VEERMATA JIJABAI TECHNOLOGICAL INSTITUTE

(VJTI)

MATUNGA, MUMBAI 400 019

(Autonomous Institute affiliated to University of Mumbai)

Curriculum

(Scheme of Instruction & Evaluation and Course contents)

For

Multi-Disciplinary Minor

in

Robotics

Implemented for the batch admitted in Academic Year 2023-24

V J T I Veermata Jijabai Technological Institute
(Central Technological Institute, Maharashtra State, INDIA)
H. R. Mahajani Marg, Matunga, Mumbai 400019
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Credit Framework for

Multi-Disciplinary Minor

in

Robotics

Sr.	Semester	Course Code	Course Name	L	T	P	Hr	Cr	Examination Weightage in %		
									TA	MST	ESE
1	III	R5ME2201T	Introduction to Robotics	2	0	0	2	2	20	30	50
2	IV	R5ME2204T	Mechanics of Robots	2	0	0	2	2	20	30	50
3	V	R5EE3221T	Microprocessor and Embedded Systems	3	0	0	3	3	20	30	50
4	VI	R5EE3222T	Control of Robotic Systems	3	0	0	3	3	20	30	50
5	VII	R5ME4201T	Wheeled Mobile Robots	3	1	0	4	4	20	30	50
			Total					**14**			

Abbreviations: **L** Lecture, **T** Tutorial, **P** Practical, **TA** Teacher Assessment / Term work Assessment, **MST** Mid Semester Test, **ESE** End Semester Written Examination,

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – III*
Course Code	**R5ME2201T**	
Course Title	**Introduction to Robotics**	
Prerequisites		

COURSE OUTCOMES

After completion of course, students would be able:

1. To understand the terminologies related to Robotics.
2. To select robotic sub-systems and systems.
3. To understand basic principles of robot system integration.
4. To understand Socio-Economic aspect of robotic technology.

COURSE CONTENTS

Introduction to robotics

Brief History, Basic Concepts of Robotics such as Definition , Three laws, Elements of Robotic Systems i.e. Robot anatomy, DOF, Misunderstood devices etc., Classification of Robotic systems on the basis of various parameters such as work volume, type of drive, etc., Associated parameters i.e. resolution, accuracy, repeatability, dexterity, compliance, RCC device etc., Introduction to Principles & Strategies of Automation, Types & Levels of Automations, Need of automation, Industrial applications of robot.

Grippers and Sensors for Robotics

Grippers for Robotics - Types of Grippers, Guidelines for design for robotic gripper, Force analysis for various basicgripper system.

Sensors for Robots - Types of Sensors used in Robotics, Classification and applicationsof sensors, Characteristics of sensing devices, Selections of sensors. Need for sensorsand vision system in the working and control of a robot.

Drives and Control for Robotics

Drive - Types of Drives, Types of transmission systems, Actuators and its selection while designing a robot system. Control Systems: Types of Controllers, Introduction to closed loop control

Programming and Languages for Robotics

Robot Programming: Methodsof robot programming, WAIT, SIGNAL and DELAY commands, subroutines, Programming Languages: Generations of Robotic Languages, Introduction to various

types such as VAL, RAIL, AML, Python, ROS etc., Development of languages since WAVE till ROS.

Related Topics in Robotics

Socio-Economic aspect of robotization. Economical aspects for robot design, Safety for robot and standards, Introduction to Artificial Intelligence, AI techniques, Need and application of AI, New trends & recent updates in robotics.

References

1. S. K. Saha, Introduction to Robotics 2e, TATA McGraw Hills Education (2014)
2. Asitava Ghoshal, Robotics: Fundamental concepts and analysis, Oxford University Press (2006)
3. Dilip Kumar Pratihar, Fundamentals of Robotics, Narosa Publishing House, (2019)
4. R. D. Klafter, Thomas A. Chmielewski, and Mechael Negin, Robotic Engineering – An Integrated Approach, EEE, Prentice Hall India, Pearson Education Inc. (2009)

Additional Reading

1. R. K. Mittal, I. J. Nagrath, Robotics and Control, TATA McGraw Hill Publishing Co Ltd,New Delhi (2003)
2. S. B. Niku, Introduction to Robotics – Analysis, Contro, Applications, 3rd edition, JohnWiley & Sons Ltd., (2020)
3. J. Angeles, Fundamentals of Robotic Mechanical Systems Theory Methods andAlgorithms, Springer (1997)
4. Mikell Groover, Mitchell Weiss, Roger N. Nagel, Nicholas Odrey, Ashish Dutta,Industrial Robotics 2nd edition, SIE, McGraw Hill Education (India) Pvt Ltd (2012)
5. https://nptel.ac.in/courses/107106090
   Introduction to robotics, Dr. Krishna Vasudevan, Dr. Balaraman Ravindran, Dr. T Asokan, IIT Madras
6. https://nptel.ac.in/courses/108108147
   Sensors and Actuators Prof. Hardik Jeetendra Pandya, IISc Bangalore

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – IV*
Course Code	**R5ME2204T**	
Course Title	**Mechanics of Robots**	
Prerequisites		

COURSE OUTCOMES

After completing this course, students will be able to:

1. To understand terminologies related to Kinematics and Dynamics of Robots.
2. To apply mathematics for manipulator positioning and motion planning.
3. To analyse basics of motion programming as per kinematics.
4. To estimate the force/torque required to drive a robot.

COURSE CONTENTS:

Mathematical Preliminaries of Robotics

Spatial Descriptions: positions, orientations, and frame, mappings: changing description from frame to frame, Operators: translations, rotations and transformations, transformation arithmetic, compound Transformations, inverting a transform, transform equations, Euler Angles, Fixed Angles, Euler Parameters.

Robot Kinematics

Manipulator Kinematics, Link Description, Link to reference frame connections, Denavit-Hartenberg Approach, D-H Parameters, Position Representations, Homogeneous Transformation Matrix, Forward Kinematics. Inverse Kinematics, Geometric and analytical approach.

Velocities & Statics

Cross Product Operator for kinematics, Jacobians - Direct Differentiation, Basic Jacobian, , Jacobian Jv / Jw, Jacobian in a Frame, Jacobian in Frame {0}, Kinematic Singularity, Kinematics redundancy, Force balance equation, Forces, Velocity/Force Duality, Virtual Work, Force ellipsoid, Jacobian, Kinematic Singularity, Kinematics redundancy, Mechanical Design of robot linkages,

Path Planning

Definition-Joint space technique, Use of P-degree polynomial-Cubic,polynomial- Cartesian space technique, parametric descriptions, straight line and circular paths, position and orientation planning

Robot Dynamics

Introduction to Dynamics, Velocity Kinematics, Acceleration of rigid body, mass distribution

Newton’s equation, Euler’s equation.

Text Books

1. S. K. Saha, Introduction to Robotics 2e, TATA McGraw Hills Education (2014).
2. Dilip Kumar Pratihar, Fundamentals of Robotics, Narosa Publishing House, (2019)
3. J. J. Craig, “Introduction to Robotics: Mechanics and Control”, 3rd edition, Addison-Wesley (2003).

Additional Reading

1. Asitava Ghoshal, Robotics: Fundamental concepts and analysis, Oxford UniversityPress (2006)
2. M. Spong, M. Vidyasagar, S. Hutchinson, Robot Modeling and Control, Wiley & Sons, (2005).
3. https://nptel.ac.in/courses/112105249
   Robotics, Prof. Dilip Kumar Pratihar, IIT Kharagpur
4. https://nptel.ac.in/courses/112101098
   Robotics, Prof. P. Seshu, Prof. P.S. Gandhi, Prof. K. Kurien Issac, Prof. B. Seth, Prof. C. Amarnath, IIT Bombay

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – V*
Course Code	**R5EE3221T**	
Course Title	**Microprocessor and Embedded Systems**	
Prerequisites		

COURSE OUTCOMES:

After completion of course, students would be able to:

1. Prepare block diagrams for any robotic control-hardware design,
2. Choose appropriate flow of embedded systems for a specific application.
3. Write code for micro controller devices.
4. Use advanced embedded processor and software.

COURSE CONTENTS

Introduction to Embedded Systems and microcomputers

Introductionto Embedded Systems, Embedded System Applications, Block diagram of embeddedsystems, Trends in Embedded Industry, Basic Embedded System Models, Embedded System development cycle, Challenges for Embedded System Design, Evolution of computing systems and applications. Basic Computer architecture: Von-Neumann and Harvard Architecture. Basics on Computer organizations. Computing performance, Throughput and Latency, Basic high performance CPU architectures, Microcomputer applications to Embedded systems and Mechatronics.

Microprocessor

8086 Microprocessor and its Internal Architecture, PinConfiguration and their functions, Mode of Operation, Introduction to I/O and Memory, Timing Diagrams, Introduction to Interrupts. Introduction to C language, Instruction format, C language programming format, Addressing mode, Instruction Sets, Programming 8086 microprocessor.

Microprocessor Interfacing

Introduction to interfacing, Memory Interfacing, Programmable Peripheral Interfacing, Programmable I/O, Programmable Interrupt Controller, Programmable Timers, Programmable DMA Controller, Programmable Key Board Controller, Data acquisition Interfacing: ADC, DAC, Serial and parallel data Communication interfacing. Microcontroller: Introduction to Microcontroller and its families, Criteria for Choosing Microcontroller. Microcontroller Architecture, Programming model, addressing modes, Instruction sets, Assembly and C

programming for Microcontroller, I/O programming using assembly and C language, Interrupt Controller, I/O interfacing, Timers, Real Time Clock, Serial and parallel Communication protocols, SPI Controllers. LCD Controller.

Microcontroller Interfacing

Introduction to Microcontroller Interfacingand applications: case studies: Display Devices, controllers and Drivers for DC, Servoand Stepper Motor.

Introduction to Advanced Embedded Processor and Software

ARM Processor, Unified Model Language (UML), Embedded OS, Real Time Operating System (RTOS), Embedded C.

Microprocessor and Embedded System Laboratories

Basic C language programming implementation on Microprocessor and Microcontroller. Interfacing Displays, Key boards and sensors with Microprocessors and Microcontrollers, Data Acquisition using Microprocessor and Microcontroller, Implementation of Controlling schemes for DC, Servo, Stepper motor using C programming in microprocessors and Microcontrollers.

Text Books/References:

1. K. V. Shibu, Introduction to Embedded Systems, McGRAW Hill Publications (2009).
2. Raj Kamal, Embedded Systems, TATA McGRAW Hill Publications (2003).
3. M. Morris Mano, Computer System Architecture, 3ed, Pearson Publication, (2007).
4. D. V. Hall, 8086 Microprocessors and Interfacings, TATA McGRAW Hill, (2005).

Additional Reading

1. B. B. Brey, The Intel Microprocessors, Prentice Hall Publications, 8th ed, (2018).
2. M. A. Mazidi, R.D. Mckinlay and D. Casey, PIC Microcontrollers and Embedded Systems, Pearson Publications, (2008).
3. M. Predko, Programming and Customizing the PIC Microcontroller, McGRAW Hill Publications. 3ed, (2017).
4. R. Barnett, L. O'Cull and S. Cox, Embedded C Programming and Microchip PIC,Cengage Learning, (2003).
5. https://nptel.ac.in/courses/108102045
   Embedded Systems, Prof. Santanu Chaudhary, IIT Delhi

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – VI*
Course Code	**R5EE3222T**	
Course Title	**Control of Robotic Systems**	
Prerequisites		

COURSE OUTCOMES

After completion of course, students would have thorough understanding of linear, non-linear control systems and Motion Control.

COURSE CONTENTS

Basics of Control

Differential Equation, Transfer function, Frequency response, Routh-Hurwitz test, relative stability, Root locus design, construction of root loci, phase lead and phase-lag design, lag-lead design, Bode, polar, Nyquist plot.

Linear Control

Concept of states, state space model, different form, controllability, observability; pole placement by state feedback, observer design, P, PI & PID Controller, control law partitioning, modelling and control of a single joint.

Non-Linear Control System

Common physical non-linear system, phase plane method, system analysis by phase plane method, stability of non-linear system, stability analysis by describing function method, Liapunov's stability criterion, the control problems for manipulators.

Motion Control

Point to Point Control, trajectory generation, Continuous Path Control, Joint based control, Cartesian Control, Force Control, hybrid position/force control system.

Text Books

1. M. Gopal, Control Systems, McGraw-Hill (2012)
2. K. Ogata, "Modern Control Engineering", Prentice Hall India (2009).
3. M. Spong, M. Vidyasagar, S. Hutchinson, Robot Modeling and Control, Wiley & Sons, (2005).

Additional Reading

1. J. J. Craig, "Introduction to Robotics: Mechanics and Control", 3rd edition, Addison-Wesley (2003).
2. S. K. Saha, Introduction to Robotics 2e, TATA McGraw Hills Education (2014).
3. Thomas Kailath, "Linear Systems", Prentice Hall (1980).
4. Alok Sinha, "Linear Systems: Optimal and Robust Control", Taylor & Francis(2007).
5. https://nptel.ac.in/courses/112107289,
   Robotics and Control : Theory and Practice, Prof. N. Sukavanam, Prof. M. Felix Orlando, IIT Roorkee
6. https://nptel.ac.in/courses/107106081
   Control systems, Prof. C.S.Shankar Ram, IIT Madras

Programme Name	*Bachelor of Technology in Mechanical Engineering*	*Semester – VII*
Course Code	**R5ME4201T**	
Course Title	**Wheeled Mobile Robots**	
Prerequisites		

COURSE OUTCOMES

The student should be able to –

1. Interpret sensor systems for state measurement, navigation, and localization in mobile robots.
2. Apply motion planning and navigation schemes for autonomous operation of mobile robotic systems.
3. Analyze the mechanical and electrical subsystems involved in robot locomotion and manipulation.
4. Design basic mobile robotic systems by integrating sensing, control, navigation, and actuation techniques.

Course Contents

Introduction to Mobile Robotics and Locomotion

Introduction to mobile robots and mobile manipulators. Principles of locomotion and types of locomotion. Types of mobile robots: ground robots (wheeled and legged robots), aerial robots, underwater robots and water surface robots. Kinematics of wheeled mobile robot, degree of freedom and maneuverability, generalized wheel model, different wheel configurations, holonomic and non-holonomic robots.

Dynamics of mobile robot

Lagrange-Euler and Newton-Euler methods. Computer based dynamic (numerical) simulation of different wheeled mobile robots.

Sensors for mobile robot navigation

Magnetic and optical position sensor, gyroscope, accelerometer, magnetic compass, inclinometer, tactile and proximity sensors, ultrasound rangefinder, laser scanner, infrared rangefinder, visual and motion sensing systems. Robot navigation: Localization, Error propagation model, Probabilistic map based loclaisation, Autonomous map building, Simultaneous localization and

mapping (SLAM).

Motion and path planning

collision free path planning and sensor-based obstacle avoidance.

Motion control of mobile robots

Motion controlling methods, kinematic control, dynamic control and cascaded control.

Introduction to modern mobile robots

Swarm robots, cooperative and collaborative robots, mobile manipulators, autonomous mobile robots.

Textbooks

1. Siegwart R, Nourbakhsh I R and Scaramuzza D, Introduction to Autonomous Mobile Robots, 2nd Edition, MIT Press 2011.
2. Tzafestas S G, Introduction to Mobile Robot Control, 1st Edition, Elsevier 2014.
3. Peter Corke, Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Springer Tracts in Advanced Robotics, 2011.
4. S. M. LaValle, “Planning Algorithms”, Cambridge University Press, 2006. (Available online http://planning.cs.uiuc.edu/)
5. Thrun, S., Burgard,W., and Fox, D., Probabilistic Robotics. MIT Press, Cambridge, MA, 2005.

Recommended Readings

1. Melgar, E. R., Diez, C. C., Arduino and Kinect Projects: Design, Build, Blow Their Minds, 2012.
2. H. Choset, K. M. Lynch, S. Hutchinson, G. Kantor, W. Burgard, L. E. Kavraki, and S. Thrun, Principles of Robot Motion: Theory, Algorithms and Implementations, PHI Ltd., 2005.
3. Dudek G and Jenkin M, Computational Principles of Mobile Robotics, 2nd Edition, Cambridge University Press, 2010.
4. Kelly A, Mobile Robotics: Mathematics, Models, and Methods, 1st Edition, Cambridge University Press, 2013