Scheme and Syllabus for

M.Tech. in

Robotics and Automation

Scheme/Structure for
M.Tech. in Robotics and Automation

Semester I						
S. No.	Course Code	Course Name	Category	I	P	C
1		Scientific Computing	PEC	2	2	3
2		Robotic Engineering	PEC	3	3	5
3		Basic Control system for robots	PEC	3	3	5
4		Fluid Power System for Automation	PEC	3	3	5
5		Elective-I	PEC	3	0	3
6		Seminar	PCD	0	3	2
Total				14	14	23
Semester II						
S. No.	Course Code	Course Name	Category	I	P	C
1		Industrial IoT and Cloud Computing	PEC	3	3	5
2		Autonomous Navigation and Path Planning	PEC	3	3	5
3		Deep learning for Computer Vision	PEC	3	3	5
4		Elective-II	PEC	3	0	3
5		Elective-III	PEC	3	0	3
6		Comprehensive Viva-Voce	PCD	2	0	2
Total				17	9	23
Semester III						
1		Dissertation Work-I	PCD	0	25	10
2		Skill development Course-I	PEC	3	0	Pass/ Fail
Total				0	25	10
		Semester IV				
1		Dissertation Work-II	PCD	0	25	15
Total				0	25	15

Grand total number of credits for M.Tech = 76

Course Title	Course Code	Structure (I-P-C)		
Scientific Computing		**2**	**2**	**3**

Pre-requisite, if any: Nil.

Course Outcomes: At the end of the course the students will be able to:

CO1	Solve the system of linear equations and eigenvalue problems numerically.
CO2	Solve numerically algebraic/transcendental equations.
CO3	Interpret experimental data using interpolation.
CO4	Apply numerical integration methods to evaluate the definite integral.
CO5	Find the numerical solutions of ODEs and PDEs.

Syllabus:

Numerical Methods in Linear Algebra: Direct and iterative solution techniques for simultaneous linear algebraic equations – Gauss elimination, Gauss-Jordon, LU Decomposition, QR Method, Jacobi and Gauss-Seidel Methods, Eigenvalues and Eigenvectors, Power and inverse power method, physical interpretation of eigenvalues and eigenvectors.

Solution of Algebraic and Transcendental Equations: Solution of nonlinear algebraic equations: Bisection method, fixed-point iteration method, Newton-Raphson, Secant method, solution of system of nonlinear algebraic equations

Interpolation: Polynomial interpolation, Lagrange interpolating polynomial, Hermite interpolation, Cubic Spline interpolation, interpolation in 2 and 3 dimensions.
Numerical Differentiation and Integration: Finite difference formula using Taylor series, Differentiation of Lagrange polynomials, Simpson's rule, Gauss-quadrature rule, Romberg method, multiple integrals.

Numerical Solution of Differential Equations: Ordinary Differential Equations – Euler, Heun's method and Stability criterion, second order and fourth order Runge-Kutta methods, Adams-Bashforth-Moulton method, system of ODEs, Finite difference method for ODE, Partial Differential Equations – Classification of PDEs, Elliptic equations, Parabolic equations (Transient diffusion equation), Hyperbolic equations (wave equation)

Text Book(s) and References:

1. David Kincaid and Ward Cheney, "Numerical Analysis: Mathematics of Scientific Computing'', AMS, 2009.
2. Richard L. Burden and J. Douglas Faires, Numerical Analysis, Cengage Learning India Private Ltd.
3. M. K. Jain, S.R.K. Iyengar and R. K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International Publications, 2008.
4. K. E. Atkinson, "An Introduction to Numerical Analysis", Wiley, 2nd Edition, 1989.
5. S.D. Conte, Carl de Boor, "Elementary Numerical Analysis: An Algorithmic Approach'', SIAM, 2018.

Course Title	Course Code	Structure (I-P-C)		
Robotic Engineering		**3**	**3**	**5**

Pre-requisite, if any: Nil

Course Outcomes: At the end of the course the students will be able to:

CO1	Gain knowledge of basic mechanical designing, electrical wiring, robotic sensors and actuators, PCB design and communication protocols.
CO2	Gain an understanding of the theoretical background necessary to understand advanced robotic technologies and their specific applications.
CO3	Demonstrate proficiency in design, construction, and operation of robotic systems.
CO4	Develop problem-solving skills by applying principles of robotics engineering to real-world problems.
CO5	Communicate effectively about robotics engineering technologies, their workings and potential applications.

Syllabus:

Module 1: Introduction to Robotics

- To introduce students to Robotics Engineering as a discipline and expose them to the multifaceted world of robots.
- Types of robots, Degrees of freedom of robots, Robot configurations and concept of workspace, Overview of robot subsystems, Mechanisms and transmission, End effectors and Different types of grippers, vacuum and other methods of gripping. Pneumatic, hydraulic and electrical actuators, applications of robots, specifications of different industrial robots.

Module 2: Rigid-body motions and twists.

- Rotations and angular velocities
- Homogenous transformation matrices
- Twists

Module 3: Formulation of Forward and Inverse kinematics.

- Forward kinematics in space frame and end-effector frame
- Analytical and numerical inverse kinematics

Module 4: Velocity kinematics and statics.

- Manipulator Jacobian; Relationship between space and body Jacobian
- Statics of open chains; Singularity analysis

Module 5: Dynamics of open chain robot manipulators.

- Lagrangian formulation; Dynamics of single rigid body
- Newton-Euler inverse dynamics
- Dynamic of open chains
- Constrained dynamics; Numerical algorithms for forward and inverse dynamics

Module 6: Robot subsystems:

- Sensors and Actuators; Image Processing and Computer Vision
- Robotic Control Systems

Module 7: Introduction to RoboAnalyzer

- DH Parameters Visualization
- Forward Kinematics; Inverse Kinematics; Forward Dynamics; Inverse Dynamics
- Building Virtual Robot Module

Module 8: Robotics Applications and Project Work and Presentation

- the advanced robotics applications, including automation systems,
- robotic arm design and control, robot-vehicle interaction, and collaborative robots, robotic inspection and safety considerations.
- Objective of Project Work and Presentation: To apply the principles and concepts learned in the course to design a robotic system. Students will have to build and test a fully functional robotic system that meets the specific requirements. Finally, students will present their projects to the class.

Text Book(s) and References:

1. S. K. Saha, "Introduction to Robotics", Tata McGraw Hill Education Pvt. Ltd., New Delhi.
2. R. K. Mittal, I. J. Nagrath, "Robotics and Control", Tata McGraw-Hill Publishing Company Ltd.
3. J. J. Graig, "Introduction to Robotics – Mechanics and Control", 2nd edition, Pearson Education, Inc.
4. K. S. Fu, R. C. Gonzalez, and C. S. G. Lee, "ROBOTICS – Control, Sensing, Vision, and Intelligence", McGraw-Hill Book Company.
5. Saeed Niku, "Introduction to Robotics – Analysis, Control, Applications", John Wiley & Sons.
6. Mohsen Shahinpoor, Harper and Row, "A Robot Engineering Textbook", New York
7. Roboert J. Schilling, "Fundamentals of Robotics – Analysis & Control", Prentice-Hall of India Pvt. Ltd.
8. S. R. Deb and S. Deb, "Robotics Technology and Flexible Automation", Second Edition, Tata McGraw Hill Education Pvt, Ltd., New Delhi

Course Title	Course Code	Structure (I-P-C)		
Digital Control for Automation		**3**	**3**	**5**

Pre-requisite, if any: Nil

Course Outcomes: At the end of the course, the students will be able to:

CO1	Obtain a working mathematical model of a system of robot.
CO2	Do time-domain and frequency-domain analyses of the model to predict the system's behavior of the robot.
CO3	Design control systems for robots that meet design specifications

Syllabus:

Introduction: Motivation, examples of control systems, feedback control systems.

Mathematical modelling: Mathematical modelling of: electrical systems, mechanical systems, electro-mechanical systems. Laplace transforms, transfer functions, electrical analogues of other dynamical systems. State-space modelling of dynamical systems. Block diagrams, block diagram reductions. Signal flow graph, Mason's gain formula. Linearity, time-invariance versus nonlinearity and time-variance. Linearization. Distributed parameter systems.

Time response of dynamical systems: Obtaining solutions from mathematical models. Poles and zeros and their effects on solutions. Step response of standard second order systems, time-domain specifications and their formulae.

Stability: Definition of stability. Routh-Hurwitz test. Lyapunov theory.

Properties of feedback: Basic idea of feedback control systems. Error analysis. P, PI, PD, PID controllers. **Frequency domain analysis:** Bode plot, Nyquist plot, Nyquist stability criterion, gain and phase margins, robustness.

Design of controllers: The root-locus technique, steps in obtaining a root-locus. Design of controllers using root-locus. Pole placement with state feedback, controllability. Pole placement with output feedback, observability, Luenberger observer. LQR control.

List of Text Books and References:

1. Kuo B.C., Automatic Control Systems, Prentice-Hall of India Pvt Ltd., New Delhi, 6th edition, 1991.
2. Franklin G.F., Powell J.D., Emami-Naeini A., Feedback Control of Dynamic Systems,
3. Pearson, Upper Saddle River, New Jersey, 5th edition, 2006.
4. Ogata K., Modern Control Engineering, Prentice-Hall of India Pvt Ltd., New Delhi, 3rd edition, 2000.
5. C. J. Payne, et al., "An Implantable Extracardiac Soft Robotic Device for the Failing Heart: Mechanical Coupling and Synchronization," Soft Robotics, vol. 4, no. 3, pp. 241-250, 2017.

Course Title	Course Code	Structure (I-P-C)		
Fluid Power System for Automation		**3**	**3**	**5**

Pre-requisite, if any: Nil

Course Outcomes: At the end of the course the students will be able to:

CO1	Identify and describe the key components of fluid power systems.
CO2	Explain the underlying scientific principles behind the operation of fluid power systems.
CO3	Demonstrate knowledge of different types of fluid power systems and their applications.
CO4	Design and analyze fluid power systems for automation.
CO5	Develop innovative and practical applications of fluid power systems in automation.

Syllabus:

Module 1: Introduction to Fluid Power Systems
- Definition of fluid power systems; Components of fluid power systems
- Advantages and disadvantages of fluid power systems; Properties of fluids used in fluid power systems
- Basic laws of fluid mechanics and their application in fluid power systems

Module 2: Hydraulic Systems
- Introduction to hydraulic systems; Components of hydraulic systems
- Hydraulic fluids and their properties; Principles of hydraulic press operation
- Applications of hydraulic systems in automation

Module 3: Pneumatic Systems
- Introduction to pneumatic systems; Components of pneumatic systems
- Pneumatic fluids and their properties; Principles of pneumatic press operation
- Applications of pneumatic systems in automation.

Module 4: Design and Analysis of Fluid Power Systems for Automation
- Design considerations for fluid power systems
- Calculation of hydraulic and pneumatic system parameters
- Analysis of fluid power systems
- Troubleshooting methods for fluid power systems.

Module 5: Industrial Automation - Programmable Logic Controller
- Functions of PLCs - Features of PLC - Selection of PLC - Architecture – IEC61131-3 programming standard and types - Basics of PLC Programming – Ladder Logic Diagrams
- Communication in PLC – Programming Timers and Counters – Data Handling - PLC modules – Advanced motion controlled Multi Axis PLC

Module 6: Industrial Robotics through Fluid Power
- Subsystem in the robotics – Architecture
- Communication and Control

Module 7: Innovative and Practical Applications of Fluid Power Systems in Automation
- Case studies of innovative applications of fluid power systems in automation
- Practical applications of fluid power systems in automation

- Applications in the Industry 4.0

Module 8: Group projects on designing and implementing a fluid power system for automation.

Text Book(s) and References:

1. Hydraulic and Pneumatic Power for Production by Harry L.Stewart.
2. Fluid Power with Applications by Anthony Esposito.
3. Fundamentals of Fluid Power Control by John Watton.

Course Title	Course Code	Structure (I-P-C)		
Industrial IoT and Cloud Computing		**3**	**3**	**5**

Pre-requisite, if any: Nil

Course Outcomes: At the end of the course the students will be able to:

CO1	Understand the existing IoT architectures
CO2	Design an IoT system with cloud infrastructure
CO3	Implement a prototype of the IoT/cloud system design
CO4	Understand the existing cloud architectures

Syllabus:
Introduction, Physical design of IoT, Logical design of IoT, IoT enabling technologies, Domain specific IoTs, IoT design methodology, logical design

IoT physical devices (such as Raspberry Pi, pcDuino, Beaglebone black, Cubieboard)
Introduction to cloud computing: cloud models, cloud service examples, cloud based services & applications

Virtualization, load balancing, scalability, deployment, replication, monitoring, SDN, network function virtualization, MapReduce, identity and access management, SLAs.

Cloud service and platforms: Commercial clouds (such as Amazon elastic compute cloud, Google Compute engine, Windows Azure), Storage services, database services, application services, content delivery services, analytics services, Open source private clouds.

Case studies: Industrial automation, Cloud for IoT

Practice:
These Laboratory classes aim at:
1. Understanding the phenomena involved
2. Study of influencing parameters
3. Develop setup, instrumentation, equation, product, etc.
4. Modelling & Simulation of the process
5. Simple project
6. Creation of concept
7. Application to real problem
8. Assignments suggested by the instructor.

Some practice exercises can be mini projects: Using IoT devices small systems like classroom automation, smart parking, environment monitoring can be designed and implemented. Also, hadoop cluster can be set up and studied. Cloud computing with IoT for healthcare and industrial automation can be studied

Text Book(s) and References:

1. A. Bahga and V. Madisetti, Internet of Things, A hands-on approach, CreateSpace Independent Publishing Platform, 1st edition, 2014, ISBN: 978-0996025515.
2. A. Bahga and V. Madisetti, Cloud Computing, A hands-on approach, CreateSpace Independent Publishing Platform, 1st edition, 2013, ISBN: 978-1494435141
3. S. Jeschke, C. Brecher, H. Song, and D. B. Rawat, Industrial Internet of Things: Cybermanufacturing Systems, Springer, 1st edition, 2017, ISBN: 978-3319425580.
4. T. Erl, Z. Mahmood, and R. Puttini, Cloud Computing: Concepts, Technology & Architecture, Prentice Hall, 1st edition, 2013, ISBN: 978-0133387520.

Course Title	Course Code	Structure (I-P-C)		
Autonomous Navigation and Path Planning		**3**	**3**	**5**

Pre-requisite, if any: Nil

Course Outcomes: At the end of the course the students will be able to:

CO1	Students will be able to understand the basic concepts of autonomous navigation and path planning.
CO2	Students will be able to analyze and design autonomous navigation and path planning algorithms.
CO3	Students will be able to evaluate the effectiveness of different autonomous navigation and path planning algorithms in different situations.
CO4	Students will be able to implement these algorithms in real-world applications.

Module 1: Introduction to Autonomous Navigation and Path Planning
- Definition and basic concepts of autonomous navigation and path planning
- Applications of autonomous navigation and path planning
- Sensors and odometry

Module 2: Introduction to various techniques and algorithms used for navigation and path planning
- State estimation methods (Kalman filter, unscented Kalman filter, particle filtering),
- Camera modelling and calibration, structure from motion, visual motion estimation

Module 3: Navigation Techniques and Algorithms
- Sensor-based navigation
- Dead reckoning
- Beacon-based navigation
- Landmark-based navigation

Module 4: Obstacle Avoidance Techniques
- Potential field method
- Virtual force field method
- Artificial potential fields method

Module 5: Optimal Path Planning Techniques and Trajectory Planning
- Dijkstra's algorithm
- A* algorithm
- Probabilistic road map method
- Trajectory planning for Mobile Robots and Unmanned Aircraft System (UAS)

Module 6: Case Studies and Examples
- Introduction to Robot Operating System (ROS), ROS2, and GAZEBO
- Real-world case studies and examples of autonomous navigation and path planning
- Analysis and evaluation of different techniques and algorithms used in different situations
- Performing at least two experiments each with ROS and GAZEBO

Module 7: Implementation of Autonomous Navigation and Path Planning Algorithms
- Implementation of various algorithms in real-world applications
- Hands-on exercises and projects to develop an autonomous navigation and path planning system

Module 8: A project to implement an autonomous navigation and path planning system to be evaluated in the final week

Text Book(s) and References:

1. Steven M. LaValle, Planning Algorithms Hardcover – Illustrated, 29 May 2006
2. J.-P. Laumond, Robot Motion Planning and Control, 1998
3. Roland Siegwart, Illah Reza Nourbakhsh, Davide Scaramuzza, Introduction to Autonomous Mobile Robots", Bradford Company Scituate, USA, 2004.
4. J. J. Graig, "Introduction to Robotics – Mechanics and Control", 2nd edition, Pearson Education, Inc.
5. K. S. Fu, R. C. Gonzalez, and C. S. G. Lee, "ROBOTICS – Control, Sensing, Vision, and Intelligence", McGraw-Hill Book Company.
6. Mohsen Shahinpoor, Harper and Row, "A Robot Engineering Textbook", New York.

Course Title	Course Code	Structure (I-P-C)		
Deep learning for Computer Vision		3	3	5

Pre-requisite, if any: Nil

Course Outcomes: At the end of the course the students will be able to:

CO1	Gain knowledge of basics of Deep Learning.
CO2	Gain an understanding of the theoretical background necessary to work with Computer Vision
CO3	Demonstrate proficiency in design and suggesting architecture for computer vision problems with Deep Learning
CO4	Develop problem-solving skills by applying principles of deep learning and computer vision to real-world problems.
CO5	Communicate effectively about deep learning and computer vision, their workings and potential applications.

Syllabus:

Module 1: Course introduction
- Introduction to neuron, Introduction to neural networks,
- Introduction to deep learning,
- Introduction to Image Formation, Capture and Representation; Linear Filtering, Correlation, Convolution

Module 2: Simple Neural Networks
- Multilayer perceptron (MLP),
- Gradient descent, Backpropagation in MLP,
- Hands-on implementation of simple MLP

Module 3: Visual Features and Representations:
- Edge, Line detection, Corner Detection; Blobs, Feature Detection, Scale Space and Scale Selection; SIFT, SURF; HoG, LBP, etc. Blob detection, SIFT, Feature descriptors, SURF

Module 4: Convolutional Neural Networks (CNNs):
- Introduction to CNNs;
- Evolution of CNN Architectures: AlexNet, ZFNet, VGG, InceptionNets, ResNets, DenseNets, U-nets etc.
- Simple implementation of CNN

Module 5: Visualization and Understanding CNNs and Applications:
- Visualization of Kernels; Backprop-to-image/Deconvolution Methods;
- CNNs for Recognition and Verification (Siamese Networks, Triplet Loss, Contrastive Loss, Ranking Loss);
- CNNs for Detection: Background of Object Detection, R-CNN, Fast R-CNN, Faster R-CNN, YOLO, SSD, RetinaNet;
- CNNs for Segmentation: FCN, SegNet, U-Net, Mask-RCNN

Module 6: Recurrent Neural Networks (RNNs):

- Review of RNNs; CNN + RNN Models for Video Understanding: Spatiotemporal Models, Action/Activity Recognition
- Automated Visual Inspection with one Industrial Application

Module 7: Advanced Methods in Deep Learning for Vision:
- Introduction to Attention Models in Vision; Vision and Language: Image Captioning, Visual QA, Visual Dialog; Spatial Transformers; Transformer Networks
- Deep Generative Models: Review of (Popular) Deep Generative Models: GANs, VAEs; Other Generative Models: PixelRNNs, NADE, Normalizing Flows, etc
- Variants and Applications of Generative Models in Vision
- Zero-shot, One-shot, Few-shot Learning; Self-supervised Learning; Reinforcement Learning in Vision; Other Recent Topics and Applications

Module 8: Mini Project based application in the Industrial environment

Text Book(s) and References:

1. Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning, 2016
2. Michael Nielsen, Neural Networks and Deep Learning, 2016
3. Yoshua Bengio, Learning Deep Architectures for AI, 2009
4. Richard Szeliski, Computer Vision: Algorithms and Applications, 2010.
5. Simon Prince, Computer Vision: Models, Learning, and Inference, 2012.
6. David Forsyth, Jean Ponce, Computer Vision: A Modern Approach, 2002.
7. David Marr, Vision, 1982.
8. Richard Hartley, Andrew Mitchell, Tom. Machine Learning. New York, NY: McGraw-Hill, 1997. ISBN: 9780070428072.
9. Bishop, Christopher. Neural Networks for Pattern Recognition. New York, NY: Oxford University Press, 1995. ISBN: 9780198538646.
10. Bishop, Christopher M. Pattern Recognition and Machine Learning. Springer, 2006. ISBN 978-0-387-31073-2
11. Duda, Richard, Peter Hart, and David Stork. Pattern Classification. 2nd ed. New York, NY: Wiley-Interscience, 2000. ISBN: 9780471056690.
12. Zisserman, Multiple View Geometry in Computer Vision, 2004.

Course Title	Course Code	Structure (I-P-C)		
Comprehensive Viva-Voce		**2**	**0**	**2**

Pre-requisite, if any: Nil

Course Outcomes: At the end of the course the students will be able to:

CO1	Students will be able to demonstrate a thorough understanding of the subjects in the course.
CO2	Students will be able to think critically and solve problems related to the subjects in the course.
CO3	Students will be able to communicate their ideas clearly and effectively.

Syllabus:

I. Introduction

- Comprehensive Viva-Voce would be conducted towards end of the second semester on the subjects that were taught to the students. Each one would be asked to identify their topic of interest to present to the panel; however, the Question-Answer session would be on the subjects that were covered along with individual elective subject(s).

II. Presentation (15- 30 minutes)

- Each student will give a brief presentation on a topic covered in the course.
- The presentation will be followed by questions from the panel.

III. Question-Answer Session (15-30 minutes)

- The panel will ask questions to each student, related to the subjects in the course.
- The questions will be designed to assess the students' understanding, critical thinking, and problem-solving skills.

IV. Feedback and Evaluation (5-10 minutes)

- The panel will provide feedback to each student on their performance in the comprehensive viva-voce.
- The panel will evaluate each student's performance based on their understanding of the subjects in the course, critical thinking, problem-solving skills, and communication abilities.

V. Conclusion (5 minutes)

- Summarize the purpose and importance of the comprehensive viva-voce.
- Thank the students for their participation.

Assessment Method:

- Each student will be assessed based on their understanding of the course material, critical thinking, problem-solving skills, and communication abilities.
- The panel will provide feedback to each student on their performance in the comprehensive viva-voce.
- The results of the comprehensive viva-voce will be recorded and will contribute to the overall grade for the course.