Tishk International University
Mechatronics Engineering Department
MEDICAL MECHATRONICS
Lecture 1: Introduction to Medical Mechatronics
Date: 14/10/2021

MEDICAL MECHATRONICS

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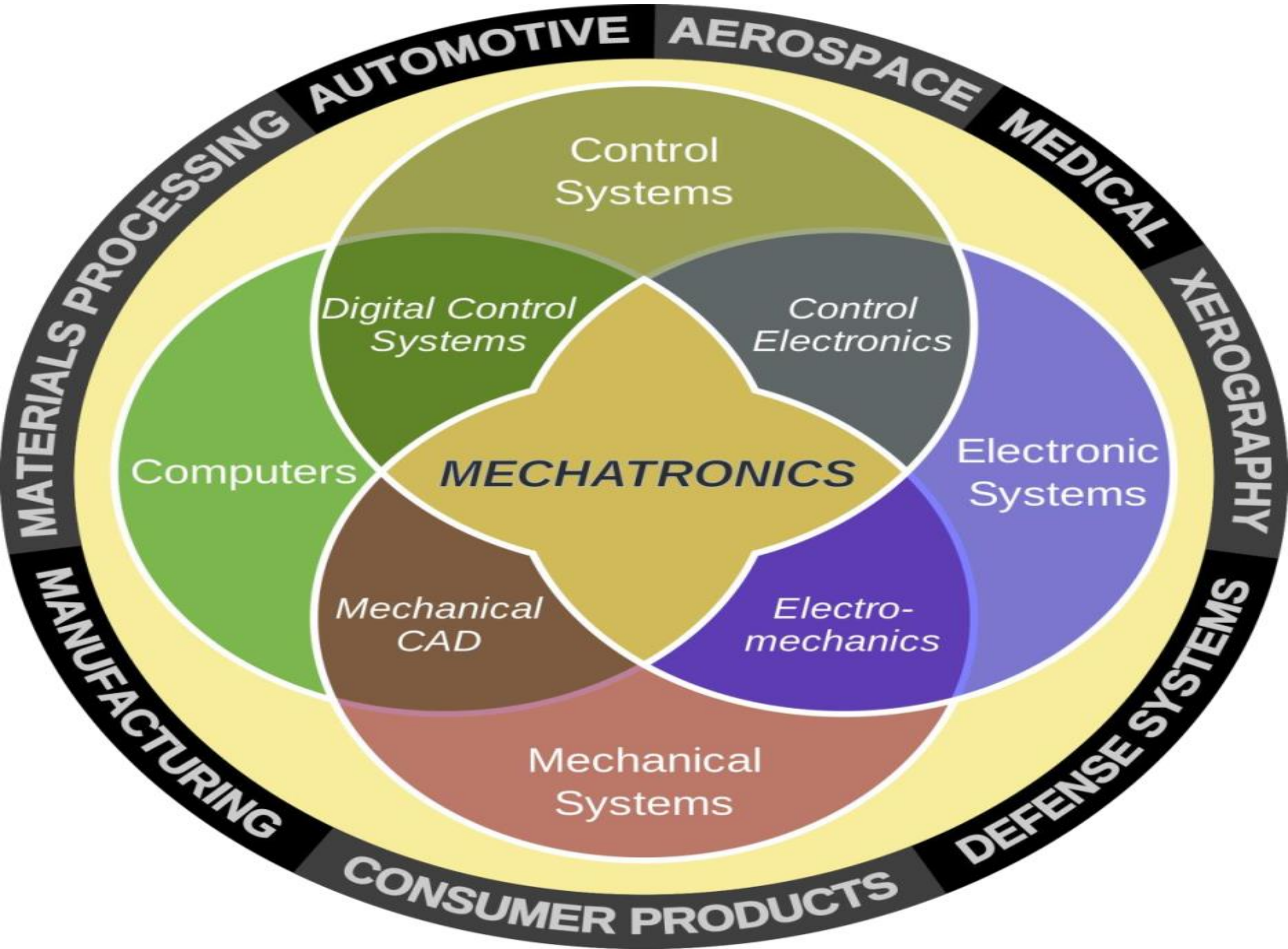
MECHATRONICS

Mechatronic engineering is the synergistic combination of mechanical, electronic, computer, and control systems along with a dash of systems engineering as illustrated in the coming figure.

This interdisciplinary combination brings together the requisite technology and skills to design new and to improve existing electromechanical systems.


AUTOMOTIVE
AEROSPACE
MEDICAL
XEROGRAPHY
DEFENSE SYSTEMS
CONSUMER PRODUCTS
MANUFACTURING
MATERIALS PROCESSING
Control Systems
Digital Control Systems
Control Electronics
Computers
MECHATRONICS
Electronic Systems
Mechanical CAD
Electro-mechanics
Mechanical Systems

BIOMECHATRONICS

- Biomechatronics = Mechatronics + Biology (Medicine)
- Biomechatronics = Bioelectrics + Biomechanics
- Biomechatronics = Bionics, Biomimetics

COURSE DESCRIPTION

This course will cover the interdisciplinary elements of biomechatronic systems engineering and provides insight into the diverse applications of current biomechatronic technologies. Most lectures incorporate examples of emerging research and development activities across the medical and engineering fields.

COURSE EVALUATION

Assignments:	3	5%
Quiz:	2	5%
Mid-Term Exam:	1	25%
Project (presentation):	1	10%
Final Exam:	1	40%

SYLLEBUSE AND TOPICS

Week 1: Introduction to Biomechatronics

- Bio-mechanics, Bio-electrics, Bionics, and Bio-mechatronics
- Course Description and Evaluation
- Syllabus and Topics
- Elements of Biomechatronic system
- The Human Factors: Stimulus, Sensing, and Actuation
- Safety and Ethical Aspects

Week 2: Physiological and Bio-mechanical Systems

- Physiological systems
- Human physiology
- Biochemical system
- Anatomy, cell and cell structure
- Nervous system
- Cardiovascular system
- Respiratory system
- Musculoskeletal system
- The future of biomechatronic systems

SYLLEBUSE AND TOPICS

Weeks 3:Signal Processing

Biomedical and Bioelectric Signals
iosignal Acquisition
Amplifiers and Noise
Time Domain Analysis
Frequency Domain Analysis
Practical Considerations

Weeks 4: Power supply and Energy Harvesting system

Week 5: Sensors in mechatronics and medical applications

Simple Sensors: Switches, Resistive, Capacitive, Inductive, Magnetic
Sonar and Optical Sensors
Inertial Measurement Units
Temperature, Pressure, and Tactile Sensing
Body-Surface Biopotential Electrodes

SYLLEBUSE AND TOPICS

Week 6-7: Actuators in medical applications

Simple Actuators: Solenoids, DC Motors, Stepper Motors, Servo Motors

Linear Actuators

Pneumatic Muscles

Shape Memory Alloys

Week 8-9: Feedback and Control Systems

Biological Feedback Mechanisms

Biomechatronic Feedback Mechanisms

Proportional and Higher-Order Controllers

System Representation

Analyzing Complex Models

System Stability

SYLLEBUSE AND TOPICS

week 10: Hearing Aids
Introduction: Hearing Aids and Implants
Hearing Loss and Diagnosis
Hearing Aid Technologies
Bone Conduction Devices
Middle Ear Implants
Auditory Brainstem Implants
Current Research Activities

Week11: Visual Prostheses
Anatomy and Physiology of the Visual Pathway
Main Causes of Blindness
Optical Prosthetics: Glasses, Thermal Imagers, Night Vision
Sonar-Based Systems: Sonar-Based and Laser-Based Systems
Sensory Substitution: Auditory, Electrotactile, and Vibrotactile Substitution
Visual Neuroprostheses and Implants
Current Research Activities

SYLLEBUSE AND TOPICS

- **Weeks 12: Active Prosthetic Limbs**

  A Brief History of Prosthetics
  Active Rehabilitation
  Structure of the Arm and Kinematic Models
  Structure of the Leg and Kinematic Models
  Actuation and Control of Upper Limb Prostheses
  Actuation and Control of Lower Limb Prostheses
  Current Research and Applications

- **Weeks 13-14: Final Presentation**

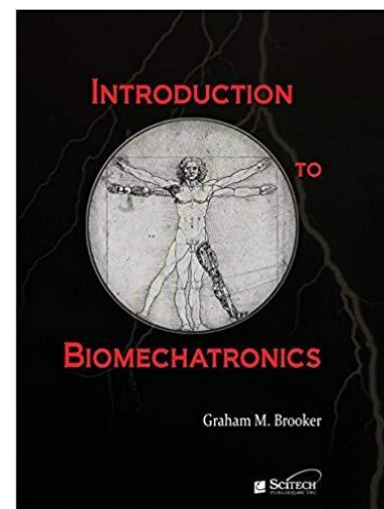
REFERENCES

- Jacob Segil, ed. **Handbook of Biomechatronics**, Academic Press, 1st Ed., 2019.

[Handbook of Biomechatronics - Google Books]

- G. Brooker, **Introduction to Biomechatronics**, SciTech Pub., 1st Ed., 2012.

[Introduction to Biomechatronics - Graham Brooker - Google Books]



INTRODUCTION

- **Medical mechatronics (Biomechatronics)**: is the application of mechatronic engineering to human biology (medicine field), and, as such, it forms an important subset of the overall biomedical engineering discipline.
- As with mechatronics, which is often synonymous with robotics, biomechatronics is often thought of as restricted to the development of prosthetic limbs. However, in reality, biomechatronics covers a much wider genre than this, and along with prosthetic limbs this course examines some of the more interesting applications including those related to:
- hearing,
- respiration,
- vision,
- and the cardiovascular system.

*BIOMECHATRONIC SYSTEMS

- Ultimately, biomechatronics can be thought of in a similar manner to any other engineering system with one of its elements, generally the most complex one, being the human being.
- Unfortunately, the human element is not only the most complex and least understood but also the most difficult to interface to.
- The **human body** is not a simple machine, but an amazingly complex **chaotic** system.
- The defining characteristics of Chaos are A deterministic rule
- Unpredictable outcomes due to an exponential sensitivity to initial data

*BIOMECHATRONIC SYSTEMS

- Attempts to measure and stimulate the human body are not completely deterministic, and repeated application of a set of inputs will not always produce the same response. In fact, even when under conscious control, responses (or actions) are seldom identical.
- Consider, for example, the best sportsmen in the world: With practice and talent they are able to produce fairly repeatable performances, but subtle changes in initial conditions, within and external to their bodies, results in some variations.
- This uncertainty is manifest across the complete range of physiological responses, from slight variations in the resting heart rate through the apparently chaotic nature of firing neurons.

*BIOMECHATRONIC SYSTEMS

- A chaotically healthy heart would be governed by a rule that maintains function while leading to changes in heart rate that cannot be predicted.

- The heart rate does not change very much and looks predictable when measured on an hourly basis. But when measurements made every minute, heart rate fluctuates in a nonlinear and unpredictable way.

- Body temperature is a complex, non-linear variable, subject to many sources of endogenous and exogenous variation.

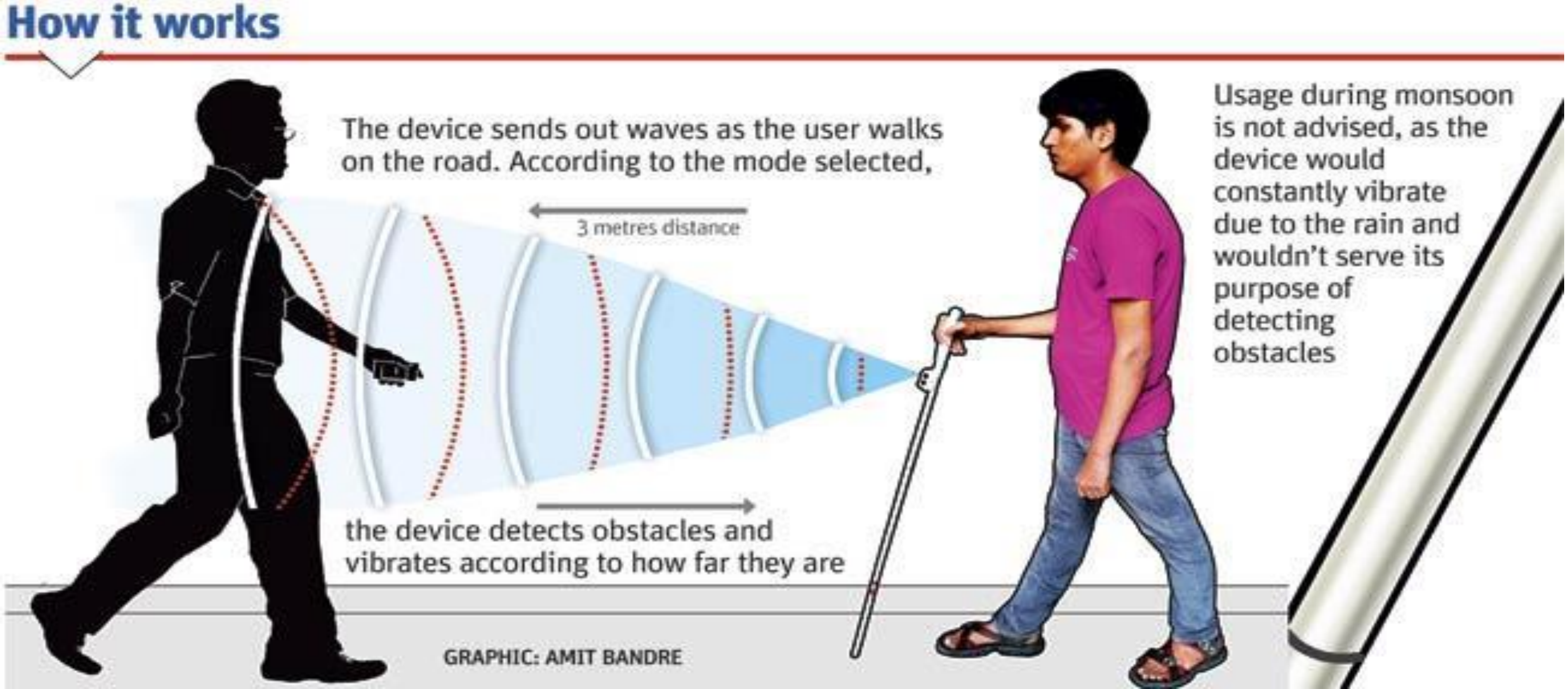
- In a typical biomechatronic system, a number of components can be identified.

ELEMENTS OF A BIOMECHATRONIC SYSTEM

- These include the following:
- The human (or animal) subject
- Stimulus or actuation
- Transducers and sensors
- Signal conditioning elements
- Recording and display
- Feedback elements

Example: Smart Cane

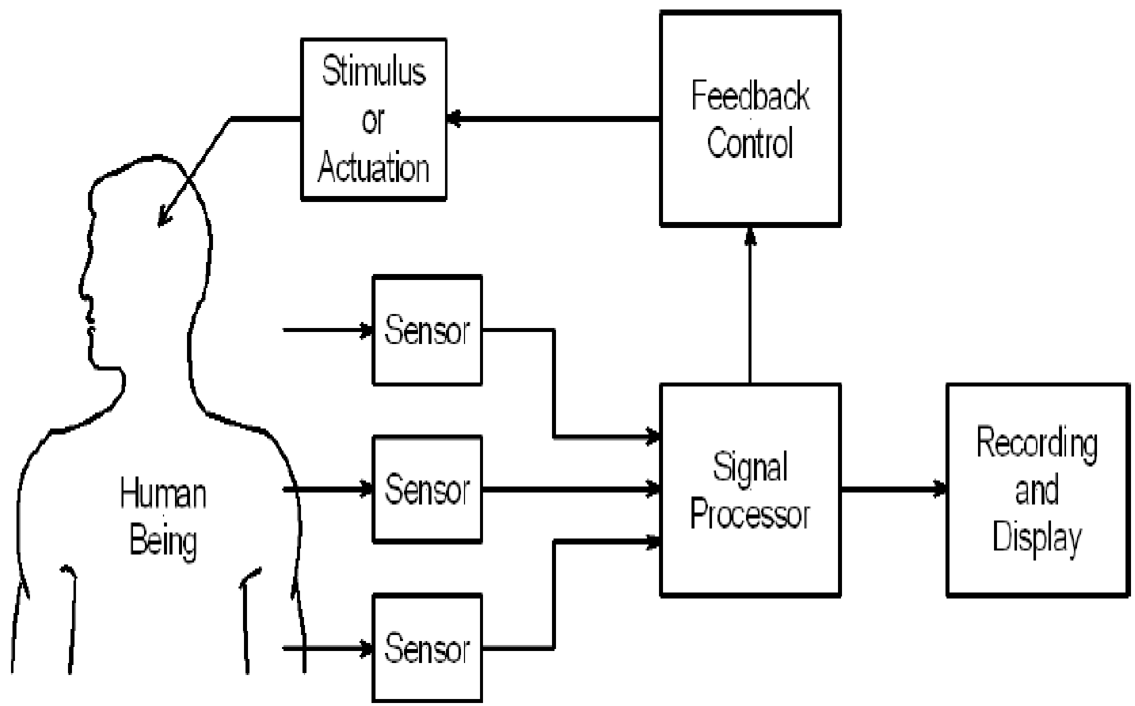
- An example of a biomechatronic system is a smart version of whitecane called smartcane.
- Smart cane produce stimulus that is triggered in response to obstacles around a blind person to prevent him or her from collision.



THE HUMAN (OR ANIMAL) SUBJECT

- The human subject adds the ***bio*** to this ***mechatronic control*** and ***monitoring process***. What makes biomechatronics particularly interesting compared with other mechatronic systems is the diversity and complexity of human physiology. Unlike the usual engineering systems, the behavior of which can be more or less predicted, each human being is unique and ever changing.

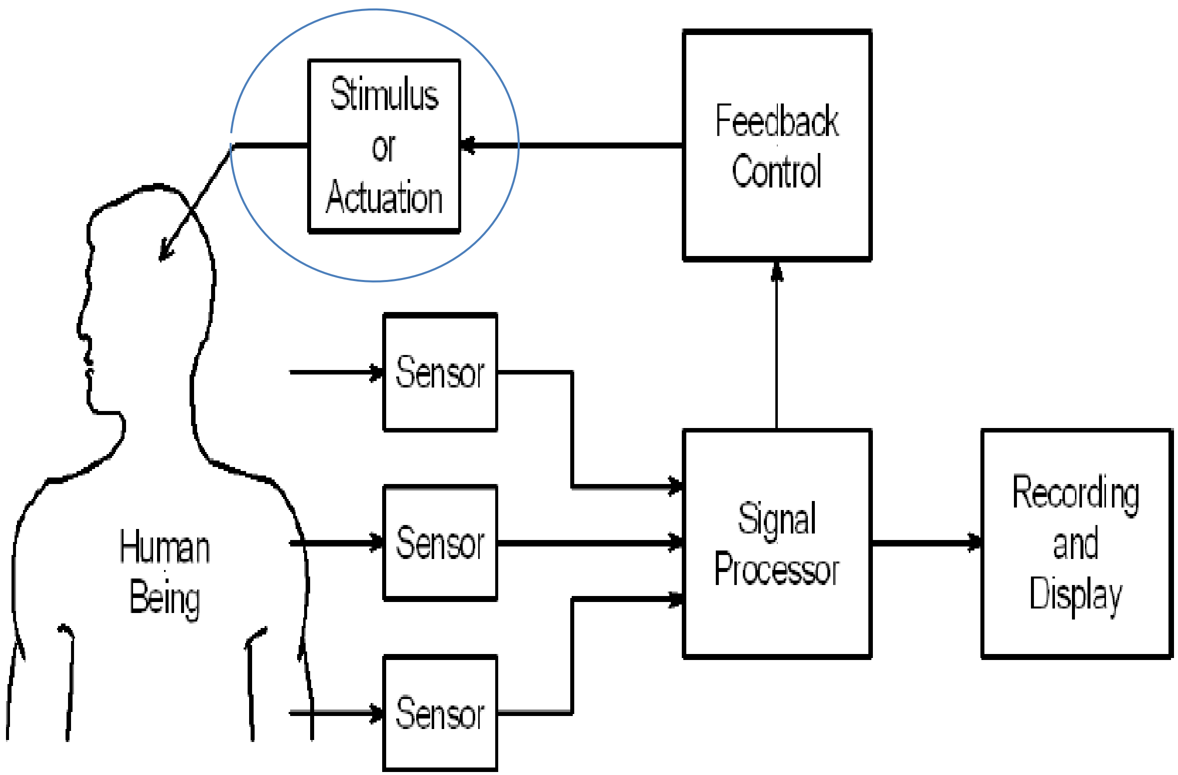
FIGURE:
Block diagram showing the elements of a biomechatronic system .

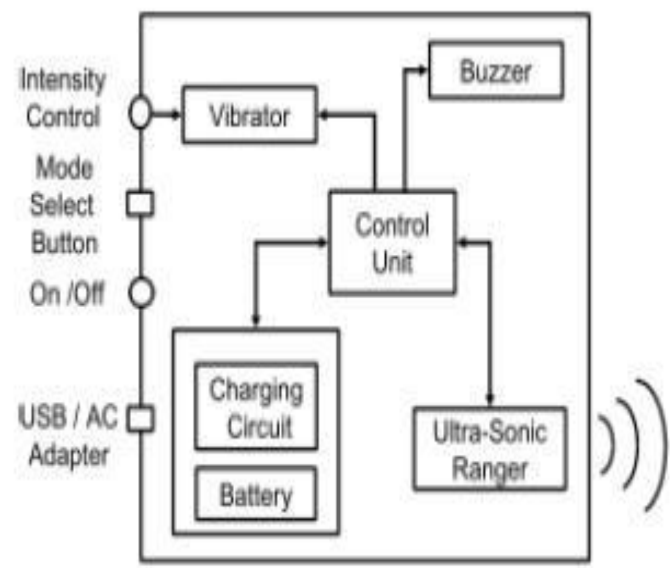


Stimulus or Actuation

- The process of stimulation can be introduced as a feedback element, as shown in Figure 1-2, or as a naturally occurring input.
- Sources of stimuli can encompass any modality that has an effect on the human element. This can include electrical stimuli, an audio tone, control of air or blood flow, a source of light, a tactile stimulus, or even the physical actuation of a limb.

Stimulus or Actuation

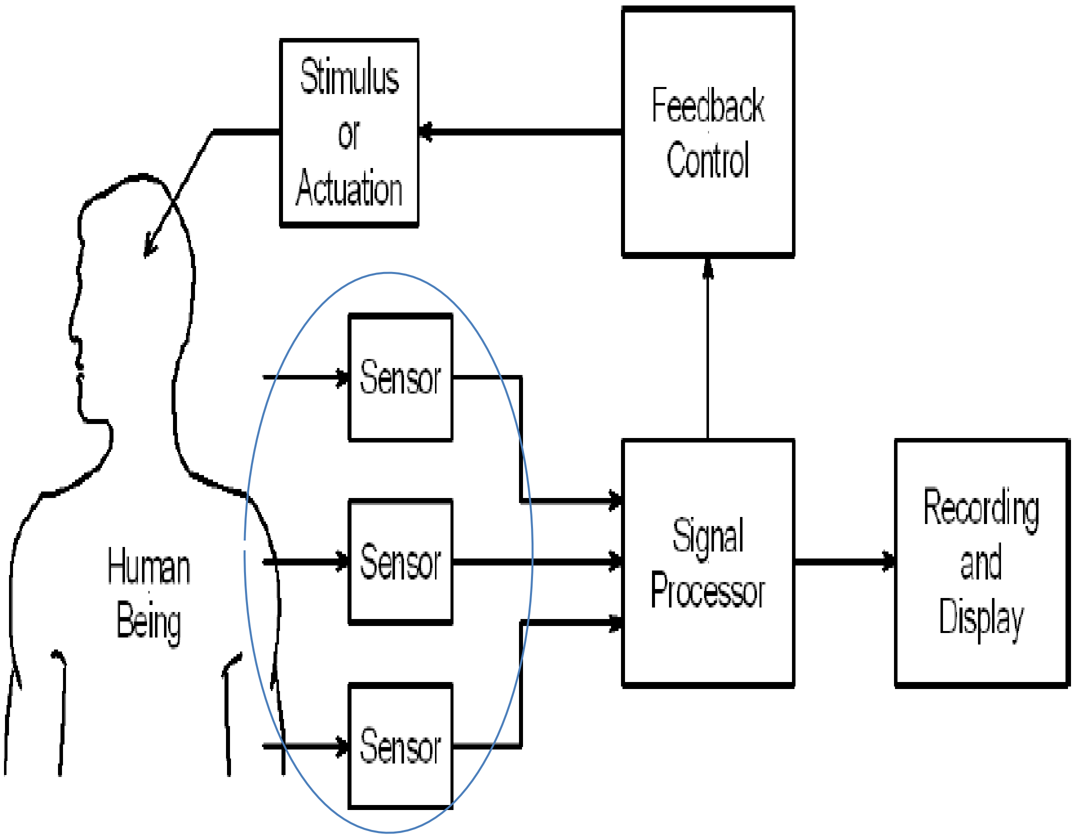


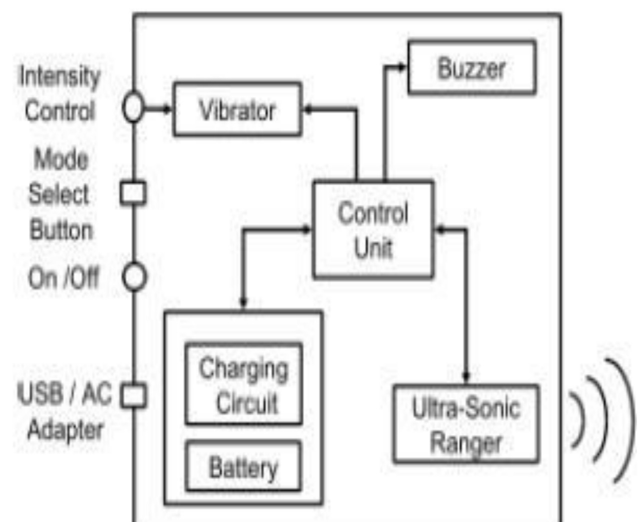


Transducers and Sensors

- Transducers and sensors are the devices that convert physiological outputs into signals that can be used. In most cases, these are sensors that amplify electrical signals or convert them from chemical concentration, temperature, pressure, or flow into electrical signals that can be further processed.
- Interfacing to the human body is not a trivial task, as embedded sensors must be biocompatible, flexible, and extremely robust to survive in the aggressive internal environment, while surface sensors, particularly electrodes, must be able to form a compatible and relatively stable conductive interface across the skin.

Transducers and Sensors

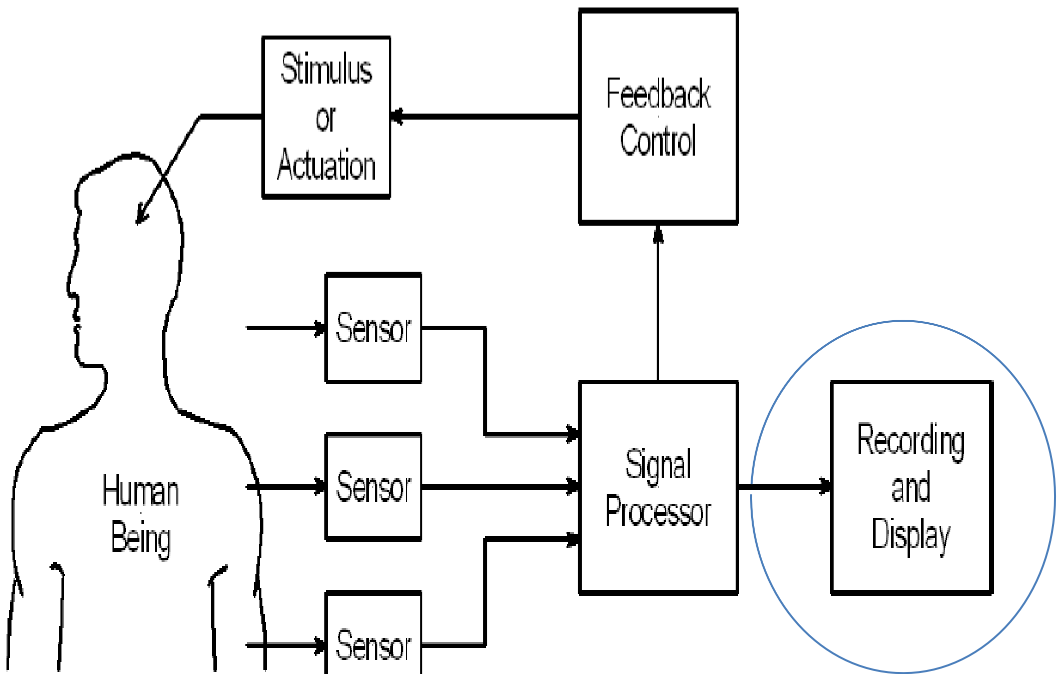


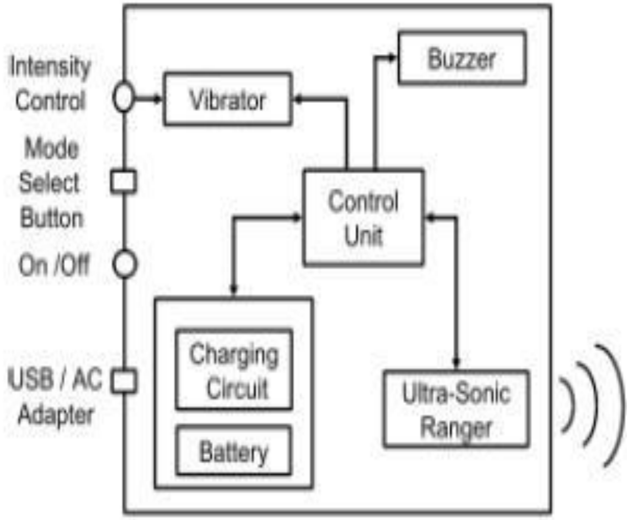


Recording and Display

- In many cases, the biomechatronic device functions to monitor a physiological process or response. In these cases it may be important to display the information in a form that is easy to interpret, or to store it for later analysis. Common examples of such devices are the now ubiquitous 12-lead electrocardiograph, pneumotachographs and sphygmomanometers. In the past many of these devices were mechanical and outputs were recorded onto paper tape or photographic film, but with the advent of modern electronics, most have been replaced by their electronic equivalents— random access memory (RAM) and liquid crystal displays.

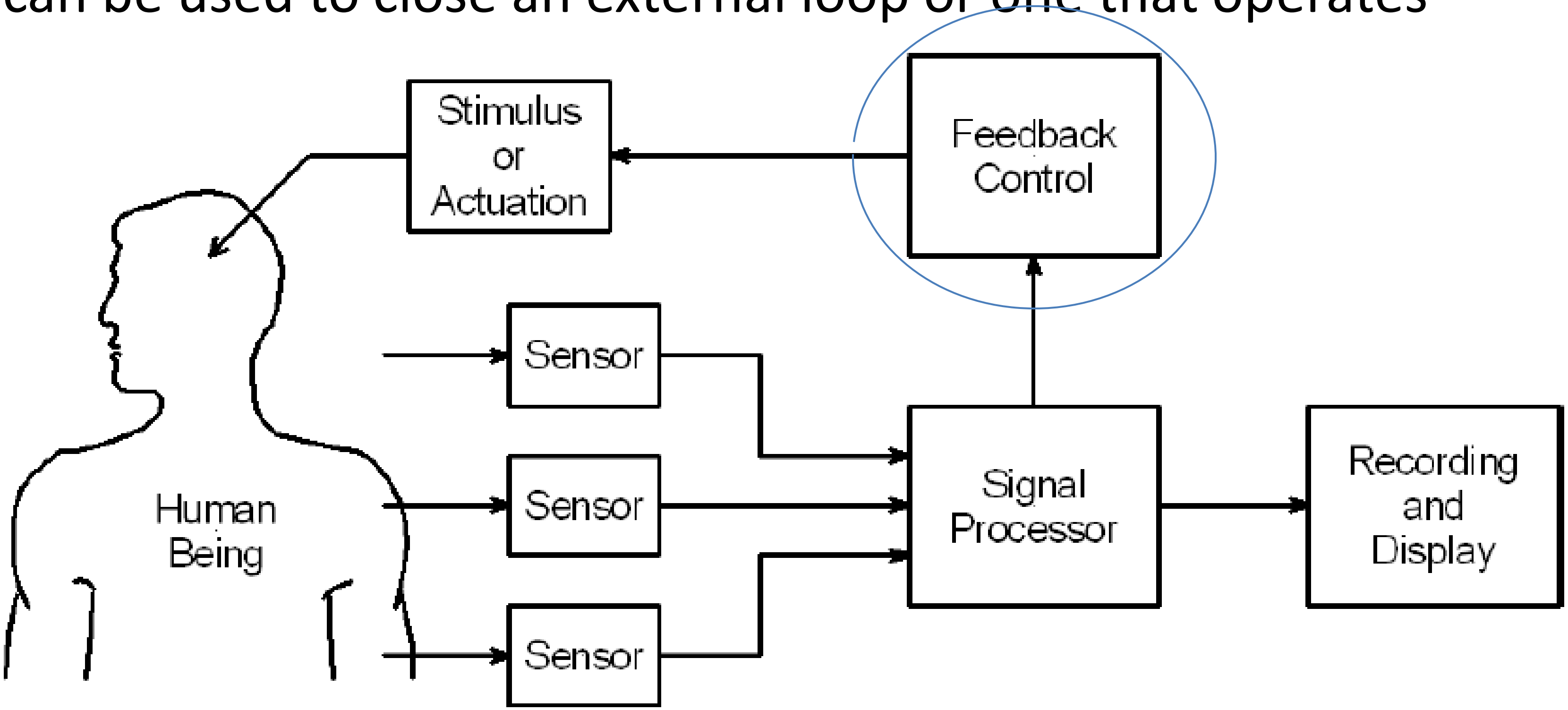
Recording and Display





Feedback Elements

- In a closed-loop control application, any stimulus or excitation signal is conditioned by the processed outputs of one or a number of sensors monitoring the physiological process. The link that connects the sensing output back to the stimulus includes further processing through control elements. This feedback can be used to close an external loop or one that operates



Safety and Ethics

MEDICAL ethics

Ethics

- **Ethics**
    - Protocol
    - Letter of Information
- **Protocol**

Project Name / Start Date / End Date

Project Members / Funding Source

Background/Objectives/Method/Analysis

Standard of Care / Drug / Preliminary Results

Study Design / Inclusion & Exclusion Criteria

Risks & Benefits / Impact on Society

Consent / Confidentiality / Security

Data Sharing / Conflict of Interest

Ethics

- **Letter of Information**

Introduction / Study Funding

Inclusion & Exclusion Criteria

Tasks Involved / Visits / Scheduling

Tools / Drugs

Benefits / Risks / Inconveniences

Use of Information

Reimbursement

Team Members

Safety

- Global Harmonization Task Force
- Governmental Regulation
- Standards
- Safety of Medical Devices
- Risk Management
- Quality Control
- Regulatory Resources