Short Syllabus

BCSE422L Robot Modeling and Simulation (2-0-0-2)

Mathematical Modeling of Robots - Symbolic Representation of Robot Manipulators, Classification of Robotic Manipulators, Robotic Systems, Underactuated and Mobile Robots; Kinematics, Differential Kinematics and Statics - Trajectory Planning, Actuators & Sensors - Control Architecture & Dynamics - Motion Control and Force Control - Introduction to Visual Servoing - Mobile Robots and Motion Planning.

Course Code	Course Title	L	T	P	C
BCSE422L	Robot Modeling and Simulation	2	0	0	2
Pre-requisite	BCSE421L	Syllabus Version			
		1.0			

Course Objectives:

1. To create parameter models of simple dynamic systems
2. To make quantitative estimates of model parameters from experimental measurements
3. To obtain the time-domain response of linear systems to initial conditions and/or common forcing functions by computational methods
4. To obtain the frequency-domain response of linear systems to sinusoidal inputs
5. To compensate the transient response of dynamic systems using feedback techniques
6. To model multi-domain engineering systems at lower level of granularity suitable for design and control system implementation

Course Outcomes:

After the completion of the course, student will be able to:

1. Comprehend, classify and analyze the fundamentals: kinematics, statics and trajectory planning
2. Analyze the characteristics of the actuators, sensors and control unit
3. Gain the knowledge about the concepts of dynamics and motion control of robot manipulators
4. Elucidate the construction and working of mobile robot
5. Realize the trends in robot movements and motion planning
6. Build and master a program to simulate the system and produce the expected results

Module:1	Mathematical Modeling of Robots	3 hours
Symbolic Representation of Robot Manipulators, The Configuration Space, The State Space, The Workspace, Robots as Mechanical Devices, Classification of Robotic Manipulators, Robotic Systems, Accuracy and Repeatability, Wrists and End Effectors, Common Kinematic Arrangements, Various Manipulators, Manipulator Arms, Underactuated and Mobile Robots		
Module:2	**Kinematics, Differential Kinematics and Statics**	**5 hours**
Pose of a Rigid Body, Rotation Matrix, Composition of Rotation Matrices, Euler Angles, Angle and Axis, Homogeneous Transformations, Direct Kinematics, Kinematics of Typical Manipulator Structures, Joint Space and Operational Space, Kinematic Calibration, Geometric Jacobian, Jacobian of Typical Manipulator Structures, Kinematic Singularities, Analysis of Redundancy, Inverse Differential Kinematics, Analytical Jacobian, Inverse Kinematics Algorithms, Statics		
Module:3	**Trajectory Planning, Actuators & Sensors**	**5 hours**
Path and Trajectory, Operational Space Trajectories, Joint Actuating System, Drives, Proprioceptive Sensors, Exteroceptive Sensors		
Module:4	**Control Architecture & Dynamics**	**4 hours**
Functional Architecture, Programming Environment, Hardware Architecture, Dynamics: Lagrange Formulation, Notable Properties of Dynamic Model, Dynamic Model of Simple Manipulator Structures, Dynamic Parameter Identification, Direct Dynamics and Inverse Dynamics, Dynamic Scaling of Trajectories, Operational Space Dynamic Model, Dynamic Manipulability Ellipsoid		
Module:5	**Motion Control and Force Control**	**4 hours**
Motion Control: The Control Problem, Joint Space Control, Decentralized Control, Computed Torque Feedforward Control, Centralized Control, Operational Space Control Force Control: Compliance Control; Impedance Control, Force Control, Constrained motion, Natural and Artificial Constraints, Hybrid Force/Motion Control		

Module:6	**Introduction to Visual Servoing**	**3 hours**
Vision for Control, Image Processing, Pose Estimation, Stereo Vision, Camera Calibration, Position based visual Servoing, Image based Visual Servoing		
Module:7	**Mobile Robots and Motion Planning**	**4 hours**
Nonholonomic Constraints, Kinematic Model, Chained form, Dynamic Model, Planning, Motion Control, Odometric Localization, Configuration Space, Planning via Retraction, Planning via Cell Decomposition, Probabilistic Planning, Planning via Artificial Potentials		
Module:8	**Contemporary issues**	**2 hours**
	Total Lecture hours:	**30 hours**

Text Book(s)	
1.	Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, Giuseppe Oriolo, Robotics: Modelling, Planning and Control, Springer Publishing Company, 2010.
2.	M.W. Spong, S. Hutchinson and M. Vidyasagar, Robot Modeling and Control, 2nd Edition, JOHN WILEY & SONS, INC, 2020.
Reference Books	
1.	Daniel L. Ryan, Robotic Simulation, First Edition, CRC Press, 1993.
2.	John Brown, Robot Simulation and Programming: From Simulation to Real World Implementation, E-book Edition, 2018

Mode of Evaluation: Continuous Assessment Test –I (CAT-I), Continuous Assessment Test –II (CAT-II), Digital Assignments/ Quiz / Completion of MOOC, Final Assessment Test (FAT).

Recommended by Board of Studies	13-05-2022		
Approved by Academic Council	No. 66	Date	16-06-2022