M.TECH. INDUSTRIAL INTELLIGENT SYSTEMS

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

20MA603 **ADVANCED MATHEMATICS** **3 1 0 4**

Course Objective:

- To understand the advanced concepts in Linear Algebra
- To introduce the linear, dynamic and integer programming concepts in operations research

Course Outcomes

CO1: Understand the basic concepts of vector spaces, subspaces, linear independence, span, basis and dimension and analyze such properties on the given set.

CO2: Understand the concept of inner products and apply it to define the notion of length, distance, angle, orthogonality, orthogonal complement, orthogonal projection, orthonormalization and apply these ideas to obtain least square solution.

CO3: Understand the concept of linear transformations, the relation between matrices and linear transformations, kernel, range and apply it to change the basis, to get the QR decomposition, and to transform the given matrix to diagonal/Jordan canonical form.

CO4: Apply different types of Optimization Techniques in engineering problems.

Linear Algebra, Eigen values and vectors, Singular Value Decomposition **2 1 0 3**

Vector Spaces: General vector spaces - Sub spaces - Linear independence - Basis – Dimension Row space, Column space and Null Space, Eigen values and Eigen vectors.

Inner Product Spaces: Inner products - Orthogonality - Orthogonal basis – Orthogonal complements - Projection on subspace - Gram Schmidt Process - QR- Decomposition – Best approximation - Least square – Least squares fitting to data - Change of basis, Singular value decomposition.

Linear Transformations: General linear transformation - Kernel and range of a linear transformation - Inverse Linear Transformation - Matrices - Similarity - Diagonalization and its applications – Jordan form and rational canonical form - Positive definite matrices - Matrix norm and condition number.

Operations Research **1 0 0 1**

Linear Programming models, simplex search, sensitivity analysis, artificial standing solutions, duality & sensitivity in linear programming, economic interpretations, integer programming, dynamic programming

Text Books/ References

1. Strang, Gilbert, “Introduction to linear algebra”, Wellesley, MA: Wellesley-Cambridge Press.

2. Kenneth Hoffmann and Ray Kunze, “*Linear Algebra”*, Second Edition, Pearson, 2015.
3. Howard Anton and Chris Rorres, “Elementary Linear Algebra”, Tenth Edition, John Wiley and Sons, 2010
4. Handy M.Taha, “Operations Research, an introduction”, 7th edition, PHI, 2003
5. Kalyanmoy Deb, “*Optimization for Engineering Design: Algorithms and Examples*”, Prentice Hall, 2002.
6. E. Clapton, “Advanced Optimization Techniques and Examples with MATLAB” CreateSpace Independent Publishing Platform, 2016

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1			3		
CO2	1		2	3		
CO3	1		2	3		
CO4	1		2	3		

20IS601 COMPUTER BASED INDUSTRIAL CONTROL 3 0 0 3

Course Objective:

- To introduce the architecture of computer controlled industrial systems
- To provide an overview of various bus standards and protocols

Course Outcomes

CO1: Understand the architecture of computer based industrial automation systems

CO2: Identify the various communication protocols for industrial networks

CO3: Apply real time programming for distributed control systems

CO4: Design applications of computer based industrial control

Current trends in computer control of process plants, fundamentals of automatic process control, building blocks of automation systems, Direct digital control-structure and software, distributed digital control: functional requirements, system architecture, distributed control systems, Distributed control Architectures, Network Architectures, Industry open protocols (RS-232C, RS- 422, and RS-485), I2C Bus, Ethernet, Fieldbus, LonWorks, Modbus, Modbus Plus, Profibus+, Data Highway Plus, Advantages and Limitations of Open networks, IEEE 1394. Network-Based Design, Internet-Enabled Systems

Real-time Programming: Introduction to Real-time operating system, Multi-tasking, task management, inter-task communications, RTOS tasks-RTOS scheduling– Interrupt processing-Synchronization-Control blocks-Memory requirements, Real-time programming languages, Personal computer in Real-time Environment: PC bus and signals, Interrupts, Interfacing PC to outside world, Industrial Personal Computer development, PC based distributed control systems Modeling and simulation for Plant Automation, Industrial Control Applications: Model based controllers, predictive control, Artificial Intelligent based systems – case studies

Text Books/ References

1. Wayne Wolf, "Computers as Components: Principles of Embedded Computing Systems Design", Academic Press, 2005
2. Karl Johan Astrom and Bjorn Wittenmark, "Computer Controlled Systems", Dover Publications, 2011
3. Krishna Kant "Computer- based Industrial Control", Prentice- Hall of India Pvt. Ltd., 2004.
4. Hermann K, Real time systems-design principles for distributed embedded Applications', Kluwer academic, 1997.
5. User Manuals of Foundation Field bus, Profibus, Modbus, Ethernet, Device net, and Control net.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1			2		
CO2	2			2		
CO3	2		1	2		
CO4	2		1	2		

20IS602 ADVANCED CONTROL SYSTEM 3 0 0 3

Course Objective:

- To analyze the LTI system in a state space framework.
- To design a state feedback controller and state observer.
- To understand and analyze the behavior of nonlinear systems.
- To gain an idea about the adaptive controllers and its applications.

Course Outcomes

CO1: Analyse linear system in state space approach

CO2: Design state feedback controller, observer and optimal controller for linear systems

CO3: Analyse non-linear system characteristics and its stability

CO4: Execute adaptive control techniques and parameter estimation of dynamic systems

Review: Concept of state, state variables and state model, Control system design in state space: concept of controllability and observability, pole placement techniques design using state feedback, design of state observers, Design of regulator systems with observer, Design of control systems with observer, Quadratic optimal regulator systems, Non-linear systems: Introduction, behavior of non-linear system, common physical non-linearity saturation, friction, backlash, dead zone, relay, multi- variable non-linearity. Phase plane method, singular points, stability of nonlinear system, limit cycles, construction of phase trajectories. Liapunov stability criteria, Liapunov functions, direct method of Liapunov and the linear system, Hurwitz criterion and Liapunov's direct method, construction of Liapunov functions for nonlinear system. Adaptive control: Closed loop and open loop adaptive control. Self-tuning controller, parameter estimation using least square and recursive least square techniques, gain scheduling, model reference adaptive systems (MRAS), self-tuning regulators.

Text Books/ References

1. Ogata, "Modern Control Engineering", Fifth Edition, Prentice Hall, 2009.
2. Hassan K. Khalil, "Nonlinear Systems", 3rd Edition, Pearson, 2002.
3. Franklin and Powell, "Feedback Control of Dynamics Systems", Seventh Edition, Pearson Hall, 2014.
4. Richard C. Dorf and Robert H. Bishop, "Modern Control Systems", Eleventh Edition Prentice Hall, 2008.
5. Karl J Astrom and Bjorn Wittenmark, "Adaptive Control", Addison –Wesley Series,1995

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		2	2		
CO2	2		2	2		
CO3	2		2	2		
CO4	2		2	2		

20IS611 DATA ANALYTICS AND DATA MINING 2 0 2 3

Course Objective:

- To comprehend the process of data handling through data preprocessing and data analysis
- To provide insight into data visualization methods

Course Outcomes

CO1: Understand the different matrix decomposition and statistical modelling techniques

CO2: Apply various data preprocessing techniques to perform feature selection

CO3: Analyze the data using the evaluation metrics

CO4: Examine the processed data through clustering techniques

Introduction -Big Data and Data Science – Datafication - Current landscape of perspectives - Skill sets needed; Matrices - Matrices to represent relations between data, and necessary linear algebraic operations on matrices -Approximately representing matrices by decompositions (SVD and PCA); Statistics: Descriptive Statistics: distributions and probability - Statistical Inference: Populations and samples - Statistical modeling - probability distributions - fitting a model - Hypothesis Testing – Intro to R/ Python.
Data preprocessing: Data cleaning - data integration - Data Reduction Data Transformation and Data Discretization. Evaluation of classification methods – Confusion matrix, Students T-tests and ROC curves-Exploratory Data Analysis - Basic tools (plots, graphs and summary statistics) of EDA, Philosophy of EDA - The Data Science Process; Feature Generation and Feature Selection - Feature Selection algorithms. Clustering: Choosing distance metrics - Different clustering approaches - hierarchical agglomerative clustering, k-means (Lloyd's algorithm), - DBSCAN - Relative merits of each method - clustering tendency and quality. Data Visualization: Basic principles, ideas and tools for data visualization.

Text Books/ References

1. Cathy O'Neil and Rachel Schutt, "Doing Data Science, Straight Talk From The Frontline", O'Reilly, 2014.
2. Jiawei Han, Micheline Kamber and Jian Pei, "Data Mining: Concepts and Techniques", Third Edition, 2011.
3. Mohammed J. Zaki and Wagner Miera Jr, "Data Mining and Analysis: Fundamental Concepts and Algorithms", Cambridge University Press, 2014.
4. Matt Harrison, "Learning the Pandas Library: Python Tools for Data Munging, Analysis, and Visualization, O'Reilly, 2016.
5. Joel Grus, "Data Science from Scratch: First Principles with Python", O'Reilly Media, 2015.
6. Wes McKinney, "Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython", O'Reilly Media, 2012.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1			2		
CO2	2	1		3	3	
CO3	2	1	2	3	3	
CO4	2	1	2	3	3	

20IS612 EMBEDDED SYSTEM DESIGN 2 0 2 3

Course Objective:

- To introduce Embedded system principles and programming concepts

- To expose the concepts of microcontroller based system integration and interfacing by introducing ARM architecture.

Course Outcomes

CO1: Understand the terminologies and characteristics of basic embedded systems

CO2: Apply modelling and programming concepts for embedded product development

CO3: Examine different interfacing techniques to communication with embedded hardware

CO4: Investigate case studies in industrial embedded systems

Introduction to Embedded systems, Characteristics and quality attributes (Design Metric) of embedded system, hardware/software co-design, Embedded micro controller cores, embedded memories, Embedded Product development life cycle, Program modeling concepts: DFG, FSM, Petri-net, UML.

Embedded C-programming concepts, Basic embedded C programs/applications for ARM-v7, Interfacing and Integration of microcontroller based systems, communication protocols like SPI, SCI (RS232, RS485), I2C, CAN, USB (v2.0), fundamentals of wireless networks for embedded system - Bluetooth, Zig-Bee. Examples of Industrial process automation, software development using python, Introduction to Linux OS, Rapid prototyping using low cost hardware (STM32 discovery board, Raspberry Pi)

Text Books/ References

1. Jonathan Valvano, “Embedded Systems: Introduction to ARM® Cortex™-M Microcontrollers”, Fourth Edition, Create Space Publishing, 2013.
2. K.V.Shibu, “Introduction to Embedded Systems”, McGraw Hill Education, 2009
3. Edward A. Lee, and Sanjit A. Seshia, “Introduction to Embedded Systems- A Cyber Physical Systems Approach”, Second Edition, 2015.
4. Jeff C. Jensen, Edward A. Lee, and Sanjit A. Seshia, “An Introductory Lab in Embedded and Cyber-Physical Systems”, First Edition, 2015.
5. Sai Yamanoor, Srihari Yamanoor, Python Programming with Raspberry Pi, Packt Publishing Ltd, 2017

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1					
CO2	2			2	3	
CO3	2	1	1	2	3	
CO4	2	1	1	2		

20IS623 MODELING AND SIMULATION LAB 0 0 3 1

Course Objective:

- To equip students with skills in various packages like MATLAB, LABVIEW, etc. and to give exposure in implementation of Digital control system techniques

Course Outcomes

CO1: Model dynamic systems using MATLAB/LABVIEW
CO2: Develop microcontroller-based system interface
CO3: Design Data Acquisition systems using LABVIEW

Modeling and analysis of dynamic systems using MATLAB/LABVIEW software, Microcontroller based system interfacing, LABVIEW based Data Acquisition Systems, Interfacing PC with Real-time systems

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	1	2	3	
CO2	2	2	1	2	3	
CO3	2	2	1	2	3	

20IS603 ARCHITECTURE OF INTELLIGENT SYSTEMS 3 0 0 3

Course Objective:

- To provide the fundamental concepts of expert systems
- To introduce algorithms for developing agent-based architectures

Course Outcomes

CO1: Understand the characteristics of knowledge base systems
CO2: Apply the object-oriented concepts in intelligent systems
CO3: Identify the characteristics and architectures of multi agent systems
CO4: Implement different algorithms for multi-agent systems

Knowledge-based systems, Expert systems, Knowledge acquisition, Computational intelligence, Rule-based systems, Forward-chaining (a data-driven strategy), Conflict resolution, Backward-chaining (a goal-driven strategy), Sources of uncertainty, Bayesian updating, Certainty theory, Possibility theory: fuzzy sets and fuzzy logic, Object-oriented systems, Data abstraction, Inheritance, Encapsulation, Unified Modeling Language (UML), Dynamic (or late) binding, Intelligent agents - Characteristics of an intelligent agent, Agent architectures, Multiagent systems, Symbolic learning, Learning by induction, Case-based reasoning (CBR), Hill-climbing and gradient descent algorithms, Simulated annealing, Genetic algorithms, Systems for interpretation and diagnosis, Systems for design and selection, Systems for control, Hybrid intelligent systems, application based case studies.

Text Books/ References

1. Adrian A. Hopgood, "Intelligent systems for engineers and scientists", Second Edition, CRC press, 2001
2. Crina Grosan, Ajith Abraham, "Intelligent Systems: A Modern Approach ",Springer-Verlag, 2011
3. Bogdan M. Wilamowski, J. David Irwin, "The Industrial Electronics Handbook. Second Edition: Intelligent Systems", CRC Press, 2011
4. Abraham-Kandel, Gideon-Langholz, "Hybrid-Architectures for Intelligent Systems", CRC-Press, 1992

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1			1		
CO2	2		1	2		
CO3	2		1	1		
CO4	2		1	2		

20IS614 COMPUTATIONAL INTELLIGENCE 2 0 2 3

Course Objective:

- To provide a probabilistic learning approach for data analysis
- To introduce basic machine learning algorithms with case studies

Course Outcomes

CO1: Understand the basic terminologies in machine learning
CO2: Apply the probabilistic approach for feature analysis
CO3: Implement the different regression algorithms
CO4: Design the applications of ensemble methods

Introduction to Machine learning, different forms of learning: supervised and unsupervised learning, classification and regression, parametric and nonparametric models, curse of dimensionality, Basics of probability theory and probability distributions, information theory, Bayesian learning, Gaussian Mixture models and the EM algorithm, Factor analysis, Principal components analysis, Independent Component Analysis, Basic Machine Learning Algorithms: Association Rule mining - Linear Regression- Logistic Regression - Classifiers - k-Nearest Neighbors (k-NN), k-means -Decision tree - Naive Bayes - Random Forest, Neural Networks, Kernels and kernel functions, Support vector machines for regression and classification, CART, Ensemble Methods: Boosting - Adaboost, Gradient Boosting; Bagging - Simple methods, Markov and hidden Markov models, Introduction to deep learning, Examples and case studies in machine learning.

Text Books/ References

1. Christopher M. Bishop, "Pattern Recognition and Machine Learning", Springer, 2006.
2. Kevin P. Murphy, "Machine Learning: A Probabilistic Perspective", The MIT Press, 2012.
3. Trevor Hastie, Robert Tibshirani, Jerome Friedman, "The Elements of Statistical Learning: Data Mining, Inference, and Prediction", Second Edition, Springer, 2009.
4. Bernhard Schölkopf and Alexander J. Smola, "Learning with Kernels - Support Vector Machines, Regularization, Optimization, and Beyond", MIT Press, 2001.
5. Tom M. Mitchell, "Machine Learning", McGraw-Hill, 1997.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1			1		
CO2	2	1	2	2	3	
CO3	2	1	2	2	3	
CO4	2	1	2	2	3	

20IS615 FAULT DIAGNOSTIC SYSTEMS 3 0 2 4

Course Objective:

- To provide insight into the signal processing techniques for fault handling
- To expose different fault diagnosis procedures through case studies

Course Outcomes

CO1: Comprehend the basic terminologies in fault modelling
CO2: Interpret different signal types in fault models
CO3: Identify diverse fault detection and diagnosis methods
CO4: Apply fault detection, diagnosis and tolerant methods in real time applications

Supervision and fault management of processes, Reliability, Availability and Maintainability, Safety, Dependability and System Integrity, Process Models and Fault Modelling, Signal models, Fault detection with limit checking, Analysis of periodic signals, Analysis of non-stationary periodic signals, Analysis of stochastic signals, Vibration analysis of machines, Identification with correlation functions, Parameter estimation for linear processes, Identification of non-linear processes, State observers and state estimation, Principle Component Analysis.

Diagnosis procedures and problems, fault diagnosis with classification methods, fault diagnosis with inference methods, Fault-tolerant design, fault-tolerant components and control. Case study: Fault detection and diagnosis of DC motor drives, Automotive systems, Pneumatic systems.

Text Books/ References

1. Rolf Isermann, 'Fault-Diagnosis Systems: An Introduction from Fault Detection to Fault Tolerance", Springer, 2006.
2. Jian Zhang, Akshya Kumar Swain, Sing Kiong Nguang "Robust Observer-Based Fault Diagnosis for Nonlinear Systems Using MATLAB", Springer, 2016
3. Chen,J. and R.J.Patton, (1999), Robust Model-based Fault Diagnosis for Dynamic Systems, Kluwer Academic Publ., Boston.
4. R.J.Patton, P.M.Frank, R.N.Clark (Eds), (2000), Issues in Fault Diagnosis for Dynamic Systems, Springer-Verlag, New York.
5. Blanke, M., M. Kinnaert, J. Lunze, M. Staroswiecki, (2006), Diagnosis and Fault Tolerant Control, Springer-Verlag, Berlin.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1			2		
CO2	2	1	2	2	3	
CO3	2	1	2	2	3	
CO4	2	1	2	2	3	

20IS616 INDUSTRIAL ELECTRONICS LABORATORY 1 0 2 2

Course Objective:

- To expose students to PLCs, HIL, SIL etc. in realizing industrial system prototypes.

Course Outcomes

CO1: Implement data logging for real time systems

CO2: Develop microcontroller-based closed loop control system

CO3: Implement HIL/SIL/PIL for real time industrial applications

Data Loggers / Data Acquisition Systems, Programmable Logic Controllers for real-time systems, Micro controller based closed loop control, Study of Hardware-in-loop/Software-in-loop/Processor-in-loop

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	2	2	3	
CO2	2	2	2	2	3	
CO3	2	2	2	2	3	

20RM600 RESEARCH METHODOLOGY 2 0 0 2

Course Objective:

- To familiarize with modeling, referencing, literature survey, etc
- To design experiments and to analyse results of the experiments
- To prepare technical reports and research papers
- To prepare material for technical presentation and do oral presentation
- To understand the purpose and terms of IPR
- To orient to ethics in research and publication

Course Outcomes

CO1: Understand types and methods of research, modeling, referencing, etc.

CO2: Able to design experiments and analyse results

CO3: Prepare and present research papers

CO4: Aware of IPR and ethics

Unit I: 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.

Unit II: 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

Unit III: 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

Unit IV: 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

Unit V: 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

Text Books/ 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, NewAge 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

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1		2			2
CO2	2	3	2			2
CO3	2	3	2			2
CO4	1		2			3

20IS701 INDUSTRIAL IOT 3 0 0 3

Course Objective:

- To impart the knowledge about various enabling technologies for IIoT, that links the automation system with enterprise, planning and product lifecycle.

Course Outcomes

CO1: Understand the key techniques and theory behind Industrial Internet of Things
CO2: Apply effectively the various enabling technologies (both hardware and software) for IIoT
CO3: Carry out the integration of Cloud and IoT, Edge and Fog Computing
CO4: Apply various techniques for Data Accumulation, Storage and Analytics
CO5: Design and build IIoT system for any one interesting Use case

UNIT 1: Introduction about IIoT, Sensors & actuators, Communication technologies, Networking technologies. Industry 4.0: Globalization and Emerging Issues, The Fourth Revolution in Industries. Basics of Industrial IoT: Industrial Processes, Industrial Sensing & Actuation, Industrial Internet Systems. IIoT Sensing, IIoT Actuating, IIoT Communication Models, IIoT Networking Technologies, IIoT Business Models, IIoT Reference Architecture, Smart and Connected Business Perspective, Smart Factories Industry 4.0: Cyber Physical Systems and Next Generation Sensors, Collaborative Platform and Product Lifecycle Management

UNIT II: Data Analytics in IIoT : Introduction, Big Data Analytics, Machine Learning, Artificial Intelligence and Data Science-R and Python Programming, Data management with Hadoop, Data Center Networks, Edge / Fog Computing, Cloud Computing in IIoT, Augmented Reality and Virtual Reality, Cyber security in Industry 4.0.

UNIT III: IIoT Application Domains: Factories and Assembly Line, Food Industry. Healthcare, Power Plants, Inventory Management & Quality Control, Plant Safety and Security (Including

AR and VR safety applications), Facility Management, Oil, chemical and pharmaceutical industry, Case Study: Applications of UAVs in Industries, Cyber Security in Industry 4.0

Text Books/ References

1. Antonio Capasso, Giacomo Veneri, "Hands-On Industrial Internet of Things", Packt Publishing, 2018
2. Arshdeep Bahga and Vijay Madisetti, "Internet of Things: A Hands-on Approach", Universities Press, 2014
3. Pethuru Raj and Anupama C. Raman, "The Internet of Things: Enabling Technologies, Platforms, and Use Cases", CRC press, 2017
4. Adrian McEwen, "Designing the internet of Things", Wiley, 2013
5. Chen, Fulong, Luo, Yonglong, "Industrial IoT Technologies and Applications", LNICST Series, Springer 2017

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1					
CO2	2		1	2		
CO3	2		1	2		
CO4	2		1	2		
CO5	2		1	2	3	

20IS702 REAL TIME OPERATING SYSTEMS 3 0 0 3

Course Objective:

- To introduce the characteristics of Real-time operating systems
- To familiarize the function of RTOS kernels and its application domains

Course Outcomes

CO1: Understand the basic concepts in real time systems.
CO2: Identify various services provided by the RTOS Kernel
CO3: Develop various real-time scheduling algorithms for uni and multi-processor systems
CO4: Analyze the schedulability of task sets using different tests and discuss blocking and priority inversion in real time systems
CO5: Design and develop real time applications using RTOS

Introduction to Real–time Systems and Real Time Operating System Basics: real–time systems characteristics, RTOS Vs General–purpose OS, RTOS characteristics, existing RTOS category, kernel architecture, functions of RTOS kernel. Introducing tasks for concurrency: Task management, process, thread and task, task– basic notation in RTOS, task classification, task configurations, writing re–entrant codes, scheduling policies. Inter task communication: with and without resource sharing, shared memory, message and message queues, inter–task communication via message queues, inter–task communication models, need for synchronization, semaphores–binary and counting semaphores, inheritance, inversion, ceiling, deadlocks and starvation, priority inversion and mutexes. Clocks in distributed RTS, timers and timer ticks, clock synchronization, watch dog timer, relative and absolute timer, interrupts– ISR under RTOS, ISR to task communication, memory/ device I/O management. Study of RTOS–VX Works and µCoS, Introduction to POSIX and OSEK standards. Embedded RTOS, RTOS for fault tolerant applications

Text Books/ References

1. Philip A. Laplante, "Real Time System Design and Analysis," Third Edition, Prentice Hall of India, 2004.
2. Jane W.S. Liu, "Real–Time Systems", First Edition, Pearson Education, 2000.
3. Krishna and Shin, "Real Time Systems", Addison Wesley, 2001
4. Charles Crowley, 'Operating systems-A design oriented approach', McGrawHill,1998
5. Raymond J.A., Donald L Baily, 'An introduction to real time operating systems' PHI, 1999

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1					
CO2	1					
CO3	2		2	2		
CO4	2		2	2	1	
CO5	2		2	2	1	

20IS703 TRANSDUCER DESIGN 3 0 0 3

Course Objective:

- To expose the students to different sensors, transducers with signal processing circuits and communication technologies

Course Outcomes

CO1: Understand the basic physical measurements
CO2: Identify the different sensors and explain the operation
CO3: Design signal conditioning circuits for the sensor measurements
CO4: Identify smart sensors and its communication technologies

Sensor fundamentals-Uncertainty aspects, Mechanical transducers: pressure measurement-diaphragms; force measurement, cantilever beams; torque measurement, strain gauge. Vibration measurement. Passive electrical transducers: Resistive, thermal radiation detectors, hotwire resistance, resistive displacement, resistive strain, resistive pressure, linear variable differential transformer. Active electrical transducers: Thermoelectric-thermocouples, RTD, piezoelectric, Hall Effect, digital displacement, photo electric. Acoustic sensors SODAR LIDAR; Non-contact NDE devices

Signal processing-frequency domain; sensor signal noise reduction techniques, Signal processing circuits: oscillators, comparators, PLL detector, first and second order active electrical filters, Modulated signals, sampling circuits, encoders and decoders, D-A and A-D converters, voltage to frequency counters, digital multiplexers and demultiplexers sensor interface into a microprocessor, Smart sensors- mems, Communication Technologies: wired, wireless. RF -Zigbee, Bluetooth, WiFi, Ethernet, GSM, GPRS.

Text Books/ References

1. Alexander D. Khazan, "Transducers and Their Elements: Design and Application", PTR Prentice Hall, 1994
2. Bella G Liptak, "Instrument Engineers Handbook, Vol 1, 2 and 3", 4th edition, CRC Press, 2005.
3. H K P Neubert, "Instrument Transducers", Oxford University Press, 1999
4. H S. Kalsi, "Electronic Instrumentation", Technical Education Series Tata McGraw-Hill, 2004

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1					
CO2	1					
CO3	2		1	2	1	
CO4	1		1			

20IS704 ELECTRONIC DATA CONVERTERS 3 0 0 3

Course Objective:

- To introduce the different data acquisition techniques and components
- To familiarize with basic nonlinear data converters

Course Outcomes

CO1: Identify the components and characteristics for Data Acquisition systems

CO2: Understand the construction and operation of different data converters

CO3: Identify the types of non-linear data converters

CO4: Select linear and non-linear data converters for real time applications

Building blocks of Automation systems – Data Acquisition System, single channel DAS, Multi-channel DAS, Components used in DAS – Converter Characteristics-Resolution-Non-linearity, settling time, Monotonicity. PC based DAS, Data loggers- Sensors based computer data systems. Overview of A/D converter, types and characteristics, A/D and S/H terms-passive support and Active support components-Single and Multi-slope, Low cost A/D conversion techniques, types-Electromechanical A/D converter. Overview of D/A converter, types and characteristics. Basic Non-linear data converters configurations – Some common NDACS and NADCS – Programmable non-linear ADCS – NADC using optimal sized ROM – High speed hybrid NADC – PLS based NADC – Switched capacitor NDCS. DAC applications – Digitally programmable V/I sources – Arbitrary waveform generators – Digitally programmable gain amplifiers – Analog multipliers/ dividers – Analog delay lines. Monolithic DACS and ADCS. Interfacing of DACS and ADCS to a microprocessor, Error sources, error reduction and noise reduction techniques in DAS. Error budget analysis of DAS, case study of a DAC and an ADC.

TEXT BOOKS/ REFERENCES

1. Dinesh K. Anvekar, B.S. Sonde, "Electronic data converters fundamentals and applications", Tata McGraw Hill
2. Hermann Schmid, "Electronic Analog/ Digital conversions", Tata McGraw Hill
3. H S. Kalsi, "Electronic Instrumentation", Technical Education Series Tata McGraw-Hill, 2004

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1					
CO2	1			1		
CO3	1		2	1		
CO4	1		2	2		

20IS705 HARDWARE SOFTWARE CO-DESIGN 3 0 0 3

Course Objective:

- To introduce model based embedded system design
- To familiarize with the high level synthesis, verification and implementation

Course Outcomes

CO1: Understand various models of computation for embedded systems

CO2: Understand the architectural selection, partitioning, scheduling and communication for embedded systems

CO3: Apply the simulation, synthesis and verification for FPGA implementation

CO4: Realize the retargetable code generation through hardware implementation

Introduction to system level design, Models of computation for Embedded Systems: Models taxonomy, State-Oriented & Activity Oriented Models, Structure & Data –Oriented Models, Heterogeneous Models, Architectural selection: Architecture taxonomy, Architectural Models, RISC,CISC, SIMD,MIMD, Partitioning: Types, issues, Hardware Software Partitioning Algorithms, Scheduling and communication: Estimations, Scheduling, allocation and binding. Scheduling Algorithms, Simulation, synthesis and verification: High Level Synthesis, Logic Synthesis and verification, Implementation case studies, Performance Analysis and Optimization, Retargetable code generation, FPGAs.

Text Books/ References

1. Ti - Yen Yen and Wayne Wolf, “Hardware-Software Co-Synthesis of Distributed Embedded Systems”, Kluwer, Reprint 2010.
2. Peter Marwedel, “Embedded System Design”, Kluwer Academic Publishers, 2003.
3. Joris van den Hurk and Jochen A.G. Jess, “System Level Hardware/Software CoDesign: An Industrial Approach”, Springer, 1997.
4. D Gajski, F Valhid, S Narayan and J Gong, “Specification and Design of Embedded Systems”, Prentice Hall PTR, 1994.
5. Jorgen Staunstrup and Wayne Wolf, “Hardware / Software Co-Design: Principle and Practice”, Kluwer Academic, 1997.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1		1	1		
CO2	1		1	1		
CO3	2		2	2	3	
CO4	2		2	2	1	

20IS706 RECONFIGURABLE COMPUTING 3 0 0 3

Course Objective:

- To provide an overview of reconfigurable computing architectures
- To familiarize with the design tools and languages used for reconfigurable computing

Course Outcomes

CO1: Understand computing models and basic concepts of Reconfigurable computing

CO2: Understand reconfigurable computing devices and architectures

CO3: Apply design tools and languages for RC application development

CO4: Familiar with Middleware, Fault tolerance, Partial reconfiguration, device characterization, etc.

General overview of computing models, Basic RC concepts, Performance, power, size, and other metrics, RC devices and architecture – fine grained and coarse grained, integration into traditional systems, FPGA computing platforms, Design tools and languages: HDLs, Synthesis, PAR, HLL and HLS, RC application development, domains and case studies, Special topics in RC: Middleware, Fault tolerance, Partial reconfiguration, device characterization.

Text Books/ References

1. Scott Hauck and Andre DeHon, "Reconfigurable Computing: The Theory and Practice of FPGA-Based Computation", Morgan Kaufmann (Elsevier), 2008.
2. M. Gokhale and P. Graham, "Reconfigurable Computing: Accelerating Computation with Field-Programmable Gate Arrays", Springer, 2005.
3. C. Maxfield, "The Design Warrior's Guide to FPGAs", Newnes, 2004.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1		2	1		
CO2	1		2	1		
CO3	2		2	2	3	
CO4	1		2	2		

20IS707 INDUSTRIAL ROBOTICS 3 0 0 3

Course Objective:

- To impart knowledge about design and control of industrial robots

Course Outcomes

CO1: Understand the principle of operation of sensors and actuators used in robotics
CO2: Develop the kinematic models of manipulators
CO3: Implement algorithms in autonomous mobile robot path planning, localization and control
CO4: Design of algorithms for various industrial robotics applications

Automation and Robotics, Historical Development, Basic Structure of Robots, Complete Classification of Robots, Fundamentals about Robot Technology. Various Sensors and their Classification. Actuators & Drives - DC Motors, Stepper Motors, Servos, H-Bridge. Concepts about Basic Control System, Control Loops of Robotic Systems.
Robotic Manipulators – Series and parallel, Anatomy – Joints, Links, Arm, Wrist, Gripper, Arm and Wrist configuration, Manipulation and Control. Direct Kinematic Model - Denavit-Hartenberg Notation, Kinematic Relationship between adjacent links, Manipulator Transformation Matrix; Inverse Kinematic Model – Manipulator Workspace, Solvability, Solution techniques, Closed form solution.

Mobile Robots - Anatomy, Concepts of Mapping, Localization and path planning for Autonomous Robots & Automated Guided Vehicles (AGVs). Robot Operating Systems.

Text Books/ References

1. Thomas Bräunl, "Embedded Robotics: Mobile Robot Design and Applications with Embedded Systems", Third Edition, Springer-Verlag Berlin Heidelberg, 2008.
2. R.K.Mittal and I.J.Nagrath, "Robotics and Control", Tata McGraw-Hill Publishing Company Ltd., New Delhi, 2003.
3. John J. Craig, "Introduction to Robotics: Mechanics and Control", Third Edition, Pearson/Prentice Hall, 2005.
4. AnisKoubaa, "Robot Operating System (ROS) The Complete Reference", First Volume, Springer, 2016.
5. K.S. Fu, R.C. Gonzalez and C.S.G. Lee, "Robotics: Control, Sensing, Vision, and Intelligence", McGraw-Hill, New York, 1987.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1		1	1		
CO2	2		2	2		
CO3	2		2	2		
CO4	2		2	2		

20IS708 HUMAN MACHINE INTERFACE 3 0 0 3

Course Objective:

- To introduce the design parameters for Human Machine Interface
- To familiarize with the different interaction models

Course Outcomes

CO1: Understand the fundamental approaches for HMI
CO2: Identify the different interaction models for interfacing
CO3: Familiar with the communication and collaboration models
CO4: Apply HMI modeling for real time applications

HMI Definitions and Basic Concepts - HMI Interfacing - Event Driven Approach - Considerations - HMI Hardware and Software Selection - HMI Ergonomics - Paradigms for Interaction – Interaction design – Design rules- HMI in the Software Process – Implementation – Universal design – User support- Models of communication – Cognitive models – Communication and Collaboration models- Modeling Rich Interaction - Graphical user interfaces overview – Ubiquitous computing and Augmented Realities – Hypertext, Multimedia and the World Wide Web – Security.

Text Books/ References

1. Prof Alan Dix, Janet E. Finlay, Gregory D. Abowd and Russell Beale, "Human-Computer Interaction", Third Edition, Prentice Hall, 2003.
2. Jonathan Lazar, Jinjuan Feng and Harry Hochheiser, "Research Methods in Human-Computer Interaction", Second Edition, Morgan Kaufmann, 2007.
3. Wilbert O. Galitz, "The Essential Guide to User Interface Design: An Introduction to GUI Design Principles and Techniques", Third Edition, Wiley, 2007.
4. Alan Cooper, Robert Reimann, David Cronin, "About Face3: Essentials of Interaction design", Third Edition, Wiley, 2007.
5. Donald A. Normann, "The Design of Everyday Things", Basic Books, Revised and Expanded Edition, 2013.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1		1	1		
CO2	1		2	2		
CO3	1		2	2		
CO4	2		2	2		

20IS709 COMMUNICATION SYSTEMS FOR INDUSTRIAL NETWORKING 3 0 0 3

Course Objective:

- To introduce the basic terminologies in communication systems
- To familiarize with wired and wireless communication protocols for industrial networks

Course Outcomes

CO1: Understand the basic terminologies in communication systems

CO2: Understand the SCADA System Components and architectures in automation industries

CO3: Explain the concepts, design considerations and design rules of industrial Ethernet

CO4: Identify wireless communication protocols for industrial networking

Communication – Terms and definitions. Modulation, Bandwidth, Channel Capacity, Baud Rate, Data Rate, Throughput, Unicast, Multicast, Broadcast, Network, Network elements – Source, Sink, Intermediate Nodes. Communication systems – Wired, Wireless Technologies and Protocol Stack.

SCADA: Fundamental Principles of SCADA, Remote Terminal Unit, The Master Station, Communication Architecture, SCADA software package. Ethernet systems - IEEE 802.3 – Physical layer - Medium access control – Collisions - Ethernet design rules - Fast and gigabit

Ethernet systems - design considerations - Internet layer protocol - UDP - TCP/IP - Layers, Functions and Protocols - ProfiNet - LAN system components – Structured cabling – Industrial Ethernet – Troubleshooting Ethernet.
Wireless communications- Radio spectrum – Frequency allocation – Radio modem – Intermodulation – Implementing a radio link – RFID: Basic principles of radio frequency identification – Transponders – Interrogators, Wireless HART.
Applications & case studies: Factory network, Transportation automation

Text Books/ References

1. Richard Zurawski, "Industrial Communication Technology Handbook", 2nd edition, CRC Press, 2017
2. Andrew S. Tanenbaum, David J. Wetherall, "Computer Networks" 5th edition, Prentice Hall, 2011.
3. David Bailey Edwin Wright, "Practical SCADA for Industry", 1st Edition, Elsevier, 2003.
4. Steve Mackay, Edwin Wright, Deon Reynders and John Park, ―Practical Industrial Data Networks: Design, Installation and Troubleshooting, Newnes (Elsevier), 2004.
5. Deon Reynders and Edwin Wright, ―Practical TCP/IP and Ethernet Networking, IDC Technologies, 2006.
6. James Powell, Henry Vandelinde, ―Catching the Process Fieldbus an Introduction to PROFIBUS for Process Automation", Momentum Press, 2013.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1		1	1		
CO2	1		1	1		
CO3	2		2	2		
CO4	2		2	2		

20IS710 ARTIFICIAL INTELLIGENCE FOR SMART GRIDS 3 0 0 3

Course Objective:

- To familiarize the concepts of smart grid
- To explore AI applications in smart grids

Course Outcomes

CO1: Understand the basics of power system management and its automation
CO2: Familiar with the features of Smart grid
CO3: Understand synchronized measurement and management systems
CO4: Employ AI in real time smart grid applications

Introduction, Grid Development History, Smart grid vs conventional grid, Smart grid technologies- Power system and ICT in Generation, Transmission and Distribution, Management aspects (Utility, Operator, Consumer), SCADA Systems, Remote Terminal unit, Synchronized Measurements, Selecting PMU Locations, Integrated Phasor Measurement Network Subsystem and Energy Management System, Distributed generation, storage, DD, DR, AMI, WAMS, WACS. Case Studies: AI applications for State Estimation paradigm, Load Shedding, Economic Emission Dispatch, Smart Metering and voltage regulation in smart grids

TEXT BOOKS/ REFERENCES

1. James Momoh, "Smart Grid: Fundamentals of Design and Analysis", Wiley IEEE Press, 2012.
2. Janaka Ekanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu and Akihiko Yokoyama, "Smart Grid: Technology and Applications", Wiley, 2012.
3. Nouredine Hadjsaïd and JeanClaude Sabonnadière, "Smart Grids", Wiley ISTE, 2012.
4. Ali Keyhani and Muhammad Marwali, "Smart Power Grids 2011", Springer, 2011.
5. Ahmed F Zobaa, Alfredo Vaccaro, "Computational intelligence Applications in smart grids", Imperial College Press, 2015.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1		1	2		
CO2	1		1	2		
CO3	2		2	2		
CO4	2		2	2		

20IS711 CYBER SECURITY FOR INDUSTRIAL SYSTEMS 3 0 0 3

Course Objective:

- To introduce the foundational concepts and tenets of IIoT security by presenting real-world case studies, threat models, and reference architectures.
- To provide with techniques and methodologies of securing industrial systems.

Course Outcomes

CO1: Understand the key techniques and theory behind cyber security of industrial systems

CO2: Understand the security threat models and reference architectures for connected industrial systems

CO3: Apply the various techniques and methodologies for securing (both hardware and software) IIoT

CO4: Apply various techniques for risk assessment and threat modelling

CO5: Design and build secured industrial system for any one interesting Use case

UNIT 1: Overview of Industrial Systems: view function-monitor function-control function, Industrial control system architecture: PLC-HMI-SCADA-Distributed control system-Safety instrumented system, The Purdue model for Industrial control systems, Industrial control system communication media and protocols, IoT Protocols-and IoT Cloud Infrastructure.
UNIT II: NIST Industrial Control System Security- cross functional team-ICS specific security policies and procedures – Security risk management framework – Security program development process for Industrial systems-device security considerations: procurement, installation and operation phase. Device Security – hardening – patching. Industrial System application security testing and patching
UNIT III: Industrial Control System Risk Assessment: Attacks, objectives, and consequences, Asset identification and system characterization, Vulnerability identification and threat modelling, Risk calculation and mitigation. The defence-in-depth model: Physical security, Network security, Computer security, Application security, Device security Policies, procedures, and awareness.
Case Study: Identification and categorization of Industrial system and network assets – Risk Assessment – mitigation activities – security improvement cycle of any interesting Industrial IoT use case.

Text Books/ References

1. Pascal Ackerman, "Industrial Cyber security", Packt Publishing, 2017
2. Sravani Bhattacharjee, "Practical Industrial Internet of Things Security", Packt Publishing, 2018
3. Joel Thomas Langill, Eric D. Knapp, “Industrial Network Security”, Syngress Publisher 2014
4. Tyson Macaulay, Bryan L. Singer, "Cybersecurity for Industrial Control Systems: SCADA, DCS, PLC, HMI, and SIS", CRC Press 2011

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1		1	1		
CO2	1		1	1		
CO3	2		2	2		
CO4	2		2	2		
CO5	1		2	2	2	

20IS712 DEEP LEARNING 3 0 0 3

Course Objective:

- To familiarize with the basic and advanced neural network models to solve industrial problems

Course Outcomes

CO1: Understand the basic terminologies in machine learning

CO2: Know the learning and forecasting methodologies in neural networks

CO3: Identify the neural models for deep learning

CO4: Apply deep learned models for real time industrial problems

Probability and Information Theory, Basics of classical Machine Learning techniques, algorithmic differentiation-forward and backward, classification and regression, time series forecasting. Introduction to Neural Networks, Backpropagation, Multi-layer Perceptrons, Deep Feedforward Networks, Regularization for Deep Learning Optimization for Training Deep Models, Convolutional Networks, Generative models, Variational autoencoders. Sequence Modeling: Recurrent and Recursive Nets. Long short-term memory networks (LSTM). Case studies in fault detection and prognosis in industrial systems, industrial robotics.

Text Books/ References

1. Ian Goodfellow, Yoshua Bengio and Aaron Courville, "Deep Learning", MIT Press, 2017

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1		2	2		
CO2	2		2	2		
CO3	2		2	2		
CO4	2		2	2	2	

20IS713 OPERATIONS RESEARCH 3 0 0 3

Course Objective:

To impart knowledge in handling optimization problems through operations research techniques

Course Outcomes

CO1: Understand decision-making in certainty/uncertainty conditions

CO2: Formulate models and solve real-time problems

CO3: Apply advanced operations research techniques to cater industrial requirements

Linear programming- Simplex method – Big M method – Two phase method cases - Goal programming. Duality, sensitivity analysis-Changes in right- hand side constants of constraints- changes in objective function co-efficient-adding a new constraints-adding a new variable.

Dual simplex method- Generalized simplex algorithm –Integer programming algorithm - Cutting plane algorithm- Branch and Bound technique – Zero-one implicit enumeration algorithm.

Deterministic dynamic programming –Recursive nature of computations in DP - Applications of dynamic programming - Cargo loading model – Work force size model – Equipment replacement model-Inventory model.

Network models - Shortest path model – Maximal flow problem - Crashing of project network – Resource leveling & Resource allocation technique.

Unconstrained nonlinear algorithms-Constrained algorithms- Separable programming - Quadratic programming-Geometric programming-Stochastic programming.

TEXT BOOKS/ REFERENCES

1. Handy M.Taha, "Operations Research, an introduction", 7th edition, PHI, 2003.
2. Don T.Phillips, A.Ravindran & James Solberg, "Operations Research: Principles and practice", John Wiley, India, 2006.
3. G.Srinivasan, "Operations Research Principles and Applications" ,PHI 2008
4. Panneerselvam R, "Operations Research", Prentice – Hall of India, New Delhi, 2002

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1		1	2		
CO2	2		2	2		
CO3	2		2	2		

20IS798 DISSERTATION 8

Course Objective:

- To review the literature and formulate a research problem
- To develop skill in use of computational and analytical tools
- To carry out the investigation and analyse the observations
- To communicate the findings orally as well as in writing
- To familiarize with project management

Course Outcomes

CO1: Understanding research methodology

CO2: Project planning

CO3: Skill in literature survey

CO4: Knowledge of computational and analytical tools

CO5: Technical communication skill

Each student should select and work on a topic related to his/her field of specialization during third semester under the supervision of a faculty member. By the end of the third semester he/she must prepare a report in the approved format and present it.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		2			
CO2	2		2			3
CO3	2	3	2			3
CO4	2		2	3	3	3
CO5	2	3	2			

20IS799 DISSERTATION 12

Course Objective:

- To review the literature and formulate a research problem
- To develop skill in use of computational and analytical tools
- To carry out the investigation and analyse the observations
- To communicate the findings orally as well as in writing
- To familiarize with project management

Course Outcomes

CO1: Skill in project planning and management
CO2: Domain knowledge
CO3: Skill in use of tool
CO4: Technical communication skill
CO5: Comprehension

During fourth semester each student should work further on the topic of the minor project or a new topic under the supervision of a faculty member. By the end of fourth semester the student has to prepare a report in the approved format and present it. Finally there has to be a research paper published in a scopus indexed conference or journal with proper affiliation and approval from the department.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2		3			3
CO2	2		3	3		
CO3	2		3	3	3	3
CO4	2	3	3			3
CO5	2		3			