University of Engineering and Management

Institute of Engineering & Management, Salt Lake Campus
Institute of Engineering & Management, New Town Campus
Institute of Engineering & Management, Jaipur

Minor Degree in "Robotics"

Course Structure							
S. No	Course Code	Title	L	T	P	Credits	Semester
1	MINOR301R	Introduction to Robotics	3	1	0	4	3
2	MINOR401R	Mechanics of Robots	3	0	0	3	4
3	MINOR501R	Microprocessor and Embedded Systems	3	0	2	4	5
4	MINOR601R	Control of Robotic Systems	3	0	0	3	6
5	MINOR781R	Project in Robotics I	1	0	6	4	7
6	MINOR881R	Project in Robotics II	0	0	2	2	8
TOTAL			15	0	6	20	

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Minor Degree

Course Title	**:**	**Introduction to Robotics**	**Credits**	**:**	**4 (L: 3; T: 1; P: 0)**
Course Code	**:**	**MINOR301R**			
Course Category	**:**	**MD**			

Course Objective: This course aims to familiarize students with basic terminologies of the robotics sciences and essential knowledge required to get started in the field of Robotics.

Course Contents:

Module 1 : 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.

Module 2: Grippers and Sensors for Robotics: Grippers for Robotics - Types of Grippers, Guidelines for design for robotic gripper, Force analysis for various basic gripper system.
Sensors for Robots - Types of Sensors used in Robotics, Classification and applications of sensors, Characteristics of sensing devices, Selections of sensors. Need for sensors and vision system in the working and control of a robot.

Module 3: 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

Module 4: Programming and Languages for Robotics: Robot Programming: Methods of 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.

Module 5: Related Topics in Robotics: Socio-Economic aspect of robotisation. 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.

Text Books/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. K. Mittal, I. J. Nagrath, Robotics and Control, TATA McGraw Hill Publishing Co Ltd, New Delhi (2003)
5. S. B. Niku, Introduction to Robotics – Analysis, Contro, Applications, 3rd edition, John Wiley & Sons Ltd., (2020)
6. J. Angeles, Fundamentals of Robotic Mechanical Systems Theory Methods and Algorithms, Springer (1997)
7. Mikell Groover, Mitchell Weiss, Roger N. Nagel, Nicholas Odrey, Ashish Dutta, Industrial Robotics 2nd edition, SIE, McGraw Hill Education (India) Pvt Ltd (2012)
8. R. D. Klafter, Thomas A. Chmielewski, and Mechael Negin, Robotic Engineering – An Integrated Approach, EEE, Prentice Hall India, Pearson Education Inc. (2009)

Alternative SWAYAM/NPTEL Course:

NPTEL Course Name	Instructor	Host Institute
Introduction to robotics	Dr. Krishna Vasudevan, Dr. Balaraman Ravindran, Dr. T Asokan	IIT Madras
Sensors and Actuators	Prof. Hardik Jeetendra Pandya	IISc Bangalore

Course Outcomes:

After completion of course, students would be able:

1. To express his views as per terminologies related to Robotics technology.
2. To apply logic for selection of robotic sub systems and systems.
3. To analyse basics of principals of robot system integration.
4. To understand ways to update knowledge in the required area of robotic technology.

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Course Title	Mechanics of Robots
Course Code	MINOR401R
Number of Credits	3 (L: 3; T: 0; P: 0)

Course Objective: This course aims to inculcate thorough understanding about basic knowledge of mathematics, kinematics and dynamics required for understanding motion programming and operational / control functionality in robotics.

Course Contents:

Module No	Topic	Sub- topics
Module 1:	**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.
Module 2:	**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.
Module 3:	**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,
Module 4:	**Robot Dynamics:**	Introduction to Dynamics, Velocity Kinematics, Acceleration of rigid body, mass distribution Newton's equation, Euler's equation, Iterative Newton –Euler's dynamic formulation, closed dynamic, Lagrangian formulation of manipulator dynamics, dynamic simulation, computational consideration.

Text Books/References:

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. Asitava Ghoshal, Robotics: Fundamental concepts and analysis, Oxford University Press (2006)
4. M. Spong, M. Vidyasagar, S. Hutchinson, Robot Modeling and Control, Wiley & Sons, (2005).
5. J. J. Craig, "Introduction to Robotics: Mechanics and Control", 3rd edition, AddisonWesley (2003).

Alternative SWAYAM/NPTEL Course:

NPTEL Course Name	Instructor	Host Institute
Robotics	Prof. Dilip Kumar Pratihar	IIT Kharagpur
Robotics	Prof. P. Seshu, Prof. P.S. Gandhi, Prof. K. Kurien Issac, Prof. B. Seth, Prof. C. Amarnath	IIT Bombay

Course Outcomes: After completion of course, students would be able:

1. To understand terminologies related to Kinematics and Dynamics of Robotics.
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.

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Subject Name: Microprocessor and Embedded Systems **Credit: 4**
Subject Code: MINOR501R

Lecture Hours: (L: 3; T: 0; P: 2)

Pre-requisite: MINOR301R, MINOR401R

Relevant Links:

STUDY MATERIAL **NPTEL**

Course Objective: This course aims to teach the detailed functioning of microprocessors and the role of embedded systems in a robotic system.

Course Contents:

Module 1: Introduction to Embedded Systems and microcomputers: Introduction to Embedded Systems, Embedded System Applications, Block diagram of embedded systems, 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 organisations. Computing performance,

Throughput and Latency, Basic high-performance CPU architectures, Microcomputer applications to Embedded systems and Mechatronics.

Module 2: Microprocessor: 8086 Microprocessor and its Internal Architecture, Pin Configuration 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.

Module 3: 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.

Module 4: Microcontroller Interfacing: Introduction to Microcontroller Interfacing and applications: case studies: Display Devices, controllers and Drivers for DC, Servo and Stepper Motor.

Module 5: Introduction to Advanced Embedded Processor and Software: ARM Processor, Unified Model Language (UML), Embedded OS, Real Time Operating System (RTOS), Embedded C.

Module 6: 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).
5. B. B. Brey, The Intel Microprocessors, Prentice Hall Publications, 8th ed, (2018).
6. M. A. Mazidi, R.D. Mckinlay and D. Casey, PIC Microcontrollers and Embedded Systems, Pearson Publications, (2008).
7. M. Predko, Programming and Customizing the PIC Microcontroller, McGRAW Hill Publications. 3ed, (2017).
8. R. Barnett, L. O'Cull and S. Cox, Embedded C Programming and Microchip PIC, Cengage Learning, (2003).

Alternative SWAYAM/NPTEL Course:

NPTEL Course Name: Embedded Systems, Instructor: Prof. Santanu Chaudhary, Host Institute: IIT Delhi

Course Outcomes:

After completion of course, students would be able:

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

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Course Code: MINOR601R

Course Title: Control of Robotic Systems

Credits: 3 (L: 3; T: 0; P: 0)

Course Category: MINOR

Course Objective

This course aims to develop the understanding of control systems, its designing and application.

Course Contents

Module 1: 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

Module 2: 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

Module 3: 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

Module 4: 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 / References

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)
4. J. J. Craig, *Introduction to Robotics: Mechanics and Control*, 3rd Edition, Addison-Wesley (2003)
5. S. K. Saha, *Introduction to Robotics 2e*, Tata McGraw-Hill Education (2014)
6. Thomas Kailath, *Linear Systems*, Prentice Hall (1980)
7. Alok Sinha, *Linear Systems: Optimal and Robust Control*, Taylor & Francis (2007)

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Course Code	MINOR781R
Course Title	Project in Robotics I
Number of Credits	4 (L: 1; T: 0; P: 6)
Course Category	Minor Degree

Course Objective:

To assimilate the theoretical knowledge gained in the lecture courses (ROB-1 to 4) for real-life practical applications in order have effective learning and skill-development, mainly, from the point of view of the employability in industries.

Course Contents:

This course is a project type. The plan of conducting this course is given below:

1. Participants will be divided into teams of two/four members within first week of the starting of the course by the course coordinators/managers depending on the number of participants registered in the course. The benefits of such team-based projects are listed in the Course Outcomes below.

2. The teams will have a team coordinator or leader, which will be identified by the coordinators/managers of the course (may be the first name in the list of a student team).

3. The projects could be of the following types:

    a. Literature search (LS) type: Studying about an aspect of robotics, say, vision, robot kinematics, dynamic, controls, etc.

b. Algorithm development (AD) type: Analyse, say, a robot kinematics using RoboAnalyzer or Matlab/Octave/Freemat/Scilab or similar software or write an algorithm using any programming language (Python, etc.). For example, writing forward kinematics of a robot or image processing in Vision.

c. Design/synthesis (DS) type: Proposing a new type of system/device for performing certain task. For example, a mobile robot for Covid-19 isolation wards.

4. The teams will be asked to contact their team members within a week and decide their topic with two weeks, i.e., within first 3 weeks of the starting of the course.

5. Students MUST spend about 6 hours in a week to discuss their progress together, study together or individually, write programmes, fabricate circuits, etc.

6. During the one lecture hour the coordinators will explain how to do literature survey, how to find the sources of hardware, which software to use for a particular purpose,
   how to select an electric motor, etc., present case studies, etc.

7. At the end of the course duration, each team will submit no more than 10 slides in .pdf file and/or not more than a video of one min to showcase their project hardware/software/plots, etc. generated during the project to a cloud (say, Google Drive).

8. Evaluation: It will be done in two parts
   a. Peer Evaluations (20%): Presentations in .pdf will be evaluated (online) by two other teams and grade them out of 10 marks.
   b. Expert evaluation (80%): Coordinators will take a presentation of 3 mins. plus, Q&A in a common online session to give marks out of 80.

Text Books/References:

Since it is a project type, some experience sharing books and links to similar activities are

listed.

1. Chuhan, M., and Saha, S.K., 2010, Robotics Competition Knowledge Based Eduation in Engineering, Pothi.com
2. Baun, M., and Chaffe, J., 2018, Engineering and Building Robots for Competitions, Amazon.com

Corresponding Online Resources:

1. http://www.ddrobocon.in/
2. http://courses.csail.mit.edu/iap/6.095/

Course Outcomes:

The outcomes are envisaged as follows:

1. Each participant will know students from other colleges/states and their work ethics/culture.
2. To Practice how to work together in a team. An essential skill in an industry.
3. To apply the theoretical knowledge learnt from other courses, which is required by an industry.
4. To learn how to make presentation in a team. A soft skill needed in research and industry.
5. Peer learning from the evaluation of other teams' work. A skill which is essential when one is in a workforce.
6. To examine different hardware components and their working/control using software.