MTech Robotics and Automation

Curriculum and Syllabus

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AMRITA VISHWA VIDYAPEETHAM

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Preface

Robotics, the branch of technology that deals with the design, construction, operation, and application of robots, has become a highly relevant and upcoming discipline. It is being increasingly applied to almost every field of activity including improving the standard of living of humans, handling dangerous and hazardous situations, relieving mankind of repetitive and tiring activities, exploring outer space and performing complex medical procedures. Many industries also use robots in their manufacturing facilities and research. For instance, robots are used in areas like high heat welding and continuous handling of heavy loads. They can function tirelessly even in the most inhospitable working conditions. Owing to this, robots are taking over from man most of the manipulative, hazardous and tedious jobs in factories, mines, atomic plants, spaceships, deep-sea vessels, etc. The automation of work through robotics has led to substantial increase in productivity in these areas.

Given its diverse applications, the robotics field today demands in-depth knowledge of a broad range of disciplines such as electronics, computers, instrumentation and mechanics. A graduate entering the workforce in the area of robotics must be thoroughly familiar with intelligent systems and proficient in computer vision, control systems, and machine learning, as well as the design and programming of robotic systems. Specialization in automation also requires the student to apply a wide range of engineering principles in order to understand, modify or control the manufacture, delivery and maintenance of technology components in a broad range of industries. Graduates must know how to develop and maintain systems that cost-effectively optimize productivity and quality control.

The Amrita Vishwa Vidyapeetham Robotics and Automation MTech Program is unique in that it provides an academic curriculum that pulls from Mechanical Engineering, Electrical and Electronics Engineering, Instrumentation Engineering and Computer Science disciplines, exposing the students to the breadth of and interdependence among the engineering disciplines and offering the students exactly what is required to master the technical knowledge required.

This MTech program will provide a comprehensive educational environment and enable students to gain expertise in next generation robotics and automation systems. By exposing our students to do course work from multiple disciplines and preparing them to think about robotics from a holistic approach, our program will prepare a skilled industry workforce as well as expert researchers who will be able to provide leadership in a world that is increasingly dependent on technology.

Program Educational Objectives of the MTech (Robotics and Automation)

PEO1: This program provides an academic curriculum that pulls from Mechanical Engineering, Electronics and Instrumentation engineering and Computer Science disciplines, exposing the students to the breadth of and interdependence among the engineering disciplines and offering the students exactly what is required to master the technical knowledge required.

PEO2: This programme provides a comprehensive educational environment and enables students to gain expertise in next generation robotics and automation systems.

PEO3: Expose students to course work from multiple disciplines and prepare them to think about robotics from a holistic approach and prepare a skilled industry workforce as well as expert researchers who will be able to provide leadership in a world that is increasingly dependent on technology.

Program Outcomes (POs)

PO1: An ability to independently carry out research /investigation and development work to solve practical problems.

PO2: An ability to write and present a substantial technical report/document.

PO3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.

CURRICULUM

Semester 1

Sl. No.	Course Code	Course Type#	Course Title	Credits			
				L	T	P	Total
1	21MA617	FC	Mathematics for Robotics and Automation	3	0	2	4
2	21RA601	FC	Control Systems	3	0	2	4
3	21RA602	SC	Kinematics and Dynamics of Robots	3	0	2	4
4	21RA603	SC	Digital Image Processing	3	0	2	4
5	21RA604	SC	Machine Learning	3	0	2	4
6	21HU601	HU	Amrita Values Program*	P/F			
7	21HU602	HU	Career Competency I*	P/F			
			Total Credits	**20**			

* Non-credit Course

Semester 2

Sl. No.	Course Code	Course Type	Course Title	Credits			
				L	T	P	Total
1	21RA611	SC	Mechatronic Devices and Systems	3	0	2	4
2	21RA612	SC	Industrial Automation	3	0	2	4
3	21RA613	SC	Autonomous Robot Systems	3	0	2	4
4		E	Elective I	3	0	2	4
5		E	Elective II	3	0	2	4
6	21RM621	SC	Research Methodology	2	0	0	2
7	21HU603	HU	Career Competency II*	P/F			
			Total Credits	**22**			

* Non-credit Course

Semester 3

Sl. No.	Course Code	Course Type	Course Title	Credits			
				L	T	P	Total
1	21RA798	P	Dissertation - Stage I				12

FC – Foundation Core, SC – Subject Core, E – Elective, HU – Humanities, P - Project

Semester 4

Sl. No.	Course Code	Course Type	Course Title	Credits			
				L	T	P	Total
1	21RA799	P	Dissertation - Stage II				14

Total Credits for MTech Program: 68

Electives I and II

Sl. No.	Course Code	Course Type	Course Title	Credits			
				L	T	P	Total
Industrial Focus							
1	21RA701	E	CNC Machines	3	0	2	4
2	21RA702	E	Process Control and Instrumentation	3	0	2	4
3	21RA703	E	Advanced Process Control	3	0	2	4
4	21RA704	E	FPGA based System Design	3	0	2	4
5	21RA705	E	Embedded System Design	3	0	2	4
6	21RA706	E	Embedded Real Time Systems	3	0	2	4
7	21RA707	E	Data Driven Methods for Robotic Systems	3	0	2	4
8	21RA708	E	Essentials for Mechatronic Prototyping	3	0	2	4
Research Focus							
9	21RA711	E	Probability and Statistics (Open Elective)	3	0	2	4
10	21RA712	E	Humanoid Robotics	3	0	2	4
11	21RA713	E	Swarm Intelligence	3	0	2	4
12	21RA714	E	Behavioural Robotics	3	0	2	4
13	21RA715	E	Frontiers of Biomechatronics	3	0	2	4
14	21RA716	E	Optimization Theory	3	0	2	4
15	21RA717	E	Haptic Interfaces	3	0	2	4
16	21RA718	E	Innovating in Technology	3	0	2	4
17	21RA719	E	Measuring User Interface Quality	3	0	2	4
18	21RA720	E	Design for People: Principles and Practices of Human Centered Design	3	0	2	4
19	21RA721	E	Mechanisms for Robot Systems	3	0	2	4
20	21RA722	E	Quadruped Robots	3	0	2	4
Software Focus							
21	21RA731	E	Design and Analysis of Algorithms	3	0	2	4
22	21RA732	E	Advanced Perception for Robotics and AI	3	0	2	4
23	21RA733	E	Computational Intelligence	3	0	2	4
24	21RA734	E	Machine Vision	3	0	2	4
25	21RA735	E	Advanced AI for Robotics	3	0	2	4
26	21RA736	E	Virtual Reality and Applications	3	0	2	4
27	21RA737	E	Non-Linear Control Theory	3	0	2	4
28	21RA738	E	Experimental Haptics	3	0	2	4
29	21RA739	E	Unmanned Aerial Vehicles	3	0	2	4

SYLLABUS

21MA617 MATHEMATICS FOR ROBOTICS AND AUTOMATION 3-0-2-4

Unit-1 (Linear Algebra)
Vector algebra, Matrices, Addition, multiplication, transpose, cofactors, determinant, trace and inverse of matrices (Revision), Linear dependence/independence of vectors, Rank of matrices, System of linear equations, Solution of system of linear equations, Vector spaces, Subspaces, Generating set, Basis, Dimension of vector spaces, Linear mapping, Transformation matrix, Basis change, Image and Kernel of linear mapping, Affine spaces, Norm of a vector space, Dot product, Quadratic form, symmetric positive definite matrices, Length, angle and orthogonality, Orthonormal basis, Inner product of functions, Orthogonal projections, Gram Schmidt orthogonalization, Eigen values and vectors, Matrix decomposition: Cholesky decomposition, Eigen decomposition, Singular value decomposition, Matrix approximation. Computer programming exercises in matrix and vector manipulations, Eigen value & SV Decompositions, Gauss elimination for the solution of system of equations.

Unit-2 (Vector calculus)
Univariate, Multivariate and vector functions, Motion of a particle in space, Differentiation and Taylor's series expansion of univariate functions, Partial differentiation, chain rule, Gradient of vector function(Jacobian), Gradient of a vectors with respect to a matrix, Gradient of matrices with respect to a matrix, Identities for computing gradients, Back propagation and automatic differentiation, Gradients in deep neural networks, Higher order partial derivatives, Hessian, Taylor's series expansion of multivariate functions, Quadratic forms, Unconstrained optimization problems, Method of steepest descends, Conjugate gradient Method. Vector calculus for physical field problems, Directional derivative and direction of maximum derivative, divergence and curl of vector fields, rotational and irrotational vector fields, Conservative vector fields, Vector integral calculus, line, surface and volume integrals, Stokes theorem, Green's theorem and Gauss divergence theorem, applications of vector calculus theorems to field problems, Algebra of Cartesian Tensors, Index notation, Isotropic tensors, Invariants of a tensor, Computer programming exercises based on these topics.

Unit-3
Random experiment, Sample space, Event space, Probability, Probability space, Discrete and continuous probabilities, PMF, CDF, PDF, sum and product rules, Conditional probability, Bayes theorem, Mean, Variance, Covariance , Correlation, Empirical means and covariances, Statistical independence, Conditional independence, Inner products, Gaussian distribution, Marginal and conditional of Gaussian, Product of Gaussian distributions, Sums and linear transformations, Conjugacy and exponential family, Binomial, Poisson and Beta distributions, Change of variables, Computer programming exercises based on these topics.

Differential equations: Types, Computer numerical solution for: Euler method, Runge-Kutta Method, Adam Bashforth method, Explicit and implicit methods, Fourier spectral method.

TEXTBOOKS/REFERENCES:

[1] Marc Peter Deisenroth, A. Aldo Faisal, Cheng Soon Ong, “Mathematics for Machine Learning”, Cambridge University Press, 2020.
[2] Ervin Kreyszig, “Advanced Engineering Mathematics”, 10th edition, Wiley, 2015.
[3] Gilbert Strang, “Linear algebra and its applications”, 5th edition, Cengage Learning, 2018.
[4] Richard A Johnson, “Miller and Freund's - Probability and Statistics for Engineers”, 7th Edition, Pearson, 2008.
[5] George F Simmons, “Differential equations with applications and Historical notes”, Tata McGraw Hill, 3rd edition, Taylor & Francis, 2016.
[6] Kevin Murphy, “Machine leaning: A probabilistic perspective”, MIT Press, 2012.

Course Outcomes

CO1: Capability to solve problems in linear algebra.
CO2: Capability to do differentiation for solving optimization problems.
CO3: Capability to solve problems in probability and develop probabilistic models.
CO4: Capability to solve problems using computers.

21RA601 CONTROL SYSTEMS 3-0-2-4

Mathematical Modeling of physical systems- Transfer function-stability with reference to 's' plane, transient and steady state analysis, steady state errors, Performance Indices. controllers- P, PI and PID modes of feedback control.
Analysis of control systems in state space -State space model of a system, state transition matrix, state space representation in canonical forms, solution of homogeneous state equations, controllability and observability.
Design of control systems in state space- Design by pole placement, State Feedback gain using Ackerman's formula. State Observers- Full order observer, reduced order observer, Design of control system with observers.
(Laboratory session on the topic Using MATLAB)

Digital control system: Sampled data systems, sampling, quantization, data reconstruction and filtering of sampled signals. Z transfer function, mapping from s plane to z plane.

Z transform analysis of closed loop and open loop systems, Stability analysis of closed loop systems in the z plane: stability tests. State space analysis of sampled data systems- Controllability, observability, control law design, decoupling by state variable feedback, Estimator/Observer design: full order observers, reduced order observers.
(Laboratory session on the topic Using MATLAB)

Nonlinear systems: Introduction - characteristics of nonlinear systems. Types of nonlinearities. Analysis through Linearisation about an operating point. Stability Analysis- Definition of stability- asymptotic stability and instability - Liapunov methods to stability of linear and nonlinear systems Introduction to robot control, Control schemes used for a robotic manipulator-Joint motion control, Resolved motion control, and Adaptive control schemes.

(Laboratory session on the topic Using MATLAB)

TEXTBOOKS/REFERENCES:

[1] Norman Nise, “Control System Engineering”, John Wiley & Sons, Inc., Sixth Edition, 2011.
[2] Dorf R. C. and Bishop R. H, “Modern control systems”, 12th Edition, Prentice Hall
[3] Katsuhiko Ogata, “Modern Control Engineering”, fifth edition, Prentice Hall of India Pvt. Ltd., New Delhi, 2015.
[4] Benjamin C. Kuo, “Automatic Control Systems”, Prentice Hall India Ltd, Sixth Edition, 2000.
[5] Loan Dore Landau, Gianluca Zito, “Digital Control Systems: Design, Identification and Implementation”, Springer, 2006.
[6] K. Ogata, “Discrete-Time Control Systems”, Pearson Education, 2011.
[7] M. Sami Fadali, Antonio Visioli, “Digital Control Engineering: Analysis and Design”, Elsevier, 2013.
[8] M. Gopal, “Digital Control and State Variable Methods”, Tata McGraw-Hill, 2006.
[9] M. Vidyasagar, "Nonlinear systems analysis", Second Edition, Prentice Hall, 1993.
[10] Dawson, D. M., Abdallah, C. T., Lewis, F. L. "Robot Manipulator Control: Theory and Practice". Ukraine: CRC Press, 2003.
[11] K.S. Fu, R.C. Gonzalez, C.S.G. Lee "Robotics: control, sensing, vision and intelligence", Tata McGraw-Hill, 2008.

Course Outcomes

CO1: Model control systems in the continuous domain using classical control approach.
CO2: Analyze control systems using state space models.
CO3: Design state feedback controllers and state observers for continuous time and discrete time Systems.
CO4: Understand the nonlinear systems characteristics and analyze the stability of nonlinear Systems.
CO5 Understand the control schemes used for robotic manipulators.
CO6: Use software tools for the analysis and design of control systems.

21RA602 KINEMATICS AND DYNAMICS OF ROBOTS 3-0-2-4

Robot types, trends, applications, classification - Anatomy and Architecture of Manipulators – Mobile Robots – Advanced Robots - Holonomic and Non-holonomic Robots - Transformations – Quaternions - Robot Kinematics: Forward and Inverse - Manipulator Jacobian - Force relations – Multi-body Dynamics: Forward and Inverse – Lagrange-Euler Dynamic Model – Recursive Newton-Euler Formulation - Trajectory planning in Joint space and Cartesian space – Matlab/RoboAnalyzer Simulations of Kinematic and Dynamic models.

TEXTBOOKS/REFERENCES:

[1] S K Saha, “Introduction to Robotics”, 2nd edition, McGraw Hill Education (India) Pvt. Ltd., 2014.
[2] Robert J Schilling, “Fundamentals of Robotics, Analysis and Control”, Prentice Hall, 2007.

[3] Reza N Jazar, “Theory of Applied Robotics: Kinematics, Dynamics and Control”, 2nd Ed. Springer, 2010.
[4] Peter Corke, "Robotics, Vision, and Control: Fundamental Algorithms in MATLAB", Springer, 2013.
[5] John J Craig, “Introduction to Robotics: Mechanics and Control”, Pearson, 2018.
[6] K S Fu, et al, “Robotics: Control, Sensing, Vision and Intelligence”, Tata McGraw Hill, 2008.
[7] Springer Handbook of Robotics, B Siciliano, O Khatib, editors, 2nd Ed., Springer, 2016.

Course Outcomes

CO1: Understand various robot classifications, specifications and applications.
CO2: Apply coordinate transformations to map position and orientation coordinates from end effector to robot base.
CO3: Apply forward and inverse kinematics to manipulate objects by robots.
CO4: Analyze forward and inverse kinematics to manipulate objects by robots.
CO5: Analyze forward and inverse dynamics to manipulate objects by robots.
CO6: Construct simulations in RoboAnalyzer/Matlab to verify kinematics and dynamics of robots.

21RA603 DIGITAL IMAGE PROCESSING 3-0-2-4

Two-Dimensional Signals and Systems: Two-dimensional convolution, 2D Discrete-Space Fourier Transform, Inverse 2-D Fourier Transform, Fourier Transform of 2-D or Spatial Convolution, Symmetry properties of Fourier Transform, Continuous-Space Fourier Transform. Sampling in two dimensions: Sampling theorem, Change in Sample rate, Down sampling, Ideal decimation, Up sampling, Ideal interpolation. Continuous Image characterization: Psychophysical vision properties, Photometry, Colorimetry. Fundamentals of Digital Image Processing: Image acquisition - Various modalities, Image sampling and quantization, mathematical representation, Image reconstruction based on interpolation. Gray level transformation, Histogram processing, Arithmetic and logic operations. Transform and filtering: Intensity transformation and spatial filtering, filtering in frequency domain, Image restoration and reconstruction, Binary image morphology. Smoothing and sharpening filters, Line detection, Edge detection, Zero crossings of the second derivative. DFT, smoothing in frequency domain filtering, Sharpening in frequency domain filtering. Degradation model, noise models, restoration in spatial domain, restoration in frequency domain. Estimation of degradation function, inverse filtering, Wiener filtering, constrained least square filtering. Color Image Processing: Color Models, the RGB Color Model, the CMY and CMYK Color Models, the HSI Color Model, Pseudo color image processing, Basics of Full Color Image Processing, Smoothing and Sharpening, Image Segmentation Based on Color. Image Segmentation-Point, Line, and Edge Detection, Thresholding-Types Boundary based and Region-Based Segmentation. Representation of Boundary Descriptors, Regional Descriptors-Texture descriptors. Matlab applications.

TEXTBOOKS/REFERENCES:

[1] John W Woods, "Multidimensional Signal, Image and Video Processing and Coding", Academic Press, 2006.
[2] Rafael C. Gonzalez and Richard E. Woods, “Digital Image Processing”, Third Edition, Pearson Education, 2009.
[3] William K. Pratt, “Digital Image Processing”, John Wiley, New York, 2007.
[4] Kenneth R. Castleman, "Digital Image Processing", Prentice Hall, 1996.
[5] Gonzalez, Woods and Eddins, "Digital Image Processing using MATLAB", Prentice Hall, 2004.

Course Outcomes

CO1: Understand 2D signals and systems.
CO2: Apply sampling in two dimensions.
CO3: Apply fundamentals of digital image processing.
CO4: Analyze transforms and filtering.
CO5: Analyze color image processing.
CO6: Construct simulations in Matlab to study digital image processing.

21RA604 MACHINE LEARNING 3-0-2-4

Introduction-ML Types- Supervised, Unsupervised, Reinforced and semi-supervised learning, Examples of ML problems, Hypothesis space and inductive bias, Evaluation and cross validation, Linear regression, Decision tree, Entropy of information, Information gain, Computer tutorials.
Underfitting and overfitting, Method for reducing overfitting, Regularization, KNN, Curse of dimensionality, Feature selection, Feature extraction, PCA, Bayesian learning, Naive Bayes, Logistic regression, Support Vector Machine (SVM), Nonlinear SVM and Kernel Function, Computer tutorials. Computational Learning theory, Finite hypothesis space, VC dimension, Introduction to ensembles, Bagging and Boosting, Introduction to clustering, K-means clustering, Agglomerative Hierarchical Clustering, Computer tutorials.

TEXTBOOKS/REFERENCES:

[1] Trevor Hastie, Robert Tibshirani and Jerome Friedman, “The Elements of Statistical Learning, 2nd edition, Springer, 2009.
[2] Tom M. Mitchell, “Machine Learning”, McGraw Hill Education, 2017.
[3] Marc Peter Deisenroth, A. Aldo Faisal, Cheng Soon Ong, “Mathematics for Machine Learning”, Cambridge University Press, 2020.
[4] Stuart J. Russel and Peter Norvig, “Artificial intelligence: A modern approach”, Pearson Education Inc, 2009.

Course Outcomes

CO1: Understand issues and challenges of machine learning: data, model selection, model complexity.

CO2: Design and implement various machine learning algorithms in a range of real-world applications.
CO3: Understand strengths and weaknesses of many popular machine learning approaches.
CO4: Analyze the underlying mathematical relationships within and across Machine Learning algorithms.
CO5: Apply the paradigms of supervised and un-supervised learning.

21RA611 MECHATRONIC DEVICES AND SYSTEMS 3 0 2 4

Sensors: General Concept of Measurement: Basic block diagram, stages of generalised measurement system, state characteristics; accuracy, precision, resolution, repeatability, reproducibility, sensitivity, zero drift, linearity, Dynamic characteristics, zero order instrument, first order instrument, time delay, Sensors and Principles: Resistive sensors, Potentiometer and strain gauges Inductive sensors: Self-inductance type, mutual inductance type, LVDT Capacitive sensors- piezoelectric sensors, thermocouples, thermistors radiation pyrometry - Fibre optic temperature sensor photo electric sensors, pressure and flow sensors, vision sensors.
Signal conditioning: Amplification, Filtering, Level conversion, Linearisation, Buffering, sample and hold circuit quantisation multiplexer/ demultiplexer, analog to digital converters, digital to analog converters. Data acquisition and conversion: General configuration single channel and multichannel data acquisition system. Digital Filtering, data logging, data conversion, introduction to digital transmission systems, PC-based data acquisition system. Interface systems and standards.
Microcontroller fundamentals: ARM ASM programming and basics of C; IO Interfacing: LED and Switch; Design and Development Process: Architecture, Micro architecture, Design, Implementation, Verification and Validation; Development Tools: Block Diagrams, Flow Charts, Call Graphs, Dataflow Graphs, Finite State Machines; The Parallel Interface: GPIO; The Serial Interface: UART; PLL programming; Timer: SysTick; Fixed Point; Software: Structs, Stacks and Recursion; IO Synchronization; Interrupts; DAC: Music Synthesis and Music Playback; ADC: Real world interfacing and Data Acquisition. Labs include prototypes of actual embedded systems using Arduino, Raspberry Pi 4 and others.

TEXTBOOKS/REFERENCES:

[1] Doeblin E.O., “Measurement Systems”, McGraw Hill, 1995.
[2] Jonathan Valvano, “Embedded Systems: Introduction to ARM® Cortex™-M Microcontrollers”, Fourth Edition, Create Space Publishing, 2013.
[3] Michael Margolis, “Arduino Cookbook”, O'Reilly Media, 2014.
[4] Massimo Banzi and Michael Shiloh, “Getting Started with Arduino”, Third Edition, 2014.
[5] Edward A. Lee, and Sanjit A. Seshia, “Introduction to Embedded Systems- A Cyber Physical Systems Approach”, Second Edition, 2015.

Course Outcomes

CO1: Understand general concept of measurement in sensors.
CO2: Apply principles of sensors.

CO3: Apply fundamentals of signal conditioning.
CO4: Analyze data acquisition and conversion.
CO5: Analyze microcontroller programming.
CO6: Construct embedded systems using Arduino, Raspberry Pi.

21RA612 INDUSTRIAL AUTOMATION 3-0-2-4

Introduction to Industrial Automation with case studies. Introduction to Industry 4.0.

Introduction to PLC based controls - Architecture of PLC, PLC networking, programming, and wiring, HMI and SCADA design for PLC, Simulations of Factory Automation.

Introduction to Pneumatic and Hydraulic Systems - Systems components, Symbols, System design and simulation using Automation Studio.

Introduction to Electric motors - Motor controls: VFD and Servo drives, Matlab Simulations.

TEXTBOOKS/REFERENCES:

[1] Anthony Esposito, "Fluid Power with Applications", 7th ed., Pearson Publishers.
[2] Kothari, Dwarkadas Pralhaddas, and I. J. Nagrath, “Electric machines”, Tata McGraw-Hill Education, 2004.
[3] Frank D. Petruzella, "Programming Logic Controllers", McGraw Hill Book Company
[4] Product Manuals: AB PLC 1400 Series A, AB Panel View HMI, AB VFD, AB Servo Drive.
[5] Vedam Subrahmaniam, “Electric Drives (Concepts and Applications)”, Tata McGraw-Hill, 2001.
[6] Nagrath I.J. and Kothari D.P., “Electrical Machines”, Tata McGraw-Hill, 1998.
[7] Pillai S.K. “A First Course on Electric Drives”, Wiley Eastern Limited, 1998.
[8] Groover M. P., "Industrial Robotics, Technology, Programming and Application", McGraw Hill Book and Co., 2012.
[9] Siemens "PLC Handbook".
[10] Ries and Ries, "Programming Logic Controllers", PHI.
[11] Werner Deppert and Kurt Stoll, “Pneumatic Control”, VOGEL Buchverlag Wurzburg, Germany.
[12] Majumdar S.R., “Pneumatic Systems Principles and Maintenance”, Tata McGraw Hill, New Delhi.
[13] Peter Croser and Frank Ebel, "Pneumatics Basic Level TP 101" Festo Didactic GMBH & Co, Germany.
[14] Hasebrink J.P. and Kobler R., “Fundamentals of Pneumatic Control Engineering”, Festo Didactic GMBH & Co, Germany.
[15] Merkle D., Schrader B. and Thomes M., "Hydraulics Basic Level TP 501" Festo Didactic GMBH & Co, Germany.
[16] Peter Rohner, “Industrial Hydraulic Control” John Wiley and Sons, Brisbane.

Course Outcomes

CO1: Understand various components of Industrial automation.
CO2: Understand PLC architecture.
CO3: Apply PLC networking and programming.
CO4: Analyze pneumatic and hydraulic circuits.
CO5: Analyze motor controls-VFD and servo drives.
CO6: Construct simulations in Automation Studio and real pneumatic and hydraulic circuits.

21RA613 AUTONOMOUS ROBOT SYSTEMS 3-0-2-4

Introduction, Types of Mobile Robots – Legged Robots, Gait Analysis, Wheeled Robots, Kinematic models for Mobile Robots, Maneuverability, Dynamic Path Planning, Scenario based control, path planning and sensor fusion, Workspace & Motion control, Sensors & Actuators for Mobile Robots, Sizing and Torque Calculations, Design and implementation of estimation algorithms for state estimation, Localization, Map-representation and Map building, Map-based localization scheme, Planning and Navigation: Dijkstra's algorithm, A* algorithm, Potential field method, Wandering standpoint algorithm, DistBug algorithm, etc. Application of Dijkstra's algorithm, A* algorithm in Floor Cleaning Robot.

Introduction to ROS - ROS Basic Concepts: Nodes, topics, parameters, services - Simple ROS programs to publish and subscribe messages. Simulation of typical robot system in ROS: Manipulators, wheeled robots in scenarios such as in a maze etc., legged robots and UAVs in various environments. Simulation of Husky Mobile Platform using ROS - Online Control of Husky in a structured environment.

TEXTBOOKS/REFERENCES:

[1] R. Siegwart and Illah R. Nourbakhsh, “Introduction to Autonomous Mobile Robots”, MIT Press, 2004.
[2] Thomas Braunl, “Embedded Robotics”, Second Edition, Springer, 2006.
[3] Siciliano and Khatib, “Handbook of Robotics”, Springer, 2008.
[4] Witold Jacak, “Intelligent Robotic Systems: Design Planning and Control”, Kluwer Academic Publishers, 1999.
[5] ROS Wiki.
[6] Jason M. O’Kane, "A Gentle Introduction to ROS" ISBN 978-14-92143-23-9.

Course Outcomes

CO1: Understand various types of mobile robots and their kinematic models.
CO2: Apply maneuverability, workspace and motion controls of mobile robots.
CO3: Analyze various algorithms for SLAM.
CO4: Understand basic concepts of ROS.
CO5: Analyze simple programs and simulate robots in ROS.
CO6: Construct simulations of Husky mobile platform using ROS.

21RA701 CNC MACHINES 3-0-2-4

Introduction: NC Machines, CNC Machines, CNC Machine Components, Co-ordinate System, Working Principle of Various CNC Systems, Direct Numerical Control, Adaptive Control, Constructional Features of CNC Machines: Introduction-Machine Structure-Guideways-Ball Screws-Accessories of Machining Centre-Spindle Drives and Feed Drives-Control System of NC Machine Tools, CNC Part Programming: Part Programming Fundamentals- G and M Codes-Interpolation Systems-Methods of CNC Part Programming-APT Language-Motion Commands-CNC Part Programming Using CAD/CAM-Computer Automated Part Programming, Tooling and Work Holding Devices: Cutting Tool Material-Preset and Qualified Tools-ISO Specification of Tools-Chip Breakers-Principle of Location-Clamping-Work Holding Devices. Economics and Maintenance: Introduction-Factors Influencing Selection of CNC Machines-Cost of Operation of CNC Machines-Practical Aspect of Introducing a CNC-Maintenance of CNC Machines-Preventive Maintenance Programs.

TEXTBOOKS/REFERENCES:

[1] M. Adithan, B.S. Pable, “CNC Machines”, New Age; Third edition, 2018.
[2] P. M. Agrawal, V. J. Patel, “CNC Fundamentals and Programming”, V. J. Patel Edition: 2nd Edition: 2017.
[3] Peter Smid, “CNC Programming Handbook: A Comprehensive Guide to Practical CNC Programming”, Industrial Press Inc., U.S.; 2nd edition, 2000.
[4] P. N. Rao – “CAD/CAM, Principles and Applications” - Tata McGraw Hill Publishers – 2004.
[5] Mikell P. Groover and Emory W. Zimmers – “CAD/CAM” - PHI Publishers - 2002.
[6] Thomas Crandell, “CNC Machining and Programming: An Introduction”, Industrial Press, Inc., 2nd edition, 2003.

Course Outcomes

CO1: Understand various components of NC and CNC machines and their working principles.
CO2: Understand constructional features of CNC machines.
CO3: Apply part programming in CNC machines.
CO4: Analyze simulation for CNC turning operations.
CO5: Analyze simulation for CNC milling operations.
CO6: Analyze economics and maintenance of CNC machines.

21RA702 PROCESS CONTROL AND INSTRUMENTATION 3-0-2-4

Process Modeling: Hierarchies. Theoretical models: transfer function, state space models, and time series models. Development of empirical models from process data- chemical reactor modeling. Feedback & feed forward control, cascade control, selective control loops, ratio control, feed forward and ratio control. Multi-loop and multivariable control: process interactions, singular value analysis. PID design, tuning, trouble shooting, tuning of multiloop PID control systems. Decoupling control: strategies for reducing control loop interactions. Instrumentation for process monitoring: codes and standards, preparation of P&I diagrams. Model predictive control. Statistical process control, supervisory control, direct digital control, distributed control, PC based automation. Programmable logic controllers: organization, programming aspects, ladder programming, final control elements. SCADA in process automation. Case studies.

TEXTBOOKS/ REFERENCES:

[1] Dale E. Seborg, Duncan A. Mellichamp, Thomas F. Edgar and Francis J. Doyle “Process Dynamics and Control”, John Wiley and Sons, 2010.
[2] Ernest O. Doebelin, “Measurement Systems Application and Design”, McGraw Hill International Editions, 2006.
[3] Johnson D Curtis, “Process Control Instrumentation Technology”, Prentice Hall India, 2013.
[4] Bob Connel, “Process Instrumentation Applications Manual”, McGraw Hill, 1996.

Course Outcomes

CO1: Understand Process Modelling hierarchies, theoretical and empirical models.
CO2: Apply Feedback & feed forward control, cascade control, selective control loops, ratio control, feed forward and ratio control, Multi-loop and multivariable control.
CO3: Apply: PID design, tuning, trouble shooting, tuning of multiloop PID control systems.
CO4: Analyze Decoupling control, Instrumentation for process monitoring and preparation of P&I diagrams.
CO5: Analyze Statistical process control, supervisory control, direct digital control, distributed control, PC based automation.
CO6: Analyze Programmable logic controllers and SCADA in process automation.

21RA703 ADVANCED PROCESS CONTROL 3-0-2-4

Introduction: Review of basics of Process Control, Control objective and benefits, Control system elements. Mathematical modeling and dynamic performance analysis process for control: Basic Concepts in modeling, models from fundamental laws, empirical model identification, dynamic performance analysis of first order, second order, multi-capacity processes, Effect of Zeros and time delay. Multivariable Process control: Cascade control, Ratio control, feedback-feed forward control, override control, selective control, modeling of multivariable process, Design of Multivariable controllers. Model Based control: Feedback-feed forward, delay compensation, Internal Model controller (IMC): Concept, IMC design Procedure. MPC: General Principles, Model forms, DMC, SISO unconstrained DMC Problem, controller tuning. Statistical Process Control (SPC): Concept, Design procedure. Mini project: Design of Fuzzy-Logic based controller, Design of Neural Network based controller.

TEXTBOOKS/REFERENCES:

[1] Thomas E. Marlin, "Process Control", McGraw-Hill International Edition.
[2] Jose A. Romagnoli and Ahmet Palazoglu, "Introduction to Process Control", CRC Taylor and Francis Group.
[3] Statistical Process Control –ISA.

[4] B.G. Liptak, "Handbook of Instrumentation - Process Control".
[5] Les A. Kane, “Handbook of Advanced Process Control Systems and Instrumentation” Springer.

Course Outcomes

CO1: Understand Process Modelling hierarchies, theoretical and empirical models.
CO2: Apply Feedback & feed forward control, cascade control, selective control loops, ratio control, feed forward and ratio control, Multi-loop and multivariable control.
CO3: Apply: PID design, tuning, trouble shooting, tuning of multiloop PID control systems.
CO4: Analyze Decoupling control, Instrumentation for process monitoring and preparation of P&I diagrams.
CO5: Analyze Statistical process control, supervisory control, direct digital control, distributed control.
CO6: Design of Fuzzy-Logic based controller, Design of Neural Network based controller.

21RA704 FPGA BASED SYSTEM DESIGN 3-0-2-4

Introduction to ASICs, CMOS logic and ASIC library design: Types of ASICs - Design Flow CMOS transistors, CMOS design rules - Combinational Logic Cell - Sequential logic cell – Data path logic cell - transistors as resistors - transistor parasitic capacitance - Logical effort - Library cell design - Library architecture. Programmable logic cells and I/O cells: Digital clock Managers- Clock management- Regional clocks- Block RAM – Distributed RAM-Configurable Logic Blocks-LUT based structures – Phase locked loops- Select I/O resources –Anti fuse - static RAM - EPROM and EEPROM technology. Device Architecture: Spartan 6 -Vertex 4 architecture- Altera Cyclone and Quartus architectures. Design Entry and Testing: Verilog and VHDL - logic synthesis - Types of simulation –Faults- Fault simulation - Boundary scan test Automatic test pattern generation. Built-in self-test. – scan test. Floor Planning, Placement and Routing: System partition - FPGA partitioning - partitioning methods - floor planning placement - physical design flow - global routing - detailed routing - special routing - circuit extraction - DRC.

TEXTBOOKS/REFERENCES:

[1] M.J.S. Smith, "Application Specific Integrated Circuits", Addison Wesley Longman Inc., 1997.
[2] Wolf Wayne, "FPGA Based System Design", Pearson Education.
[3] Design Manuals of Altera, Xilinx and Actel.

Course Outcomes

CO1: Understand ASICs, CMOS logic and ASIC library design.
CO2: Apply Combinational Logic Cell - Sequential logic cell – Data path logic cell.
CO3: Apply Logical effort, Library cell design, Library architecture, Programmable logic cells and I/O cells.
CO4: Analyze Block RAM – Distributed RAM-Configurable Logic Blocks-LUT based

structures.

CO5: Analyze Design Entry and Testing.

CO6: Analyze Floor Planning, Placement and Routing.

21RA705 EMBEDDED SYSTEMS DESIGN 3-0-2-4

Microcontroller fundamentals: ARM ASM programming and basic of C; IO Interfacing: LED and Switch; Design and Development Process: Architecture, Micro architecture, Design, Implementation, Verification and Validation; Development Tools: Block Diagrams, Flow Charts, Call Graphs, Dataflow Graphs, Finite State Machines; The Parallel Interface: GPIO; The Serial Interface: UART; PLL programming; Timer: SysTick; Fixed Point; Software: Structs, Stacks and Recursion; Device Driver: Interfacing with an Hitachi HD44780 display; IO Synchronization; Interrupts; DAC: Music Synthesis and Music Playback; ADC: Real world interfacing and Data Acquisition. Labs include prototypes of actual embedded systems, e.g., Traffic Light Controller (FSM), LCD Device Driver (Hitachi HD44780), Digital Piano (DAC, Interrupts), Digital Vernier Caliper (ADC, Interrupts, LCD), Distributed Data Acquisition (Interrupts, ADC, LCD, UART) accomplished using Arduino based system. Basics of system booting and Boot Loaders. Concurrency, Timeouts, Inter Process Communication. Capstone Design Project, A popular video game, e.g., Space Invaders, Connect-4, Pipe Dream, etc.

TEXTBOOKS/REFERENCES:

[1] Jonathan Valvano, “Embedded Systems: Introduction to ARM® Cortex™-M Microcontrollers”, Fourth Edition, Create Space Publishing, 2013.

[2] Michael Margolis, “Arduino Cookbook”, O'Reilly Media, 2014

[3] Massimo Banzi and Michael Shiloh,“Getting Started With Arduino”,Third Edition, 2014.

[4] Edward A. Lee, and Sanjit A. Seshia, “Introduction to Embedded Systems- A CyberPhysical Systems Approach”,Second Edition, 2015.

[5] Jeff C. Jensen, Edward A. Lee, and Sanjit A. Seshia, “An Introductory Lab in Embedded and Cyber-Physical Systems”, First Edition, 2015.

Course Outcomes

CO1: Understand Microcontroller fundamentals: ARM ASM programming and basic of C, IO Interfacing: LED and Switch.

CO2: Apply Design and Development Process: Architecture, Micro architecture.

CO3: Apply Development Tools: Block Diagrams, Flow Charts, Call Graphs, Dataflow Graphs, Finite State Machines.

CO4: Apply Software: Structs, Stacks and Recursion.

CO5: Analyze prototypes of actual embedded systems.

CO6: Analyze Concurrency, Timeouts, Inter Process Communication.

21RA706 EMBEDDED REAL TIME SYSTEMS 3-0-2-4

This course looks at components, interfaces and methodologies for building systems. Specific topics include microcontrollers, design, verification, hardware/software synchronization, interfacing devices to the computer, timing diagrams, real-time operating systems, data collection and processing, motor control, analog filters, digital filters, and realtime signal processing. Topics include Computer Architecture review, Design of I/O Interfaces, Software Design, Real Time Operating Systems, Multitasking (preemptive scheduling, resource sharing and priority determination), Digital Signal Processing, HighSpeed Interfacing, File system management, Interfacing Robotic Components, High-Speed Networks, Robotic Systems.

TEXTBOOKS/REFERENCES:

[1] Jonathan Valvano, “Embedded Systems: Real-Time Operating Systems for Arm Cortex M Microcontrollers”, CreateSpace Publishing, 2012.
[2] Joseph Yiu, "The Definitive Guide to ARM® Cortex®-M3 and Cortex®-M4 Processors", Third Edition, Newnes, 2013.
[3] Martin, "The Designer's Guide to the Cortex-M Processor Family: A Tutorial Approach", First Edition, Newnes, 2009.

Course Outcomes

CO1: Understand Microcontroller fundamentals: ARM ASM programming and basic of C, IO Interfacing: LED and Switch.
CO2: Apply Design and Development Process: Architecture, Micro architecture.
CO3: Apply Development Tools: Block Diagrams, Flow Charts, Call Graphs, Dataflow Graphs, Finite State Machines.
CO4: Apply Software: Structs, Stacks and Recursion.
CO5: Analyze prototypes of actual embedded systems.
CO6: Analyze Digital Signal Processing, HighSpeed Interfacing, File system management, Interfacing Robotic Components, High-Speed Networks, Robotic Systems.

21RA707 DATA-DRIVEN METHODS FOR ROBOTIC SYSTEMS 3-0-2-4

Linear Systems: Direct Solution Methods, Iterative Solution Methods, Gradient (Steepest) Descent, Eigenvalues, Eigenvectors and Solvability, Nonlinear Systems, Curve fitting: Least-Square Fitting Methods, Polynomial Fits and Splines. Singular Value Decomposition: Basics, Principal Component Analysis (PCA), Diagonalization, Proper orthogonal Modes, Dynamic mode decomposition (DMD), Dynamics of DMD versus POD. Balanced Models for Control: Model Reduction and System Identification, Balanced Model Reduction, System identification. Data-Driven Control: Nonlinear System Identification for Control, Machine Learning Control, Adaptive Extremum-Seeking Control. Applications of POD and DMD for Robotic systems.

TEXTBOOKS/REFERENCES:

[1] Kutz, J. N., Brunton, S., Brunton, B., and Proctor, J., Data driven Modeling and Scientific

Computation: Method for Complex Systems and Big Data. Oxford University Press, 2013.
[2] Kutz, J. N., Brunton, S., Data driven Science and Engineering: Machine Learning, Dynamical Systems and Control. Cambridge University Press, 2019.
[3] Holmes, P., Lumley, J. L., Berkooz, G., and Rowley, C. W., Turbulence, Coherent Structures, Dynamical Systems and Symmetry. Cambridge University Press, 2012.
[4] Kutz, J. N., Brunton, S., Brunton, B., and Proctor, J., Dynamic Mode Decomposition: DataDriven Modeling of Complex Systems. SIAM, 2016.
[5] Anton, H., and Rorres, C., Elementary Linear Algebra. John Wiley & Sons Inc. 2005.

Course Outcomes

CO1: Understand Linear Systems: Direct Solution Methods, Iterative Solution Methods.
CO2: Apply Eigenvalues, Eigenvectors and Solvability.
CO3: Apply Curve fitting: Least Square Fitting Methods, Polynomial Fits and Splines.
CO4: Apply Singular Value Decomposition.
CO5: Analyze Balanced Models for Control.
CO6: Analyze Data Driven Control.

21RA708 ESSENTIALS FOR MECHATRONIC PROTOTYPING 3-0-2-4

Introduction to computer aided engineering softwares – overview and operation of 3D modelling features and tools - parametric modelling – generative design – modelling and visualization of structural analysis parameters through FEA software – multibody dynamics simulation and evaluation - additive manufacturing guidelines and design limitations for 3D printing - microcontroller functionality & usage.

TEXTBOOKS/REFERENCES:

[1] Brown, N. J., & Brown, O. T. (2002), “Mechatronics-a graduate perspective.” Mechatronics, 12(2), 159–167.
[2] Butala, P., Vrabic, R., Skulj, G., & Oosthuizen, G. A., “Robotics competitions as motivator for project-oriented learning in mechatronics”, 2013 6th Robotics and Mechatronics Conference (RobMech).
[3] 3D Hubs. 2021. The 3D Printing Handbook by 3D Hubs | 3D Hubs. [online] Available at: [Accessed 2 May 2021].
[4] Mscsoftware.com, 2021, Adams Tutorial Kit for Mechanical Engineering Courses. [online] Available at: [Accessed 2 May 2021].
[5] Help.autodesk.com. 2021. Fusion 360. [online] Available at: [Accessed 2 May 2021].

Course Outcomes

CO1: Understand computer aided engineering softwares.
CO2: Apply overview and operation of 3D modelling features and tools - parametric modelling.
CO3: Apply generative design.

CO4: Apply modelling and visualization of structural analysis parameters through FEA software.
CO5: Analyze multibody dynamics simulation and evaluation.
CO6: Analyze additive manufacturing guidelines and design limitations for 3D printing.

21RA711 PROBABILITY AND STATISTICS 3-0-2-4

Probability: Introduction to data analysis and statistics, Algebra of sets, Counting, Axioms of probability, Conditional probability, Law of Total Probability and Bayes' rule, Independence of events, Random variables; Types of data, Descriptive statistics (measures of central tendency and variation), Graphical representation of data, Distribution functions, Expectation, variance, and moments of discrete & continuous random variables, Functions of random variables, Discrete Uniform, Bernoulli, Binomial, Poisson, and Geometric distributions, Continuous Uniform, Normal, and Exponential random variables; Measurement errors - accuracy and precision; Framing hypothesis statements (practical statement vs. statistical statement), Concept of statistical hypothesis tests; Type I Error, Type II Error, and p-value, Point estimation vs. interval estimation, Test of single mean, Test of comparison of two means (independent and paired t-tests), Test of single variance, Test of comparison of two variances, Test of comparison of more than two means (ANOVA), Test of independence of two discrete random variables (Chi-square), Correlation and covariance, Concept of Linear Regression. Estimation Theory, Bayes and Kalman filter. Introduction to SPSS/Minitab/Matlab for data Analysis.

TEXTBOOKS/REFERENCES:

[1] K.M. Ramachandran and Chris P. Tsokos, "Mathematical Statistics with Applications".
[2] Douglas C. Montgomery and George C.Runger, "Applied Statistics and Probability for Engineers", 3rd Edition, John Wiley, 2008.

Course Outcomes

CO1: Understand data analysis and statistics, Algebra of sets, Counting, Axioms of probability.
CO2: Apply Conditional probability, Law of Total Probability and Bayes' rule.
CO3: Apply Descriptive statistics.
CO4: Apply Discrete Uniform, Bernoulli, Binomial, Poisson, and Geometric distributions.
CO5: Analyze Concept of statistical hypothesis tests; Type I Error, Type II Error, and p-value.
CO6: Analyze Test of comparison of more than two means (ANOVA).

21RA712 HUMANOID ROBOTICS 3-0-2-4

The course aims at giving the students a basic understanding of the theory of humanoid robots, i.e. bipedal walking robots with an approximately humanlike shape, and a practical knowledge concerning humanoid robots, through a robot construction project. The contents of the course include Theory of humanoid robots, kinematics and dynamics. Methods for gait generation, central pattern generators. Applications of humanoid robots. Humanoid robots in society - current and future applications, comparison with other types of robots. Hardware construction, including the use of microcontrollers and servo motors in connection with humanoid robots.

TEXTBOOKS/REFERENCES:

[1] Goswami Ambarish, Vadakkepat Prahlad, "Humanoid Robotics: A Reference", Springer, 2019.
[2] Shuuji Kajita et. al., “Introduction to Humanoid Robotics”, Springer, 2014.
[3] John J Craig, "Introduction to Robotics: Mechanics and Control", Third Edition, 2003.
[4] Lorenzo Sciavicco and Bruno Siciliano, "Modelling and Control of Robot Manipulators".
[5] Jean-Claude Latombe, "Robot Motion Planning", Springer Science, 1991.

Course Outcomes

CO1: Understand various types of humanoid robots.
CO2: Apply kinematics of humanoid robots.
CO3: Apply ZMP and ground reaction forces of humanoid robots.
CO4: Apply dynamics of humanoid robots.
CO5: Analyze biped walking of humanoid robots.
CO6: Analyze various walking pattern generations of humanoid robots.

21RA713 SWARM INTELLIGENCE 3-0-2-4

Introduction to swarm intelligence and key principles (e.g., self-organization), natural and artificial examples, computational and real-time SI. Foraging, trail laying/following mechanisms. Open-space, multi-source foraging experiments: biological data and microscopic models. From real to virtual ants: Ant System (AS). Application to a classical operational research problem: The Travel Salesman Problem (TSP). From AS to Ant Colony Optimization (ACO). Ant-based algorithms (ABC, Ant-Net) applied to routing in telecommunication networks. Introduction to unsupervised multi-agent machine-learning techniques for automatic design and optimization: terminology and classification, Genetic Algorithms (GA) and Particle Swarm optimization (PSO). Application of machine-learning techniques to automatic design and optimization in single-robot and multi-robot experiments. Collective movements in natural societies; focus on flocking phenomena. Collective movements in artificial systems: Reynolds' virtual agents and experiments with multi-robot systems (flocking, formation). Multi-level modelling of self-organized robotic systems: microscopic and macroscopic models; Markov formalism; linear and nonlinear micro-to-macro mapping, model analysis. Combined modelling and machine-learning methods for off-line system design and optimization. Diversity and specialization metrics. Division of labour and task-allocation mechanisms, threshold-based algorithms, marketbased algorithm. Aggregation, segregation, and collective decisions, social insects, sensor networks, and multi-robot systems, clustering data and distributed structure building in natural and artificial systems.

TEXTBOOKS/REFERENCES:

[1] E. Bonabeau, M. Dorigo and G. Theraulaz, “Swarm Intelligence: From Natural to Artificial Systems", Santa Fe Studies in the Sciences of Complexity, Oxford University Press, 1999.
[2] Camazine, Deneubourg, Franks, Sneyd, Theraulaz and Bonabeau, "Self-organisation in Biological Systems", Princeton University Press, 2002.
[3] Mitchel Resnick, "Turtles, Termites, and Traffic Jams", MIT Press, 1997.
[4] Stuart A. Kauffman, "The Origins of Order: Self-Organization and Selection in Evolution", Oxford University Press, 1993.

Course Outcomes

CO1: Understand swarm intelligence and key principles (e.g., self-organization), natural and artificial examples.
CO2: Apply open space, multi-source foraging experiments: biological data and microscopic models.
CO3: Apply to a classical operational research problem: The Travel Salesman Problem (TSP).
CO4: Apply Ant-based algorithms (ABC, Ant-Net) to routing in telecommunication networks.
CO5: Analyze unsupervised multi-agent machine-learning techniques for automatic design and optimization.
CO6: Analyze machine-learning techniques to automatic design and optimization in single-robot and multi-robot experiments.

21RA714 BEHAVIOURAL ROBOTICS 3-0-2-4

This course is designed to investigate and study methods and models in embodied cognitive science and artificial intelligence, with particular focus on behaviour-based techniques on robots. All models and architectures will be theoretically scrutinized and evaluated with respect to their conceptual clarity, support by empirical data, plausibility, etc. without neglecting issues of practicality such as feasibility of implementation, real-time/real-world issues, computational resources, etc. Topics include introduction to embodied cognitive science and behaviour-based robotics, reactive behaviour-based architectures, perception, deliberative systems, hybrid systems, sub-umption architecture.

TEXTBOOKS/REFERENCES:

[1] Arkin, C. Ronald, “Behaviour-Based Robotics”, MIT Press, Cambridge: MA, 1998.
[2] Pfeiffer R. and Scheier Ch., "Understanding Intelligence", MIT Press, Cambridge: MA, 1999.
[3] Murphy, R., "Introduction to AI Robotics." Second Edition, MIT Press, Cambridge: MA, 2002.
[4] Bekey, G., "Autonomous Robots: From Biological Inspiration to Implementation and Control (Intelligent Robotics and Autonomous Agents)". MIT Press, Cambridge: MA, 2005.
[5] Rodney A Brooks, “Cambrian Intelligence, The Early History of the New AI”, MIT Press, Cambridge: MA, 1999.

Course Outcomes

CO1: Understand methods and models in embodied cognitive science and artificial intelligence.
CO2: Apply behaviour-based techniques on robots.
CO3: Analyze models and architectures with respect to their conceptual clarity, supported by empirical data.
CO4: Apply embodied cognitive science.
CO5: Analyze reactive behaviour-based architectures.
CO6: Analyze sub-umption architecture.

21RA715 FRONTIERS OF BIOMECHATRONICS 3-0-2-4

Topics consist of rehabilitation engineering, artificial tissue and organs, implantable neural prosthesis, orthopaedic implants and implanted devices, biology-machine interface, minimally invasive surgical instruments, surgical robot, introduces its basic principle, key technology and its development and application. They include introduction to Biomechatronic Systems, design and manufacturing of Bio-mechatronic products, musculoskeletal mechanics, review of multi-body dynamics, principles of motor control and sensorimotor integration, simulation of human movement, human locomotion and gait studies, motor control in patients with neurological disorders, artificial tissue and organ, orthopaedic implants, Biology-Machine Interface, implantable neural prosthesis, minimally invasive surgical instruments, surgical robot.

TEXTBOOKS/REFERENCES:

[1] Myer Kutz (Editor), "Biomedical Engineering and Design Handbook", Volume 1: Fundamentals, Second Edition, McGraw-Hill Companies, 2009.
[2] Mark J. Schulz, Vesselin N. Shanov andYeoheung Yun, "Nanomedicine Design of Particles, Sensors, Motors, Implants, Robots, and Devices", Artech House, 2009.
[3] Graham M. Brooker, "Introduction to Biomechatronic: The Application of Mechatronic Engineering to Human Biology", SciTech Publishing, 2012.

Course Outcomes

CO1: Understand topics that consist of rehabilitation engineering, artificial tissue and organs.
CO2: Apply its basic principle, key technology and its development and application.
CO3: Analyze design of Bio-mechatronic products.
CO4: Apply manufacturing of Bio-mechatronic products.
CO5: Analyze review of multi-body dynamics, principles of motor control and sensorimotor integration.
CO6: Analyze simulation of human movement, human locomotion and gait studies.

21RA716 OPTIMIZATION THEORY 3-0-2-4

Topics covered will include linear programming, nonlinear programming, calculus of variations and dynamic programming. Introduction to optimization, linear programming, simplex technique, Duality and Sensitivity, Unconstrained Nonlinear Programming, Constrained Nonlinear Programming, Numerical methods, Duality and Applications. Basics of the Calculus of Variations, theory of the Calculus of Variations, Applications of the Calculus of Variations, Dynamic Programming, Applications, Evolutionary Multi-objective Optimization (MOO).

TEXTBOOKS/REFERENCES:

[1] D. A. Pierre, "Optimization Theory with Applications", Dover, 1986.
[2] R. Fletcher, "Practical Methods of Optimization", Second Edition, John-Wiley and Sons, 1987.
[3] D. G. Luenberger, "Linear and Nonlinear Programming", Second Edition, AddisonWesley, 1989.
[4] J. Nocedal and S.J. Wright, "Numerical Optimization". Springer, 2000.

Course Outcomes

CO1: Understand topics of linear programming.
CO2: Understand topics of non-linear programming.
CO3: Analyze simplex technique, Duality and Sensitivity.
CO4: Apply Constrained Nonlinear Programming.
CO5: Apply Unconstrained Nonlinear Programming.
CO6: Analyze Evolutionary Multi-Objective Optimization (MOO).

21RA717 HAPTIC INTERFACES 3-0-2-4

Introduction to haptics, Kinesthetic haptic devices: Kinematics and dynamics, rendering, control, dynamic simulations, sensors and actuators. Tactile haptic devices: Types and applications. Tele-operation: Implementation, Transparency and Stability. Surface Haptics. Human haptics: Mechanoreceptors, Kinesthesia.

TEXTBOOKS/REFERENCES:

[1] Kern, Thorsten A. Engineering haptic devices: a beginner's guide for engineers. Springer Science & Business Media, 2009.
[2] Lin, Ming C., et al. Haptic rendering: Foundations, algorithms and applications. AK Peters, Ltd., 2008.

Course Outcomes

CO1: Understand topics of haptics.
CO2: Understand topics of Kinesthetic haptic devices: kinematics and dynamics.
CO3: Analyze rendering and control.

CO4: Apply dynamic simulations, sensors and actuators.
CO5: Apply Tele-operation: Implementation, Transparency and Stability.
CO6: Analyze Human haptics: Mechanoreceptors, Kinesthesia.

21RA718 INNOVATING IN TECHNOLOGY 3-0-2-4

The need for innovation. Core innovation lenses: attitudes, activities, conversations, rhythm and examples. Business, Technology and Experience goals. Working with Technology and Business constraints. Assessing one's Innovation Readiness. Innovation Truths and Innovation Myths. Cross-discipline research. Targeting Social Impact. Women Innovators in Technology. Innovation games. Asking skillful questions, Business Viability. Lateral thinking. Cultivating Curiosity. Effective brainstorming. Expanding and Contracting phases. Refining existing ideas. Innovation in methodologies and techniques. How to have collaborative conversations. Design and User Experience led innovation. Innovation & Enterprise – User desirability, technical specifications and business viability. Sketching vs. Prototyping. Working with end users. Project Management and organizational agility to support innovation. Developing an "Innovation Studio".

TEXTBOOKS/REFERENCES:

[1] Berkun, Scott. The myths of innovation. O'Reilly Media, Inc., 2010.
[2] Sawyer, Keith. Zig zag: The surprising path to greater creativity. John Wiley & Sons, 2013.

Course Outcomes

CO1: Understand Core innovation lenses: attitudes, activities, conversations, rhythm and examples.
CO2: Understand Working with Technology and Business constraints.
CO3: Analyze Assessing one's Innovation Readiness. Innovation Truths and Innovation Myths.
CO4: Apply Cross-discipline research and Targeting Social Impact.
CO5: Apply Effective brainstorming. Expanding and Contracting phases.
CO6: Analyze Sketching vs. Prototyping and Working with end users.

21RA719 MEASURING USER INTERFACE QUALITY 3-0-2-4

How to conduct a usability study. What to measure: Identifying top tasks, Common metrics, Task completion metrics, Performance metrics, Qualitative and quantitative metrics, Biometrics. When to measure: Before development, During development, Prelaunch, Post Launch, Common problems and solutions to effective timing. How to measure: overview of approaches, usability labs, automated measurement, remote testing, field testing. With Who to measure: understanding user samples, identifying valid participants, techniques for finding participants. Taking Action: communicating findings, presenting usability issues, strategies for resolution.

TEXTBOOKS/REFERENCES

[1] Albert, W., Tullis, T. Measuring the User Experience: Collecting, Analyzing, Presenting Usability Metrics. Morgan Kaufman: 2013.
[2] Krug, S. Don't Make Me Think. New Riders: 2005.
[3] Norman, D. The Design of Everyday Things. Basic Books: 2013.
[4] Gothelf, J. Lean UX: Applying Lean Principles to Improve User Experience. O'Reilly Media: 2013.

Course Outcomes

CO1: Understand how to conduct a usability study.
CO2: Understand identifying top tasks, Common metrics, Task completion metrics, Performance metrics, Qualitative and quantitative metrics, Biometrics.
CO3: Analyze when to measure: Before development, During development, Pre launch, Post Launch.
CO4: Apply overview of approaches, usability labs, automated measurement, remote testing, field testing.
CO5: Apply user samples, identifying valid participants, techniques for finding participants.
CO6: Analyze Taking Action: communicating findings, presenting usability issues, strategies for resolution.

21RA720 DESIGN FOR PEOPLE: PRINCIPLES AND PRACTISES OF HUMAN CENTERED DESIGN 3-0-2-4

Introduction to Usability: History, Classic Examples, Core Principles Representing Users: Goal and task analysis, Personas, User scenarios, Agile user stories and epics. Methods of Data Gathering and Analysis: Lean UX, Ethnographic observation, Interviews, Surveys, User studies, Usability labs, Eye tracking, Biometric measurement, Qualitative and quantitative data methods. Creating Personas: Collecting data sources, Initial drafting, Assessing with stakeholders, Final crafting and prioritization. Working with Personas: Scenario definition with personas, Functionality prioritization with personas, Quality Assurance with personas. User-centred design processes: User participation, Iteration, Identifying expand/collapse phases. Collaboration with Engineering: Managing the tech-centred and human-centred design processes together.

TEXTBOOKS/REFERENCES:

[1] Norman, D. The Design of Everyday Things. Basic Books: 2013.
[2] Gothelf, J. Lean UX: Applying Lean Principles to Improve User Experience. O'Reilly Media: 2013.

Course Outcomes

CO1: Understand Usability: History, Classic Examples, Core Principles.
CO2: Understand Methods of Data Gathering and Analysis.
CO3: Analyze Collecting data sources, Initial drafting, Assessing with stakeholders, Final crafting and prioritization.

CO4: Apply Working with Personas.
CO5: Apply User participation, Iteration, Identifying expand/collapse phases.
CO6: Analyze Collaboration with Engineering: Managing the tech-centred and human-centred design processes together.

21RA721 MECHANISMS FOR ROBOT SYSTEMS 3-0-2-4

Generalities of robot mechanics - overview of trajectory generation and planning in robot systems - motion curve definition and coefficients - analysis on effect of coefficient parameters (velocity/acceleration/ jerk) - motion curve design limitations and optimization modalities.
Kinematic pairs & trajectory generation mechanisms - motion generation through higher kinematic pairs and cam typology – criteria for cam design and follower selection - motion generation through lower kinematic pairs and design classification of linkage mechanisms – four bar mechanisms - quick return mechanisms. Actuators in the industry: electric/hydraulic/pneumatic actuators - emerging technologies for actuation: piezoelectric, magnetostrictive, thermal SMA, electroactive polymers, pneumatic muscles, magnetorheological elastomers, electrochemical actuators – motion transformation – linear transmission – rotational transmission (conventional reducers, cycloidal drives, strain wave drives) - flexible transmission (bowden cables, twisted string actuation). Challenges of designing robot mechanisms – technological constraints in actuators, speed reducers, structures – relative performance of robot mechanisms as compared to biomechanical systems.

TEXTBOOKS/REFERENCES:

[1] Angeles, J., “Fundamentals of Robotic Mechanical Systems”, Springer International Publishing, 2014
[2] Mark R. Miller; Rex Miller, “Robots and Robotics: Principles, Systems, and Industrial Applications”, McGraw-Hill Education, 2017, ISBN: 9781259859786.
[3] Alexander Verl, Alin Albu-Schäffer, Oliver Brock, Annika Raatz, 2016, “Soft Robotics: Transferring Theory to Applications”, Springer, Berlin, Germany.
[4] Siciliano, B., Sciavicco, L., Villani, L., & Oriolo, G., “Robotics”, Springer London, 2009.
[5] N. Bachschmid, S. Bruni, A. Collina, B. Pizzigoni, F. Resta and A. Zasso, “Fondamenti Di Meccanica Teorica Ed Applicata”, Publisher: Mc Graw Hill, 2015, ISBN: 9788838668869.
[6] Carlisle, B. (2000). Robot mechanisms. Proceedings 2000 ICRA. Millennium Conference. IEEE International Conference on Robotics and Automation. Symposia Proceedings (Cat. No.00CH37065).

Course Outcomes

CO1: Understand Generalities of robot mechanics.
CO2: Understand Kinematic pairs & trajectory generation mechanisms.
CO3: Analyze Actuators in the industry: electric/hydraulic/pneumatic actuators.
CO4: Apply piezoelectric, magnetostrictive, thermal SMA, electroactive polymers, pneumatic

muscles.

CO5: Apply linear transmission – rotational transmission (conventional reducers, cycloidal drives, strain wave drives).

CO6: Analyze technological constraints in actuators, speed reducers, structures.

21RA722 QUADRUPED ROBOTS 3-0-2-4

Walking Robots – Introduction, Stability in Walking Robots, Generation of Periodic Gaits, Gait Generation, Continuous Gaits, Discontinuous Gaits, Two-phase Discontinuous Gaits, Four-Phase Discontinuous Gaits, Two-phase Discontinuous Crab Gaits, Strategy for Discontinuous Walking, Discontinuous Turning Gaits, Circling Gaits, Spinning Gaits, Path Tracking with Discontinuous, Generation of Non-periodic Gaits, Free-crab Gait, Free Turning Gaits, Free Spinning Gaits, New Approaches to Stability, Geometric Stability and Required Torques, Effects of Considering a Limited Motor Torque: Simulation Study, Global-stability Criterion, Control Techniques, Kinematics and Dynamics, Forward Kinematics: The Denavit-Hartenberg Convention, Inverse Dynamics of Walking Robots, The Complete Dynamic Model, Improving Leg Speed by Soft Computing Techniques, Improving Leg Speed in On-line Trajectory Generation, The Acceleration Tuning Approach, Experimental Workspace Partitioning, Fuzzy Sets and Rules, Fuzzy Inference Map, Virtual Sensors for Walking Robots, Virtual Sensors Based on Neural Networks, Virtual-sensor Design, Using Virtual Sensors in Real Walking, The Neural Network,
Human-machine Interfaces.

TEXTBOOKS/REFERENCES:

[1] Pablo Gonzalez de Santos, Elena Garcia and Joaquin Estremera, “Quadrupedal Locomotion - An Introduction to the Control of Four-legged Robots”, Springer, 2006.

[2] Alexander, R. N., “Terrestrial Locomotion, Mechanics and Energetics of Animal Locomotion”, Alexander, R.N. and Goldspink, G., editors. Chapman and Hall, London, 1977.

[3] Berns, K. (2005). The Walking Machine Catalogue. Available: http://agrosy. informatik.uni-kl.de/wmc/start.php/

[4] Craig, J. J., “Introduction to Robotics”, Addison-Wesley, 2nd edition, 1989.

[5] Featherstone, R., “Robot Dynamics Algorithms”, Kluwer Academic Publishers, Boston-Dordrecht-Lancaster, 1987.

Course Outcomes

CO1: Understand Walking Robots – Introduction, Stability in Walking Robots.

CO2: Understand Generation of Periodic Gaits, Gait Generation, Continuous Gaits, Discontinuous Gaits, Two-phase Discontinuous Gaits.

CO3: Analyze Generation of Non-periodic Gaits, Free-crab Gait, Free Turning Gaits.

CO4: Apply Geometric Stability and Required Torques.

CO5: Apply Kinematics and Dynamics.

CO6: Analyze Improving Leg Speed by Soft Computing Techniques.

21RA731 DESIGN AND ANALYSIS OF ALGORITHMS 3-0-2-4

Algorithm Analysis: Methodologies for Analyzing Algorithms, Asymptotic Notation, Recurrence Relations. Data Structures: Linear Data Structures (Stacks, Queues, Linked-Lists, Vectors), Trees (Binary Search Trees, AVL trees, Red-Black trees, B-trees), Hash-Tables (Dictionaries, Associative Arrays, Database Indexing, Caches, Sets) and Union-Find Structures. Searching and Sorting (Insertion and Selection Sort, Quicksort, Mergesort, Heapsort, Bucket Sort and Radix Sort), Comparison of sorting algorithms and lower bounds on sorting. Fundamental Techniques: The Greedy Method, Divide and Conquer, Dynamic Programming. Graph Algorithms: Elementary Algorithms, i.e., Breadth-first search, Depth-first search, Topological sort, strongly connected components. Minimum Spanning Trees, Single-Source Shortest Paths, All-Pairs Shortest Paths, Maximum Flow, Network Flow and Matching, Flows and Cuts. Nondeterministic Polynomial Time Problems: P and NP, NP-Complete, NP-Hard, Important NP-Complete/Hard Problems. Significant labs: Implementation of algorithms using a structured or object-oriented programming language.

TEXTBOOKS/REFERENCES:

[1] T. H. Cormen, C. E. Leiserson, R. L. Rivest and C. Stein, "Introduction to Algorithms", MIT Press, 2009, 3rd Edition.
[2] S. Dasgupta, C. Papadimitriou and U. Vazirani, "Algorithms", McGraw-Hill, 2006
[3] J. Kleinberg and E. Tardos, "Algorithm Design", Addison Wesley, 2005
[4] R. Sedgewick and K. Wayne, "Algorithms", Addison Wesley, 2011, 4th Edition
[5] K. Mehlhorn and P. Sanders, "Data Structures and Algorithms: The Basic Toolbox", Springer, 2008
[6] E. Lehman, T. Leighton and A. Meyer, "Mathematics for Computer Science", MIT Press, 2010.

Course Outcomes

CO1: Understand Algorithm Analysis: Methodologies for Analyzing Algorithms.
CO2: Understand Trees (Binary Search Trees, AVL trees, Red-Black trees, B-trees).
CO3: Analyze Comparison of sorting algorithms and lower bounds on sorting.
CO4: Apply Graph Algorithms: Elementary Algorithms, i.e., Breadth-first search, Depth-first search.
CO5: Apply Network Flow and Matching.
CO6: Analyze Nondeterministic Polynomial Time Problems.

21RA732 ADVANCED PERCEPTION FOR ROBOTICS AND AI 3-0-2-4

This course is an advanced survey of the state of the art in machine vision, focused primarily on robotics applications and human-computer interfaces. Topics covered will be related to 3D reconstruction of objects and scenes from video, camera motion estimation from video, object detection and recognition, and tracking, cloud robotics as it relates to robot vision. They include optical flow estimation: motion field and optical flow, calculating optical flow, flow-based motion analysis, robust incremental optimal flow. Object detection and recognition: Global methods, transformation search-based methods, geometric correspondence-based approaches, flexible shape matching, interest point detection and region descriptors, three-dimensional object recognition. Tracking and video analysis: Point tracking, deterministic methods, statistical methods, kernel tracking, template and density based appearance models multi view appearance models, silhouette tracking, contour evolution, shape matching.

TEXTBOOKS/REFERENCES:

[1] D. Forsyth and J. Ponce, "Computer Vision: A Modern Approach". Prentice-Hall, 2003.
[2] E. Trucco and A. Verri, "Introductory Techniques for 3-D Computer Vision", Prentice Hall, 1998.

Course Outcomes

CO1: Understand robotics applications and human-computer interfaces.
CO2: Understand 3D reconstruction of objects and scenes from video, camera motion estimation from video.
CO3: Analyze optical flow estimation: motion field and optical flow, calculating optical flow.
CO4: Apply Object detection and recognition.
CO5: Apply geometric correspondence-based approaches.
CO6: Analyze Tracking and video analysis.

21RA733 COMPUTATIONAL INTELLIGENCE 3-0-2-4

Computational intelligence (CI): Adaptation, Self-organization and Evolution, Biological and artificial neuron, Neural Networks Concepts, Paradigms, Implementations, Evolutionary computing: Concepts, Paradigms, Implementation, Swarm Intelligence, Artificial Immune Systems, Fuzzy systems: Concepts, Paradigms, Implementation, Hybrid systems, CI application: case studies may include sensor networks, digital systems, control, forecasting and time-series predictions.

TEXTBOOKS/REFERENCES:

[1] R.C. Eberhart, “Computational Intelligence: Concept to Implementations”, Morgan Kaufmann Publishers, 2007.
[2] A Konar, “Computational Intelligence: Principles, Techniques and Applications”, Springer Verlag, 2005.

Course Outcomes

CO1: Understand Computational intelligence.
CO2: Understand Adaptation, Self-organization and Evolution, Biological and artificial neuron, Neural Networks Concepts, Paradigms, Implementations.
CO3: Analyze Evolutionary computing.
CO4: Apply Swarm Intelligence.
CO5: Apply Fuzzy systems: Concepts, Paradigms, Implementation, Hybrid systems.
CO6: Analyze CI application: case studies may include sensor networks, digital systems, control.

21RA734 MACHINE VISION 3-0-2-4

Active contours Model Snake- Split and merge, Mean shift and mode finding, Normalized cuts, Graph cuts and energy-based methods, Clustering based segmentation. Detectors and Descriptors, Chain Codes, Polygonal Approximations Boundary Descriptors-Fourier Descriptors, Statistical Moments Regional Descriptors-Texture-Moment Invariants, MOPS, GLOH, SIFT, PCA-SIFT, SURF. 2D and 3D feature-based alignment, 3D Pose estimation, Geometric intrinsic calibration, Feature Matching-Object Recognition, The Use of Motion in Segmentation Optical Flow & Tracking, Introduction to Object Recognition and Bag-of Words Models, KL Tracking, Object tracking using mean- shift and Kalman filters, Face detection (Viola Jones), Face Recognition using PCA, LDA. Image Formation: Geometric image formation, Photometric image formation – Camera Models and Calibration: Camera Projection Models – orthographic, affine, perspective, projective models. Projective Geometry, transformation of 2-d and 3-d, Internal Parameters, Lens Distortion Models, Calibration Methods – linear, direct, indirect and multi plane methods. Visual servo. Stereo correspondence-Epipolar geometry, Fundamental matrix, Computation- Normalized 8-point algorithm (Hartley), Robust Fundamental Matrix Estimation by Zhang, Stereo Pairs and Depth Maps Image Rectification for Stereo, Correlation Based Stereo Methods Barnard's Stereo Method Multi-view stereo. Introduction to SLAM (Simultaneous Localisation and Mapping), Machine/Deep Learning Models.

TEXTBOOKS/REFERENCES:

[1] Richard Szelinski, "Introduction to Computer Vision and its Application".
[2] E. Trucco and A. Verri, "Introductory techniques for 3D Computer Vision", Prentice Hall, 1998.
[3] Marco Treiber, "An Introduction to Object Recognition Selected Algorithms for a Wide Variety of Applications", Springer, 2010.
[4] Forsyth and Ponce, "Computer Vision – A Modern Approach", Second Edition, Prentice Hall, 2011.
[5] R. C. Gonzalez, R. E. Woods, 'Digital Image Processing', Addison-Wesley, 2002.

Course Outcomes

CO1: Understand Active contours Model Snake- Split and merge, Mean shift and mode finding.
CO2: Understand Detectors and Descriptors, Chain Codes, Polygonal Approximations.

CO3: Analyze Feature Matching-Object Recognition.
CO4: Apply Image Formation: Geometric image formation, Photometric image formation.
CO5: Apply Projective Geometry, transformation of 2-d and 3-d.
CO6: Analyze Visual servo. Stereo correspondence-Epipolar geometry, Fundamental matrix.

21RA735 ADVANCED AI FOR ROBOTICS 3-0-2-4

Problem solving: Graph based search, Algorithms for searching, Heuristic search, Robot path planning. Knowledge representation: Descriptive representation, Procedural representation, Rule-based representation, Semantic networks, Frames, Ontologies, Knowledge based systems. Expert systems. Artificial neural networks: Perceptron, Learning, Associative memories, Self-organised networks, Applications of neural networks in robotics. Fuzzy logic systems: Fuzzy logic, Fuzzy reasoning, Fuzzy logic-based techniques, Fuzzy relations, Fuzzy control, implementing fuzzy controllers, Fuzzy decision making. Genetic algorithms: Principles, Working, Design, Applications in robotics.

TEXTBOOKS/REFERENCES:

[1] Russell, S.J. and Norvig, P., "Artificial Intelligence – A Modern Approach", Prentice Hall, 2003.
[2] Negnewitsky, M., "A Guide to Intelligent Systems", Addison-Wesley, 2005.
[3] Inger, G.F., "Artificial Intelligence: Structures and Strategies for Complex Problem Solving", Addison-Wesley, 2005.
[4] Nilsson, N.J., "Artificial Intelligence: A New Synthesis", Morgan-Kaufmann, 1998.

Course Outcomes

CO1: Understand Problem solving: Graph based search, Algorithms for searching.
CO2: Understand Knowledge representation: Descriptive representation, Procedural representation.
CO3: Analyze Semantic networks, Frames, Ontologies, Knowledge based systems.
CO4: Apply Artificial neural networks: Perceptron, Learning, Associative memories.
CO5: Apply Fuzzy logic systems: Fuzzy logic, Fuzzy reasoning.
CO6: Analyze Genetic algorithms: Principles, Working.

21RA736 VIRTUAL REALITY AND APPLICATIONS 3-0-2-4

Introduction: The three I's of virtual reality, commercial VR technology and the five classic components of a VR system. VR design principles, Input Devices: Three-dimensional position trackers, navigation and manipulation, interfaces and gesture interfaces. Output Devices: Graphics displays, sound displays & haptic feedback. Modelling: Geometric modelling, kinematics modelling, physical modelling, behaviour modelling, model management. Human Factors: Methodology and terminology, user performance studies, VR health and safety issues. Applications: Medical applications, military applications, robotics applications. VR in Unity 3D.

TEXTBOOKS/REFERENCES:

[1] Gregory C. Burdea and Philippe Coiffet, "Virtual Reality Technology", Second Edition, John Wiley and Sons, Inc.
[2] Andrew Davison, "Killer Game Programming in Java, "O'Reilly-SPD, 2005.
[3] William R.Sherman and Alan Craig, "Understanding Virtual Reality, Interface, Application and Design", Elsevier(Morgan Kaufmann).
[4] Bill Fleming, "3D Modeling and surfacing", Elsevier (Morgan Kaufmann).
[5] David H.Eberly, "3D Game Engine Design", Elsevier.
[6] John Vince, "Virtual Reality Systems", Pearson Education.

Course Outcomes

CO1: Understand The three I's of virtual reality, commercial VR technology and the five classic components of a VR system.
CO2: Understand VR design principles.
CO3: Analyze Input Devices: Three-dimensional position trackers, navigation and manipulation.
CO4: Apply Output Devices: Graphics displays, sound displays & haptic feedback.
CO5: Apply Modelling: Geometric modelling, kinematics modelling, physical modelling.
CO6: Analyze Medical applications, military applications, robotics applications.

21RA737 NON-LINEAR CONTROL THEORY 3-0-2-4

Topics include Nonlinear Behaviour, Mathematical Language for Modelling Nonlinear Behaviour: Discrete Time State Space Equations, Differential Equations on Manifolds, Input/Output Models, Finite State Automata and Hybrid Systems. Linearization: Linearization around a Trajectory, Singular Perturbations, Harmonic Balance, Model Reduction, Feedback Linearization. System Invariants: Storage Functions and Lyapunov Functions, Implicitly Defined Storage Functions, Search for Lyapunov Functions. Local Behaviour of Differential Equations: Local Stability, Centre Manifold Theorems, Bifurcations. Controllability of Nonlinear Differential Equations: Frobenius Theorem, Existence of Feedback Linearization, Local Controllability of Nonlinear Systems. Nonlinear Feedback Design Techniques: Control Lyapunov Functions, Feedback Linearization: Backstepping, Dynamic Inversion, etc., Adaptive Control, Invariant Probability Density Functions, Optimal Control and Dynamic Programming.

TEXTBOOKS/REFERENCES:

[1] Hassan K. Khalil, "Nonlinear Systems", Prentice Hall.
[2] Shankar Sastry, "Nonlinear Systems: Analysis, Stability, and Control", Springer.

Course Outcomes

CO1: Understand Nonlinear Behaviour.
CO2: Understand Mathematical Language for Modelling Nonlinear Behaviour.
CO3: Analyze Finite State Automata and Hybrid Systems.
CO4: Apply Singular Perturbations, Harmonic Balance, Model Reduction, Feedback

Linearization.
CO5: Apply Storage Functions and Lyapunov Functions.
CO6: Analyze Local Stability, Centre Manifold Theorems, Bifurcations.

21RA738 EXPERIMENTAL HAPTICS 3-0-2-4

The goal of this course is to develop virtual reality simulations and applications that incorporate haptic interaction. Theoretical topics include haptic rendering in 3-D virtual environments, simulation of haptic interaction with rigid and deformable objects, haptic interfaces, psychophysics of touch. Applied topics include an introduction to the CHAI 3D/Unity 3D haptics library, implementation of algorithms for haptic rendering, collision detection, and deformable body simulation.

TEXTBOOKS/REFERENCES:

[1] Ming Lin and Miguel Otaduy,"Haptic Rendering", A K Peters, 2008.

Course Outcomes

CO1: Understand develop virtual reality simulations.
CO2: Understand haptic rendering in 3-D virtual environments.
CO3: Analyze simulation of haptic interaction with rigid and deformable objects.
CO4: Apply haptic interfaces, psychophysics of touch.
CO5: Apply CHAI 3D/Unity 3D haptics.
CO6: Analyze implementation of algorithms for haptic rendering, collision detection.

21RA739 UNMANNED AERIAL VEHICLES 3-0-2-4

Introduction to UAV - Types of UAV - Geometry and Mechanics of UAVs including transformations, angular velocity, principal moment of inertia, equations of motions, ROS based Control, Trajectories and Motion Planning, Sensing and Probabilistic State Estimation, Visual Motion Estimation, Visual SLAM, Architectures, UAV and AGV interoperable frameworks.

TEXTBOOKS/REFERENCES:

[1] Thrun, Sebastian, Wolfram Burgard, and Dieter Fox. Probabilistic Robotics. MIT press, 2005.
[2] Carrillo, Luis Rodolfo García, et al. Quad rotorcraft control: vision-based hovering and navigation. Springer Science & Business Media, 2012.
[3] Corke, Peter. Robotics, vision and control: fundamental algorithms in MATLAB® second, completely revised. Vol. 118. Springer, 2017.

Course Outcomes

CO1: Understand UAV and types of UAV.
CO2: Understand Geometry and Mechanics of UAVs including transformations.
CO3: Analyze ROS based Control, Trajectories and Motion Planning.
CO4: Apply Sensing and Probabilistic State Estimation.
CO5: Apply Visual Motion Estimation, Visual SLAM.
CO6: Analyze Architectures, UAV and AGV interoperable frameworks.

21RM621 RESEARCH METHODOLOGY 2-0-0-2

Meaning of Research, Types of Research, Research Process, Problem definition, Objectives of Research, Research Questions, Research design, Approaches to Research, Quantitative vs. Qualitative Approach, Understanding Theory, Building and Validating Theoretical Models, Exploratory vs. Confirmatory Research, Experimental vs Theoretical Research, Importance of reasoning in research.

Problem Formulation, Understanding Modeling & Simulation, Conducting Literature Review, Referencing, Information Sources, Information Retrieval, Role of libraries in Information Retrieval, Tools for identifying literatures, Indexing and abstracting services, Citation indexes.

Experimental Research: Cause effect relationship, Development of Hypothesis, Measurement Systems Analysis, Error Propagation, Validity of experiments, Statistical Design of Experiments, Field Experiments, Data/Variable Types & Classification, Data collection, Numerical and Graphical Data Analysis: Sampling, Observation, Surveys, Inferential Statistics, and Interpretation of Results.

Preparation of Dissertation and Research Papers, Tables and illustrations, Guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript. References, Citation and listing system of documents Intellectual property rights (IPR) - patents-copyrights-Trademarks-Industrial design geographical indication. Ethics of Research-Scientific Misconduct- Forms of Scientific Misconduct. Plagiarism, Unscientific practices in thesis work, Ethics in science.

TEXTBOOKS/ REFERENCES:

[1] Bordens, K. S. and Abbott, B. B., “Research Design and Methods – A Process Approach”, 8th Edition, McGraw-Hill, 2011.
[2] C. R. Kothari, “Research Methodology – Methods and Techniques”, 2nd Edition, New Age International Publishers.
[3] Davis, M., Davis K., and Dunagan M., “Scientific Papers and Presentations”, 3rd Edition, Elsevier Inc.
[4] Michael P. Marder, “Research Methods for Science”, Cambridge University Press, 2011.
[5] T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008.
[6] Robert P. Merges, Peter S. Menell, Mark A. Lemley, “Intellectual Property in New

Technological Age”, Aspen Law & Business, 6 edition July 2012.

Course Outcomes

CO1: To define research, methodology and steps involved in research.

CO2: To learn to define a problem, and research hypothesis. To understand the importance of literature survey, gaps and challenges.

CO3: To learn the basic concepts of research design, sampling, modeling & simulation and understand the importance of citation, H-index, Scopus.

CO4: To learn to write technical report, paper and thesis.

CO5: To know about intellectual property rights, ethics in research and plagiarism.