Module Code and Title:

ME3243/EE3305 Robotic System Design (4 MCs)

Module Description:

This module will introduce the mobile robot systems' architecture and key components such as various sensor and actuator technologies. Various locomotion mechanisms adopted by robotic systems will be discussed. The module will also introduce basic principles of robot motion control. Robot Operating System (ROS) will be utilized for simulation in virtual environments.

Learning Outcomes:

At the end of the module the student will be able to

1. Analyse motion of different locomotion mechanisms.
2. Understand key working principles of selected sensors and actuators used in robots; and select appropriate sensors and actuators for a robot system to achieve a given task.
3. Apply basic robot motion control principles.
4. Utilize ROS for mobile robot simulation in a virtual environment.

Syllabus:

- **Introduction to Robotics**: Definitions and history of robotics, robot components, robot Applications.
- **Robot Sensors and Actuators**: Various sensor principles and actuation technologies, degrees of freedom.
- **Robot Locomotion**: Types of locomotion, Examples: legged, wheeled, flying, swimming. Mobile robot kinematics.
- **Robot Motion Control**: Types of controls (proportional, integral and derivative), localization, path planning and navigation.
- **Robot Operating System**: Simulation of mobile robot(s) in a virtual environment.

Pre-requisites/Co-requisites:

N/A

Assessment:

Laboratories, Tests and others

Illustrative Reading List:

(a) Compulsory reading:

NIL

(b) Supplementary reading:

1. Matarić, Maja J. The robotics primer. Mit Press, 2007.

2. Siegwart, Roland, Illah R. Nourbakhsh, and Davide Scaramuzza. "Autonomous mobile robots." Massachusetts Institute of Technology (2004).

3. Joseph, L. (2018). “Robot Operating System (ROS) for Absolute Beginners: Robotics Programming Made Easy”, Apress Berkely, CA, USA.

Module Code and Title:

EE4309 Robot Perception (4 MCs)

Module Description:

The module aims to introduce the robotic senses that support natural interactions between humans and robots and enable robots to navigate in a human living environment. It examines the principles of robotic auditory system, spoken dialogue system, robotic vision system, and laser imaging system. It will study the strategy to integrate the robotic perceptual abilities to address real world problems, such as visual language grounding, and 3D semantic maps.

Learning Outcomes:

At the end of the module the student will be able to

1. Describe the basics of robot perception and robotic senses.
2. Explain the principles of robotic auditory system.
3. Explain the principles of robotic vision system.
4. Explain the principles of laser imaging system.
5. Describe the relationship between robotic senses and real-world problems through visual language grounding and 3D semantic maps.
6. Apply the design strategy of complex robotic perceptual system.

Syllabus:

- Robotic senses and human senses: an introduction
- Robotic auditory system: sound and speech acquisition, microphone array, and sound source localization
- Robotic vision system: A fundamental requirement in robotics and computer vision is to represent the position and orientation of objects in an environment. The chapter will cover topics related position, orientation and pose in 2D and 3D. image formation, image processing, and basics of computer vision
- Range sensors: Sonar, laser range finder, structured light
- Symbol grounding for robotics and intelligent system that includes, physical symbol grounding, social symbol grounding, symbol grounding for vision systems, anchoring in robotic systems, and learning symbol grounding in software systems and robotics
- Examples and Applications

Pre-requisites/Co-requisites:

EE4704 "Introduction to Computer Vision and Image Processing" or EE3731C “Signal Processing Methods”, or equivalent.

Assessment:

Tests and others

Illustrative Reading List:

(a) Compulsory reading:

NIL

(b) Supplementary reading:

Robotics, Vision & Control, Corke, 2017, Springer second edition

Module Code and Title:

BN4601 Intelligent Medical Robotics (4MCs)

Module Description:

This module will cover topics from clinical background, medical robot evolution, design specifications, design rationale, actuators and sensors, robot kinematics, data- driven modeling, motion tracking, intelligent navigation and control, new trends on soft robots and general flexible robotic systems.

Learning Outcomes:

1. Describe the history and development of robotics for medical applications. Identify the architecture and design rationale for medical robotic systems.
2. Articulate the principles for motion and force sensing technologies for medical robotics.
   Present the motion generation mechanism and kinematics modeling.
3. Analyse the basic data-driven intelligent navigation and control technologies for medical robotics.

Syllabus:

Introduction to Medical Robotics (4 hr):

- Definitions, clinical background, evolution and history of medical robotics and applications.

Compliant Medical Robotics (12 hr):

- Design specifications and design rationale
- Actuation technologies in medical robotics
- Sensors: principles for motion and force sensing technologies for medical robotics

Motion generation mechanism and kinematics modeling (12 hrs):

- Degree of freedom;
- Kinematics chain, Homogeneous Transforms.
- General introduction of multi-Joint forward kinematics and inverse kinematics.
- Rotation matrix (2D, 3D); Properties of rotation matrix; Jacobian; Equivalence of Forces; Data-driven modelling.

Intelligent Navigation and Control for Medical Robotics (12 hrs):

- Control Strategies
- Teleoperation
- Cooperative manipulation
- Intelligent image guidance with medical imaging Data flow and AI in robot motion control
- System Integration and Evaluation

Project Work: The group project work will be developed on an in-depth study of a specific topic

Pre-requisites/Co-requisites:

Nil

Assessment:

Homeworks, Tests and others

Illustrative Reading List:

(a) Compulsory reading:

NIL

(b) Supplementary reading:

1. Jocelyne Troccaz (Editor), “Medical Robotics,” ISBN: 978-1-84821-334-0, 412 pages, Wiley-ISTE, February 2012.

2. Surgical Robotics: Systems Applications and Visions Isbn:144191126X, Jacob Rosen, Blake Hannaford, Richard M. Satava 2011

3. Sashi S Kommu (Editor), “Rehabilitation Robotics,” ISBN 978-3-902613-04-2, 648 pages, Publisher: I-Tech Education and Publishing, Chapters published August 01, 2007 under CC BY-NC-SA 3.0 license

Module Code and Title:

ME4242 Soft Robotics (4MCs)

Module Description:

Soft Robotics introduces the usage of soft materials to construct and design integral parts of a robot like soft actuators and soft sensors. This module will introduce different types and genre of soft robots, mechanics of soft robots and the design, kinematics of control and applications of soft robots. The objective of this module is to introduce students to a new field of robotics that are made up of, in-part or as a whole, with soft materials and systems.

Learning Outcomes:

1. Define soft robots and the different classifications of soft robots
2. Describe the different kinds of soft materials used for robotic mechanisms and components
3. Model the physical (e.g, electrical and mechanical) behaviour of such materials in response to different energy sources
4. Explain how soft materials can be used as sensors
5. Explain how soft materials can be used as actuators
6. Design and realize active robotic components (e.g, sensors and actuators) based on soft materials.
7. Develop a mathematical model that describes the kinematic response of robotics mechanisms with soft materials
8. Develop a mathematical model that describes the kinematic response of robotics mechanisms with soft materials
9. Build a soft robot system that is capable of fast locomotion and overcoming obstacle

Syllabus:

- Introduction to Soft Robotics and recent developments Define soft robotics and the different types of soft robots developed in the recent years
- Biomimetics
  Introduce bio-inspired concept and designs of soft robots, including muscular hydrostat, growing/evolving structures etc
- Soft Fluidic Robot Systems
  Introduce the concept of fluid-based inflation and associated material designs and electronics setup for fluidic control
- Electrical Driven Dielectric Elastomer
- Polymers
  Describe new types of magnetic/thermos/electro- sensitive actuation materials, such as soft resins, shape memory alloys; polymers and resins
- Mathematical Modeling
  Describe basic models for relating the pressure- kinematics relationship of soft actuators.
- Manufacturing methods
  Describe silicone mould-casting, direct 3D-printing, fabric welding methods, including their advantages and disadvantages
- Control of soft robots
  Explain fluidic PID control in detail
- Example applications

Introduce soft wearable robots, manipulation robots and locomotion robots

Pre-requisites/Co-requisites:

Nil

Assessment:

Tests and others

Illustrative Reading List:

(a) Compulsory reading:

NIL

(b) Supplementary reading:

Liyu Wang, Surya G. Nurzaman, and Fumiya Iida. 2017. *Soft-Material Robotics*. Now Publishers Inc., Hanover, MA, USA.

Alexander Verl, Alin Albu-Schäffer, Oliver Brock, Annika Raatz, 2016, *Soft Robotics: Transferring Theory to Applications,* Springer, Berlin, Germany.

Module Code and Title:

EE4705 Human-Robot Interaction (4MCs)

Module Description:

The module introduces different modes of human robot interactions, methods for detecting humans, understanding human behaviors and intentions, and methods for human- robot coordination and collaboration. Human-robot interactions include physical and non-physical (e.g. social) interactions. Physical interactions include human assistance and wearable robotics. Non-physical interactions include natural language understanding, spoken dialogue, gestures and "body language", and multi- modal interaction fusing different interaction modalities. Human-robot coordination and collaboration include human-robot handovers, robotic assistants and co- workers. User interface design for mutual communications between robot and humans is covered, including social interaction. Several applications and scenarios will be included.

Learning Outcomes:

1. Explain the different modes of interaction between humans and robots and to distinguish them from each other

2. Describe methods for detection of body language and gestures

3. Describe natural language processing and human-robot dialogue

4. Explain human motion and interaction with machines

5. Design human-robot interface for effective interaction

6. Design different interaction modalities including physical and social interactions

7. Describe methods for fusion of multi-modal interactions towards situational awareness and effective task completion by human-robot system

8. Provide different examples and applications of human-robot systems.

Syllabus:

- Different modes of human-robot interaction: Physical vs Non-Physical: Expression, Gaze, Gestures, Speech, Tactile, Kinaesthetic, and, Assistive and Collaborative interactions. Direct proximal interaction (physical), interaction mediated through an interface and one to one interactions (gesture).
- Assistive Modes of Physical Interaction: Assistance to Elderly and people with disabilities to compensate missing capabilities, assistance to abled people to manipulate in operations.
- Collaborative Modes of Interaction: Trust models for human robot interaction, interactive robot systems, Shared Cooperative Activity.
- Understand Gestures and Body Language: Understanding human upper body gestures and expressions using combination of body movements, facial expressions and verbal language.
- Natural Language Processing: Understanding of the fundamentals of natural language processing and spoken dialogue technology; knowledge-based and statistical approach to spoken dialogue; context- sensitive interpretation to

achieve robust spoken dialogue comprehension.

- Understanding human motion: Human locomotion and manipulation skills, Human-aware motion planning.
- Predicting human intentions: Shared environments, Legible behavior, Non-verbal cues, Human activity recognition, Human intent prediction, Communicating intent.
- User interface design for human-robot interaction: Need finding, Human centered design, intuitive interfaces, Knowledge driven GUI, Haptic display interfaces, Voice control, Remote perception and manipulation, Understating error situations, Protocols.
- Examples and Applications: Examples and applications will be outlined in the above topics.

Pre-requisites/Co-requisites:

Nil

Assessment:

Laboratories, Tests and others

Illustrative Reading List:

(a) Compulsory reading:

NIL

(b) Supplementary reading:

Proceedings of Human Robot Interaction (Annual Conference)
ACM Transaction on Human Robot Interaction