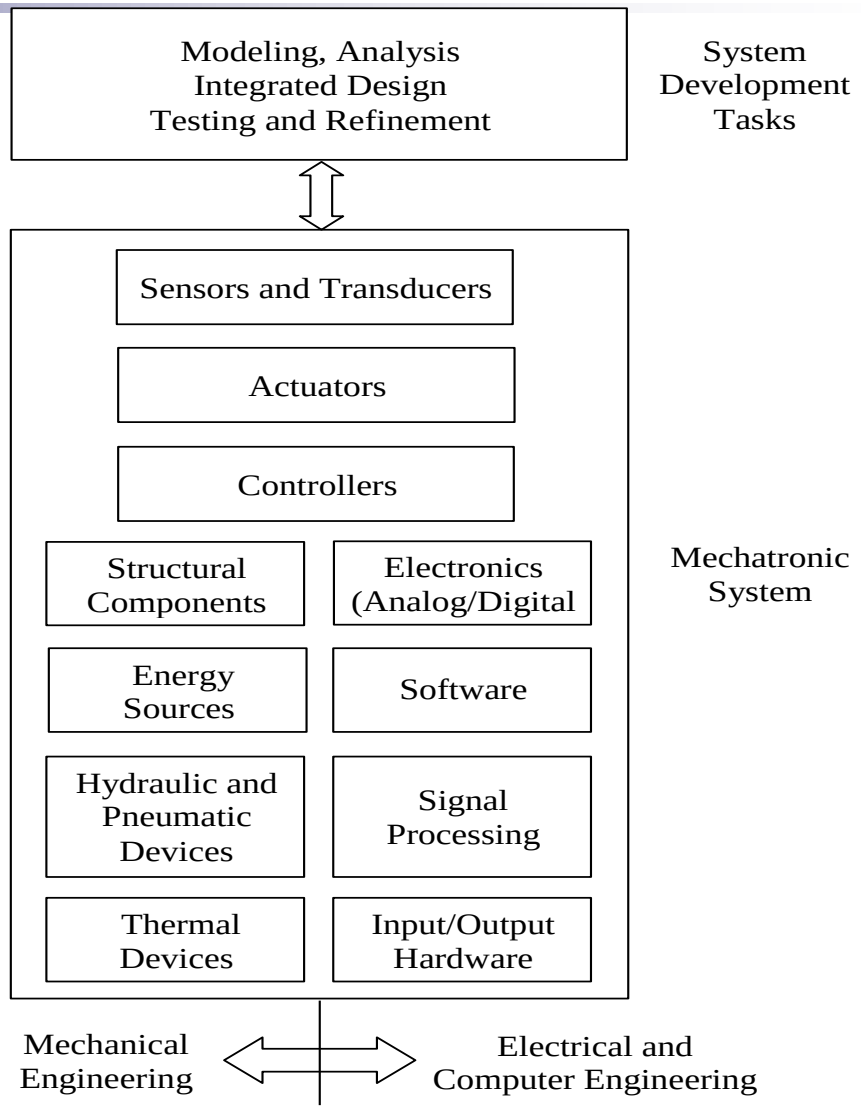
What is a Mechatronic System?

- An electromechanical system?
- A system with sensors, actuators, and controllers?
- A multi-physics system?
- A multi-domain system?
- A system designed by considering all domains/components simultaneously?
- A system designed by using similar (analogous) methods for the different domains?
- An optimized system?
- A system designed through a mechatronics approach? Then, what is the mechatronic approach?

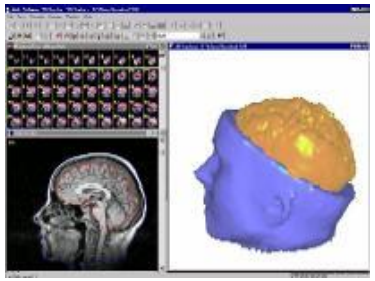
Mechatronics

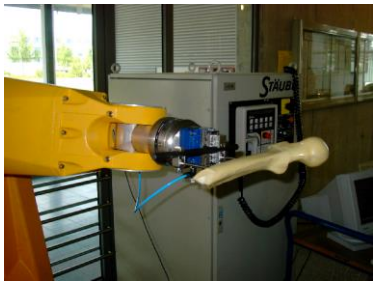
- Origin of Term: "MECHAnics and elecTRONICS," Yasakawa Electric Co., 1969
- **Accepted Definition:**

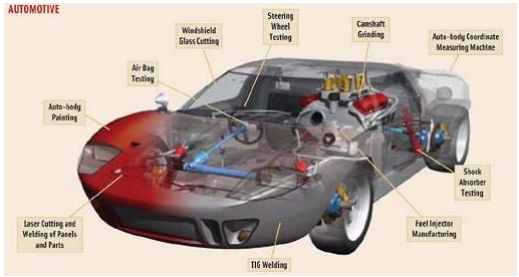
Synergistic application of mechanics, electronics, control engineering, and computer science in the development of **electromechanical** products and systems, through **integrated design**



Traditional Definition of Mechatronics







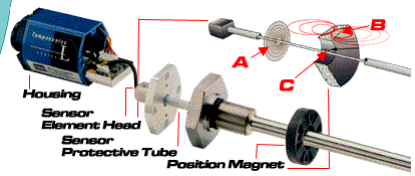
Information Technology

(Control & Computer Engineering)

Mechanical Engineering

Electrical Engineering

Mechatronics



Exploring the Definition of a Mechatronic System

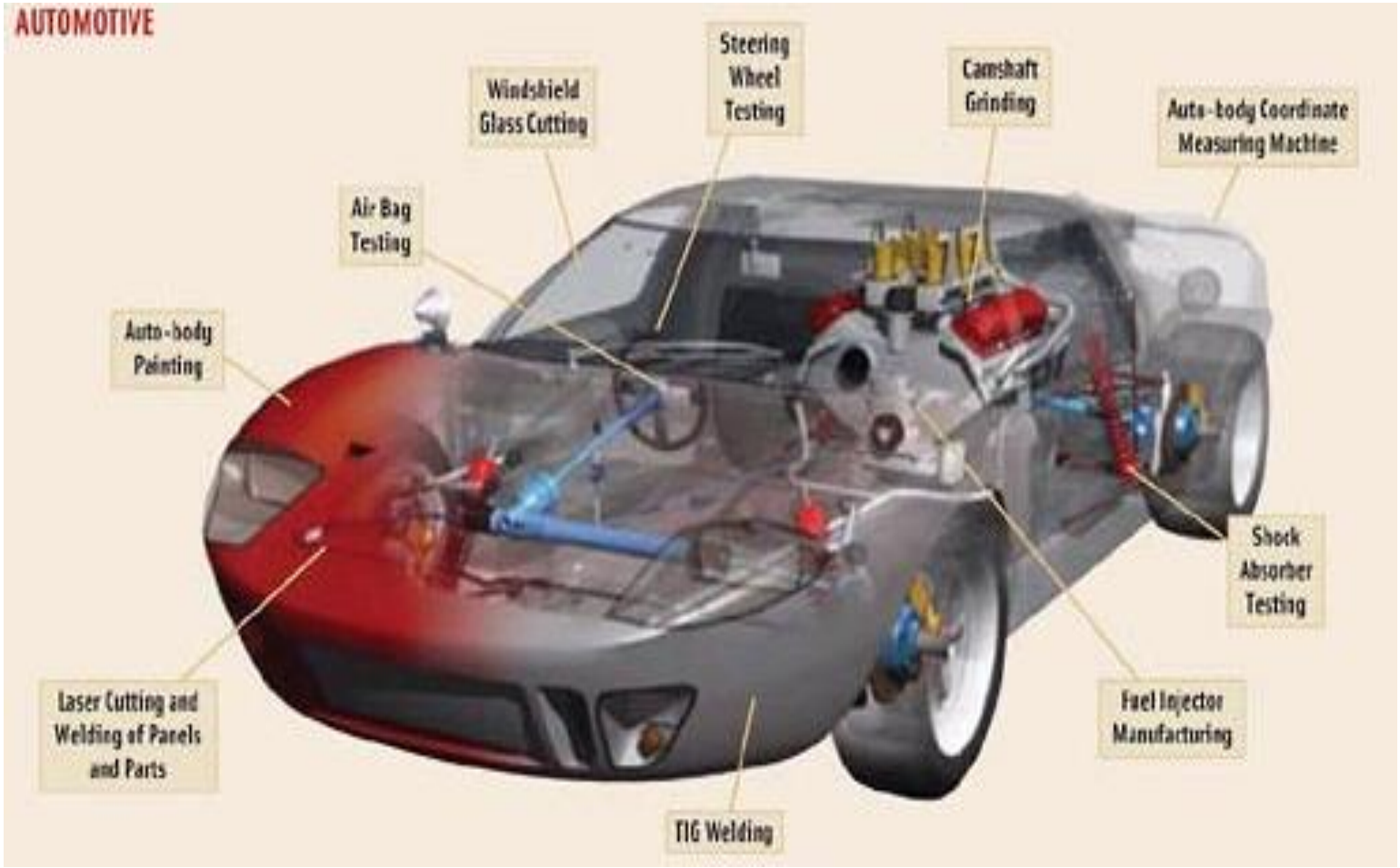
- There is some validity of everything that was listed before
- The key aspects of the popular definition: Synergistic application; multi-domain (mechanics, electronics, control engineering, computer science); electromechanical products and systems; integrated design

Our "Extended" Definition for a Mechatronic System

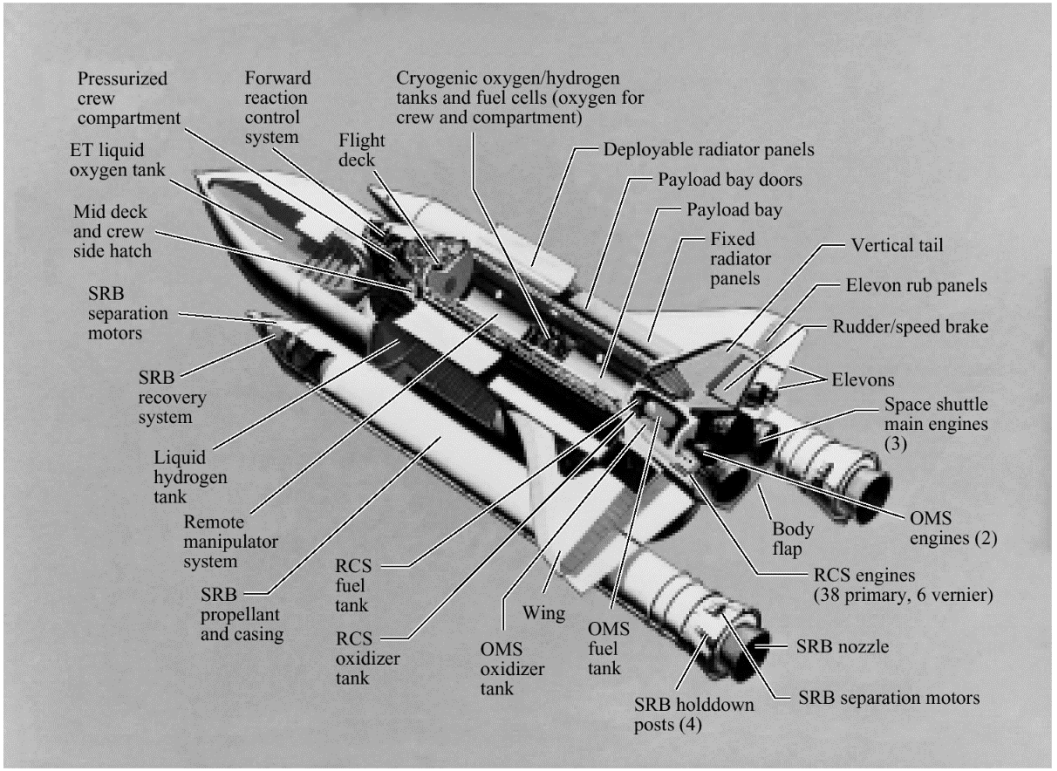
- A multi-physics system (not limited to electro-mechanical)
- Approach used in the development:
  - Integrated (concurrent, synergistic, etc.) approach → All domains are considered together
  - Unified (analogous, etc.) approach → similar approaches are used for the different domain
  - Unique result → typically, optimal result (only one best solution)
  - Systematic approach → Clearly articulated set of steps are used in the development

Note: These considerations are applicable to modeling, design, instrumentation, control, operation, etc.

An Example of Mechatronic System

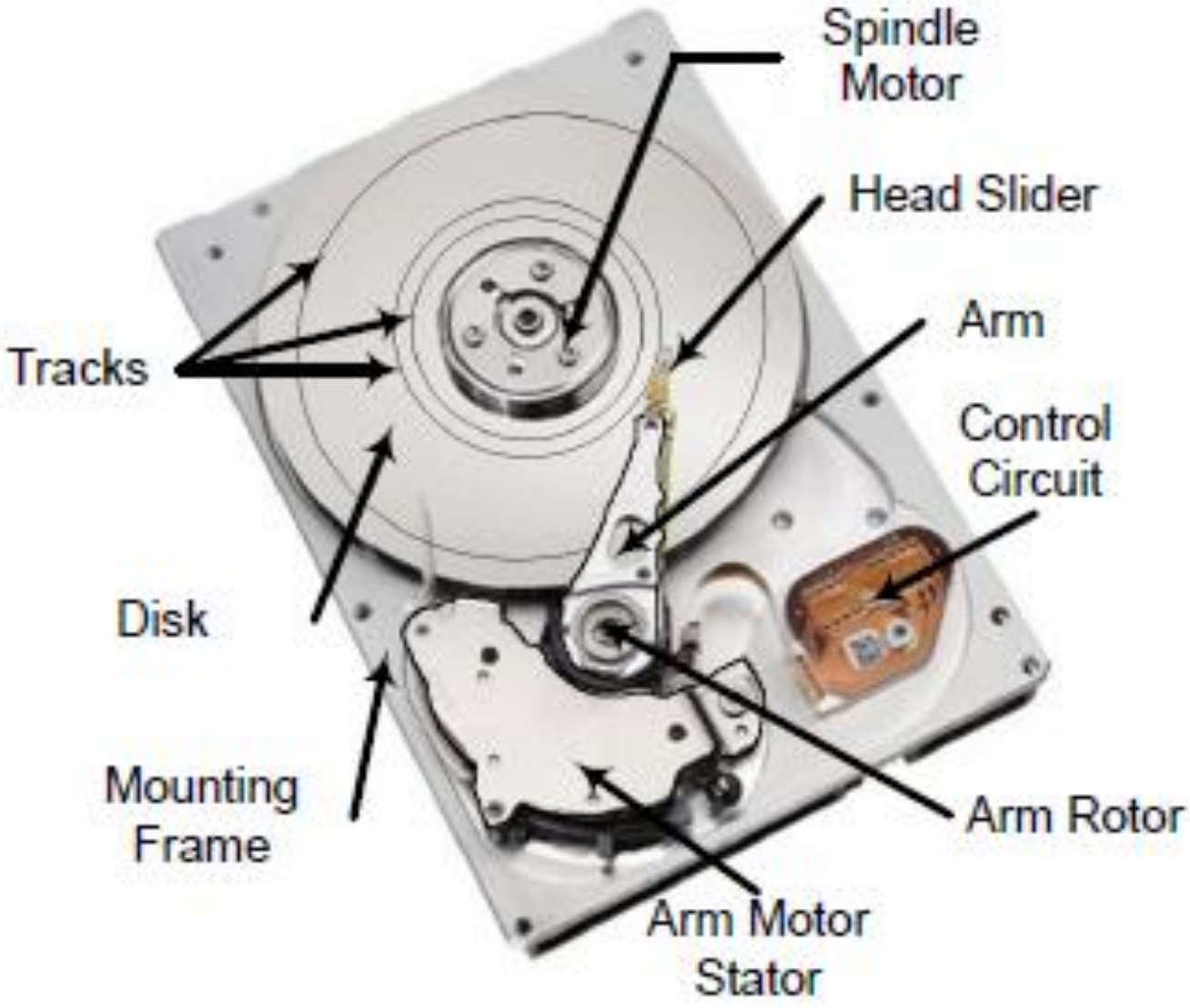


A spacecraft is a multi-domain system consisting of multiple subsystems



Computer Hardware

E.g., Hard-disk drive (HDD) unit of a computer



Questions on Mechatronics

Think about answers to the following questions (not necessarily now):

- **Meaning of Mechatronics?**
- **Key steps of development of a mechatronic product?**
- **Advantages of Mechatronics?**

White Board Discussion on Mechatronics

The mechatronic approach is said to be: Integrated, Unified, Systematic, and Unique.

Why? What are its advantages?

Motivation for Mechatronic Products

- Sequentially designed and instrumented components of existing "multi-domain" systems are not optimally matched; coupling/interactions are not considered
- High potential for improvement through concurrent, unified, and optimal design and instrumentation

Benefits of Mechatronic Design and Instrumentation:

- Optimality and better component matching
- Increased efficiency
- Cost effectiveness
- Ease of system integration and expansion/enhancement
- Compatibility & ease of cooperation with other systems
- Improved controllability
- Increased reliability
- Increased product life

"Why" (for each benefit)?

“Mechatronic” Instrumentation

Mechatronic Approach to Instrumentation—Concurrent & Unified Instrumentation

- **Treat instrumentation as an integral part of design**
- **Design/incorporate the instrumentation concurrently**

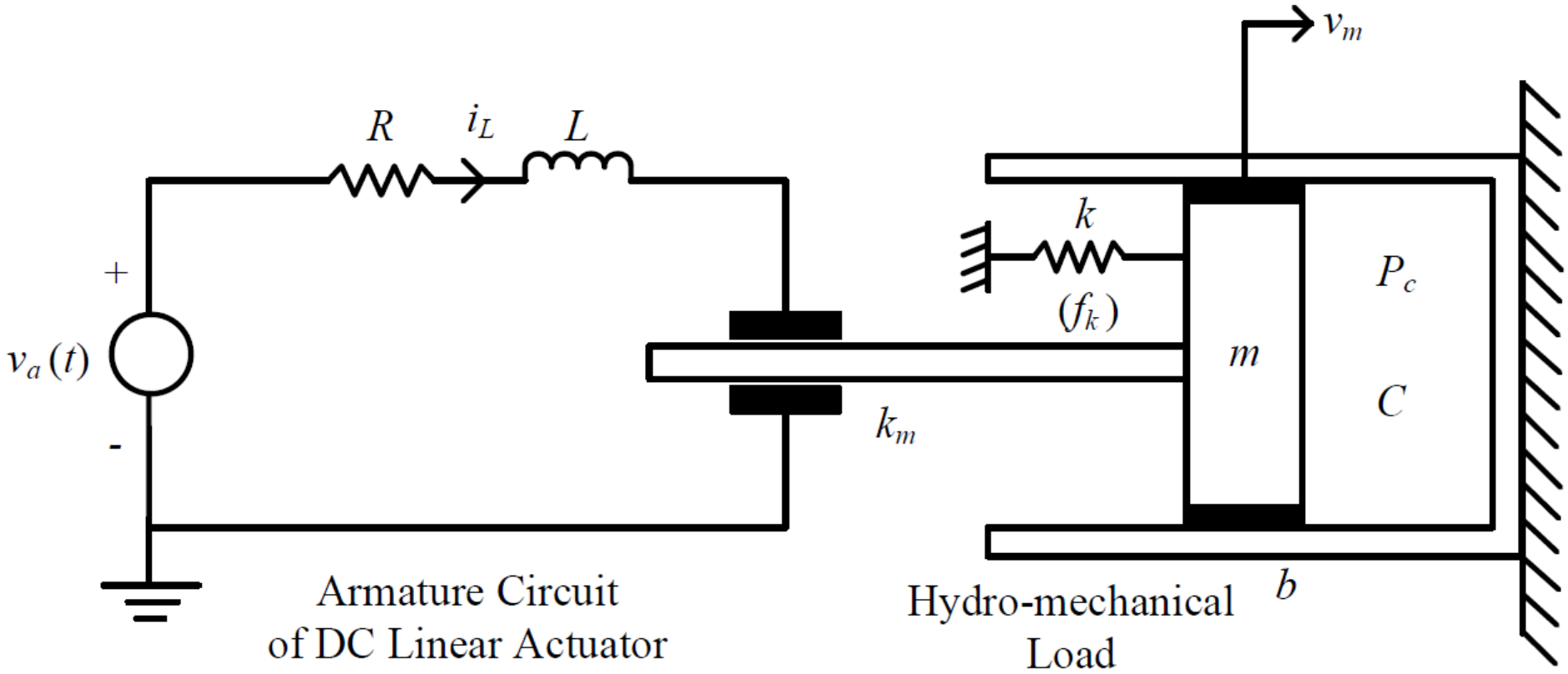
(consider all aspects and components of instrumentation simultaneously)

- **Use similar techniques for different domains in the system**

Mechatronic Approach: Integrated, Unified, Unique, Systematic

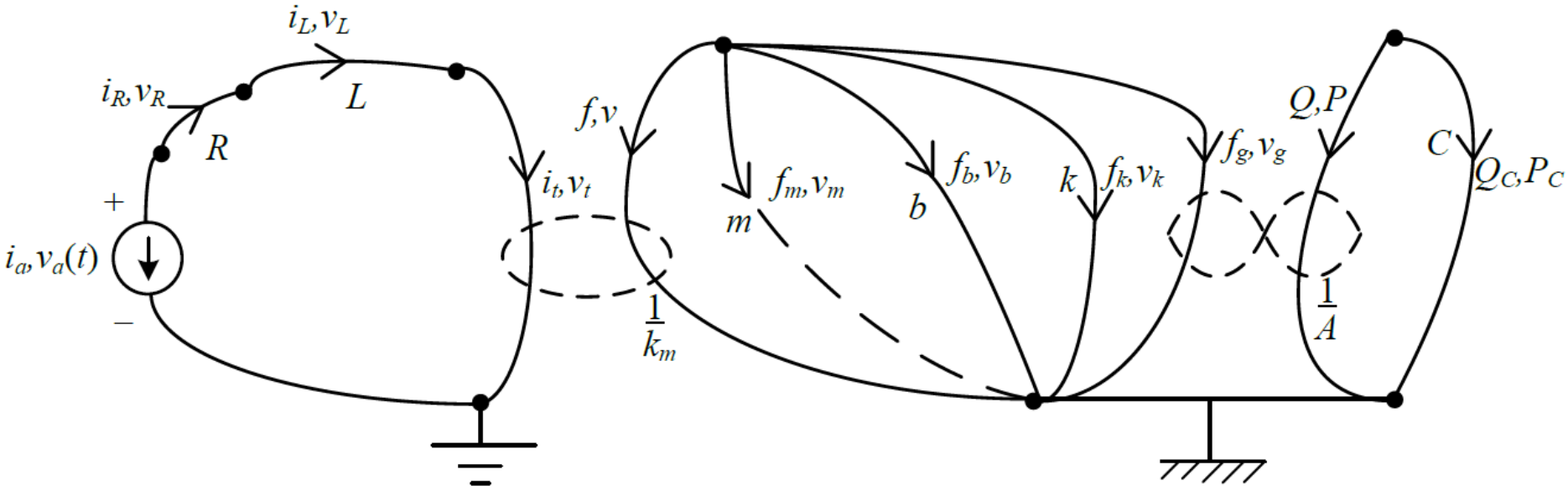
An Example to Justify the "Unified" Approach

Mechatronic Approach: Integrated, Unified, Unique (Optimal), Systematic

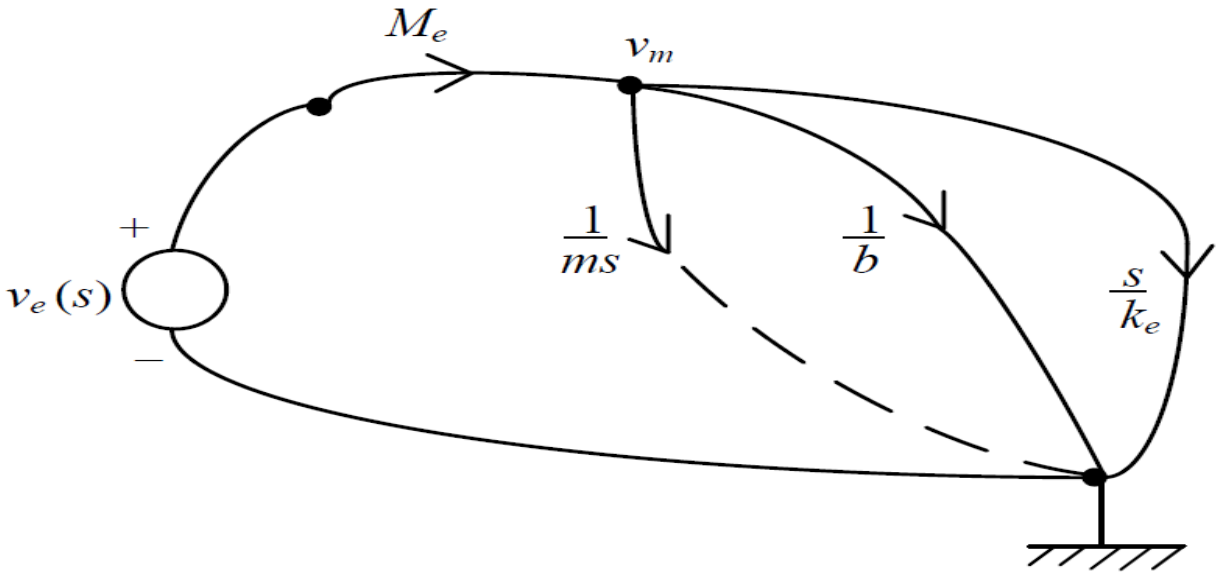


A DC linear motor-driven hydro-mechanical load

An Example to Justify the "Unified" Approach (Cont'd)



Linear Graph (Mixed-domain—electrical, mechanical, fluid)



Equivalent Linear Graph Entirely in the Mechanical Domain

TERMINOLOGY

- **Plant or Process:** System to be controlled
- **Inputs:** Excitations (known/unknown; desirable/undesirable) to the system
- **Outputs:** Responses of the system (desirable/undesirable)
- **Sensors:** Measure system variables (excitations, responses, etc.)
- **Actuators:** Drive various parts of the system
- **Controller:** Device that generates control signal/action
- **Control Law:** Relation or scheme according to which the control signal/action is generated
- **Control System:** Plant and controller, at least (Can include sensors, signal conditioning, communication, etc.)
- **Feedback Control:** Control signal is determined according to (by measuring) actual plant response
- **Open-loop Control:** No feedback of plant response into controller
- **Feed-forward Control:** Control signal is determined according to plant excitations (or a model) without knowing the actual outputs

Questions on System Definition

- Difference between a system and a dynamic system?
- What is a control system?
- Is an engineering system a dynamic system? Why?
- Is an engineering system a control system? Why?
- What things are “sensed” (measured) in a control system?
- Where are the “actuators” used in a control system?

Instrumentation Procedure

Instrumentation Procedure

- Study the instrumented system (plant)
- Identify and group the system components (possibly, according to the physical domain—mechanical, electrical, fluid, thermal, etc.)
- Develop a preliminary System Architecture
- Formulate physical equations (Model)—for computer simulation, design, control, etc.
- Indicate operating requirements (performance specifications) for the plant

System level

Instrumentation Procedure (Cont'd)

- Identify constraints related to cost, size, weight, environment (e.g., operating temperature, humidity, dust-free or clean room conditions, lighting, wash-down needs)
- Select type and nature of sensors/transducers, actuators, signal conditioning devices (including interfacing and data acquisition hardware and software, filters, amplifiers, modulators, ADC, DAC, etc.)
- Establish the associated ratings/specifications of components (signal levels, bandwidths, accuracy, resolution, dynamic range, power, torque, speed, temperature, and pressure characteristics, etc.)
- Identify manufacturers/vendors for the components (model numbers, data sheets, etc.)

Component level

Instrumentation Procedure (Cont'd)

- **Revise system architecture (include controllers and/or control schemes if necessary). Revise the original computer model as necessary**
- **Carry out computer simulations. Make modifications to instrumentation until the system performance meets the specifications (A mechatronic optimization scheme may be used)**
- **Once acceptable results are achieved, acquire and integrate the actual components. Some new developments (designs) may be needed (new devices, interface hardware, fixtures, etc.)**

Commercially available components ➔ Instrumentation
New developments ➔ Design

Instrumentation and Design

Design:

Develop a system to meet the performance requirements

1. **Basic components of the system are identified during conceptual design**
2. **Their details, including parameter values, are decided during detailed design (final optimization is done here)**

- **Instrumentation is an integral part of design**
- **Both have the same end objective (meeting the specified performance)**

In Design: Parameter choice can be **infinite** (in a continuous rage), particularly during optimization. Commercially unavailable components may have to be developed new.

In Instrumentation: Component choice is **finite, and typically the components are commercially available**

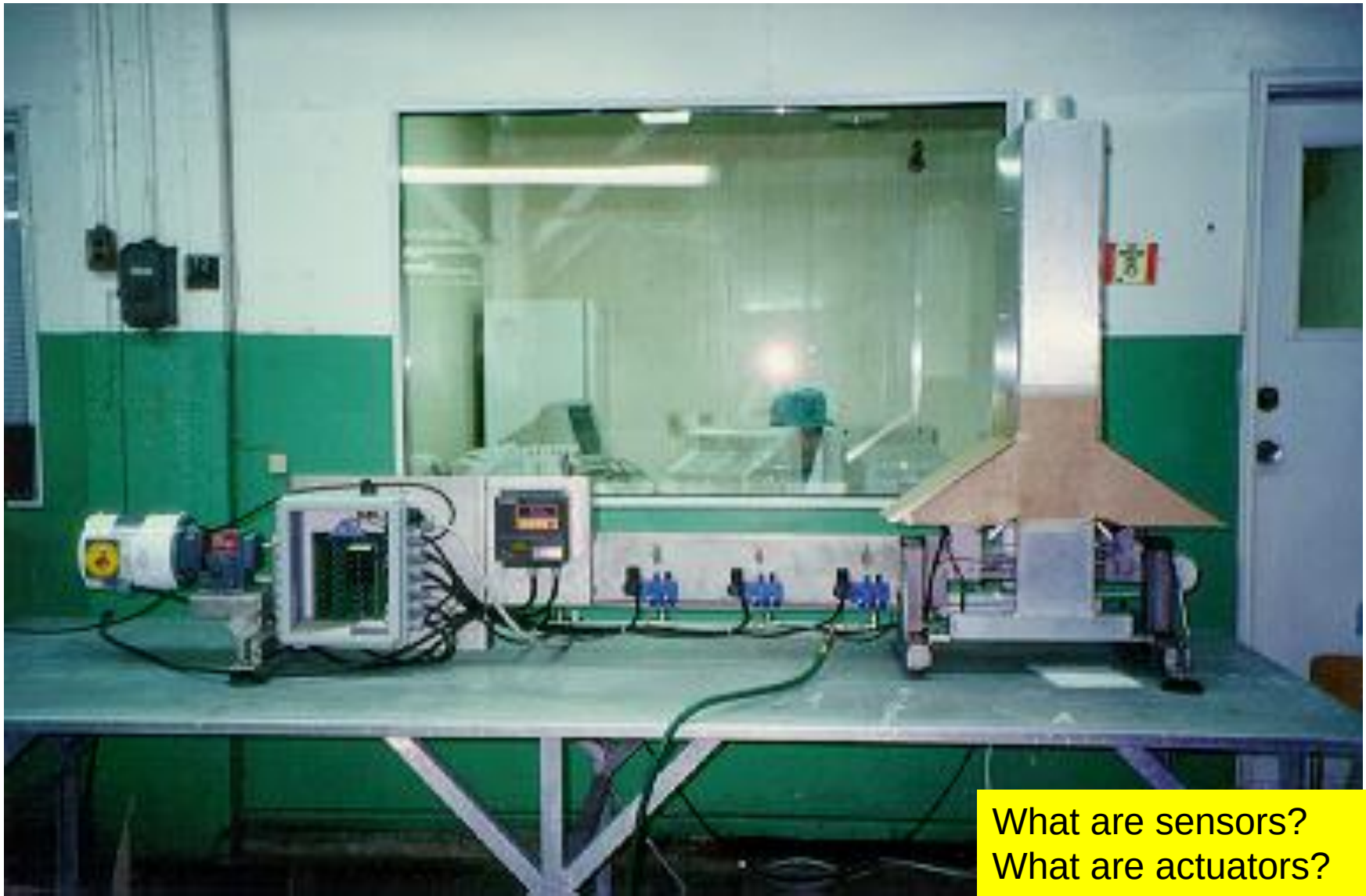
Questions on Mechatronic Instrumentation

- **Difference between instrumentation and mechatronic instrumentation?**
- **Key objectives of mechatronic instrumentation?**
- **Main steps of mechatronic instrumentation?**

Examples

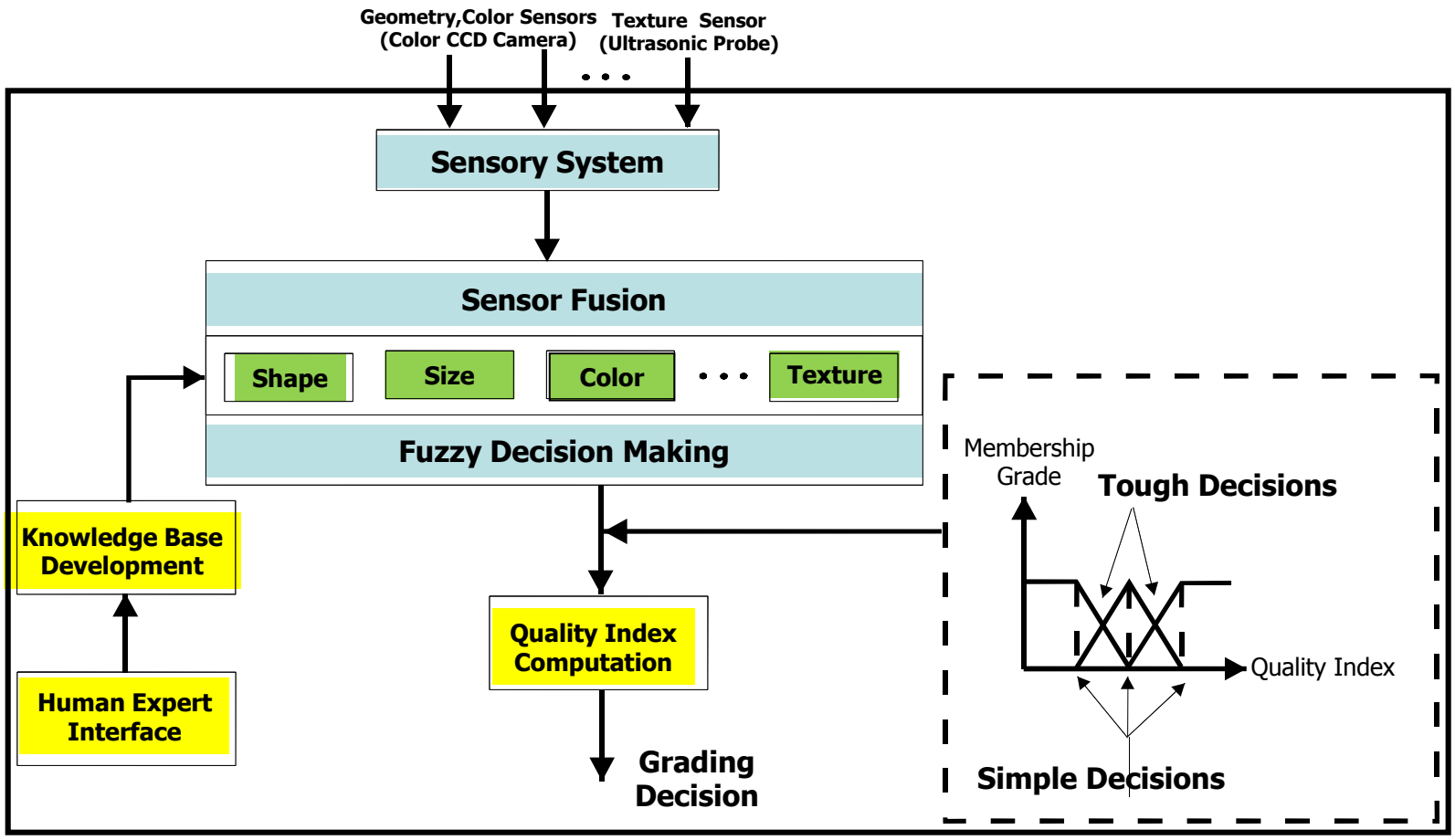
Intelligent Herring-Roe Grader

Is this an instrumentation problem or a design problem?



What are sensors?
What are actuators?

Architecture of the Grading System



Operation of the Roe Grading Machine

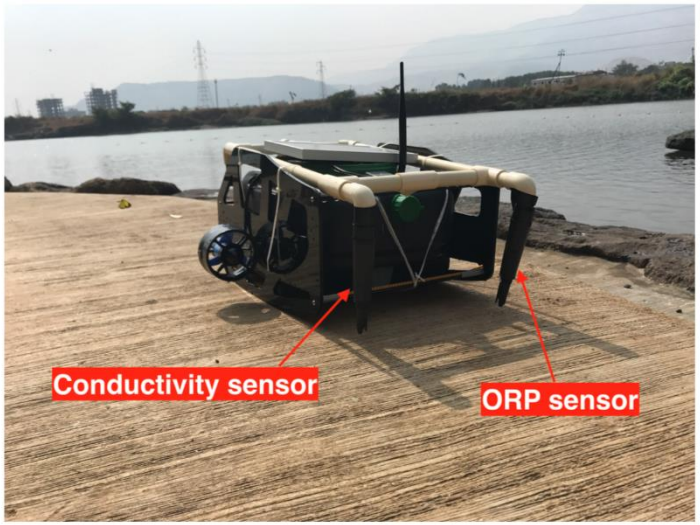
Questions on Herring Roe Grader

- **Is this a mechatronic system? Why?**

- **If not a mechatronic system, how would you make it one?**

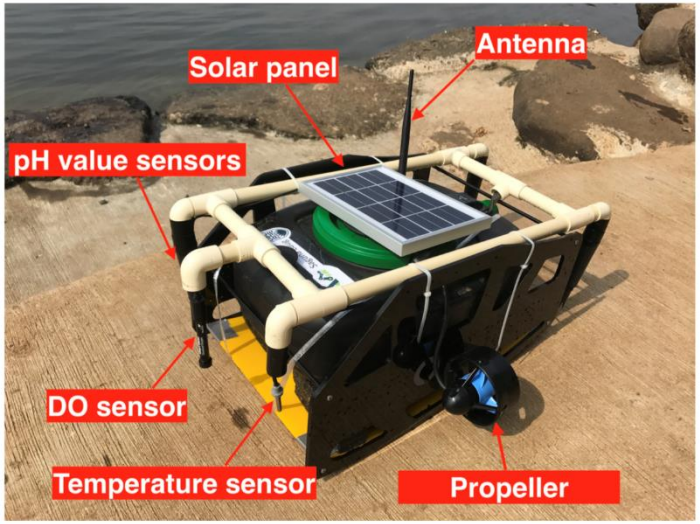
Mobile Autonomous Sensor Module for Water Quality Monitoring

(a) Top view.



(b) Back view.

Is this an instrumentation problem or a design problem?



(c) Front-right view.

(d) Side view.

Sleep Disorder Monitoring

Is this an instrumentation problem or a design problem?

Sleep Disorders

- Sleep Apnea (breathing interruption)
- Restless legs syndrome
- Insomnia

Symptoms

- Snoring
- Choking
- Cessation of abdominal & breathing

Risks

- Vulnerability to cardiovascular or metabolic diseases
- In worst cases, strokes or even death (in long term cases)