Proposed New Curriculum and New Courses
for
M.Tech Embedded System
Amrita Vishwa Vidyapeetham, Coimbatore

M.Tech Embedded Systems is a multidisciplinary programme which caters to diverse domains of engineering starting from electronics, communication, electrical, instrumentation, computer science and even mechanical with an exponential growth in job opportunities and research. It commenced as the second PG programme of the EEE department. The course is well supported by a highly equipped laboratory (Amrita Microsoft Embedded Systems Laboratory).

Amrita Microsoft Embedded Systems Laboratory was established in the year 2008 with the inception of M. Tech (Embedded Systems) by the department of EEE in the year 2008. The lab can accommodate up to forty students at a time. It was set up with financial support from MICROSOFT for half a crore. The embedded systems lab has state of the art facilities with several hardware and software platforms for the entire course.

The MTech. Embedded Systems curriculum is framed to cater to all the hardware boards by offering various subjects like Real Time Systems, Embedded System Programming, Computer Architecture using ARM, Digital Signal Processors, Artificial Intelligence, Embedded Systems Programming, IoT, Robotics, Automotive in addition to the large number of elective courses offered.

Each subject has an associated lab which corroborates that practical training in the domain of Embedded Systems. The Dissertation at the end of the program also helps in perpetuating that the laboratory is fully utilized. The laboratory is open from 9 am to 10.30 pm to enable students to work on various boards and update their skills.

With a strong focus on imparting research skills among the students, in significant areas of Embedded Systems the program includes key components which would make the graduates suited and employable in, industrial, government R&D, and academic settings, spanning diverse areas of the exponentially growing embedded domain.

Program Educational Objectives (PEOs)

The educational objectives of the MTech Embedded Systems program include:

1. Graduates will acquire the ability to migrate to all domains of embedded solutions.
2. Graduates will practice ethics in their professional domain and imbibe the professional attitude developed
3. Graduates will learn to work well in team environment considering the multidisciplinary aspect of embedded systems.

Program Outcomes (POs):

On completion of the MTech (Embedded Systems) program, the graduate will develop:

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 that the requirements in the appropriate bachelor program.
PO4: Ability to acquire state-of-the-art technologies for development of embedded solutions.
PO5: Ability to work in a multidisciplinary environment employing fundamental knowledge in embedded systems.

CURRICULUM

I Semester

Course Code	Type	Subject	L T P	Credits
21MA610	FC	Applied Mathematics for Embedded Systems	3-1-0	4
21ES601	FC	Embedded System Programming	3-0-2	4
21ES602	FC	Embedded System Design using ARM	3-0-2	4
21ES603	FC	Signal & Image Processing	3-0-2	4
	E	Elective I	3-0-0	3
21ES681	SC	Application Lab for Embedded Systems	0-0-2	1
21RM609	FC	Research Methodology	2-0-0	2
21HU601	HU	Amrita Values Program**		P/F
21HU602	HU	Career Competency I**		P/F
		Credits		22

II Semester

Course Code	Type	Subject	L T P	Credits
21ES611	SC	Real Time Operating Systems	3-0-2	4
21ES612	SC	FPGA Based System Design	3-0-2	4
21ES613	SC	Machine Learning for Embedded Applications	2-0-2	3
21ES614	SC	Internet of Things	3-0-2	4
	E	Elective – II	3-0-0	3
	E	Elective – III	3-0-0	3
21HU603	HU	Career Competency II	0-0-2	1
		Credits		**22**

III Semester

Course Code	Type	Subject	L T P	Credits
21ES798	P	Dissertation I		10
		Credits		10

IV Semester

Course Code	Type	Subject	L T P	Credits
21ES799	P	Dissertation II		16
		Credits		**16**
		Total Credits		**70**

List of Courses

Foundation Core

Course Code	Subject	L T P	Credits
21MA610	Applied Mathematics for Embedded Systems	3-1-0	4
21ES603	Signal and Image Processing	3-0-2	4
21ES601	Embedded System Programming	3-0-2	4
21ES602	Embedded System Design using ARM	3-0-2	4
21RM609	Research Methodology	2-0-0	2

Subject Core

Course Code	Subject	L T P	Credits
21ES681	Application Lab for Embedded Systems	0-0-2	1
21ES611	Real Time Operating Systems	3-0-2	4
21ES612	FPGA Based System Design	3-0-2	4
21ES613	Machine Learning for Embedded Applications	2-0-2	3
21ES614	Internet of Things	3-0-2	4

Electives

21ES631	Distributed Computing	3-0-0	3
21ES632	Hardware Software Co-Design	3-0-0	3
21ES633	Embedded System Design Process	2-0-2	3
21ES634	Embedded Systems for Automotive Applications	2-0-2	3
21ES635	Embedded Systems in Robotics	2-0-2	3
21ES636	Embedded Systems in Biomedical Applications	3-0-0	3
21ES637	Video Processing	3-0-0	3
21ES638	GPU Architecture and Programming	2-0-2	3
21ES639	Advanced Image Processing and Computer Vision	2-0-2	3
21ES640	Cryptography and Network Security	3-0-0	3
21ES641	Web Technologies and Applications	3-0-0	3
21ES642	Mobile Application Development	2-0-2	3
21ES643	Advanced Mobile and Wireless Networks	3-0-0	3
21ES644	Multi Core Architectures	2-0-2	3
21ES645	Fault Tolerant System	3-0-0	3
21ES646	Embedded Systems in Smart Grid	2-0-2	3
21ES647	Design for IoT and Cloud Computing	2-0-2	3
21ES648	Intelligent Systems Design	3-0-0	3

SYLLABUS

21MA610 APPLIED MATHEMATICS FOR EMBEDDED SYSTEMS 3-1-0-4

Linear Algebra: Review of Matrices. Vector spaces and subspaces, linear independence, basis and dimensions, linear transformations, orthogonality, projections, and least square applications. Eigenvalues and eigenvectors, Positive Definite Matrices - Minima, Maxima and saddle points, semidefinite and indefinite matrices, Singular value decomposition.

Optimization: Least-squares and linear programming, convex and non-linear optimization. Convex sets, convex optimization Problems, Optimization problem in standard form, Quasiconvex optimization, linear optimization, quadratic optimization, inequality constraints, semi definite programming, vector optimization. Duality, approximation and fitting, statistical estimation, geometric problems, Unconstrained minimization, gradient descent method, steepest descent method, Newton's method, Equality constrained minimization, eliminating equality constraints, Newton's method with equality constraints, Interior point method.

TEXTBOOKS/REFERENCES:

1. Gilbert Strang, *"Linear Algebra and Its Applications"*, Fourth Edition, Cengage, 2006.
2. Howard Anton and Chris Rorres *"Elementary Linear Algebra"*, John Wiley & Sons, 1994, Seventh Edition.
3. Edwin K.P. Chong, Stanislaw H. Zak, *"An introduction to Optimization"*, 2nd edition, Wiley, 2013.
4. Kalyanmoy Deb, *"Optimization for Engineering Design: Algorithms and Examples"*, Prentice Hall, 2002.
5. Stephen P. Boyd and Lieven Vandenberghe D, *"Convex Optimization"*, Cambridge University Press, 2004.

CO Code	**Course outcome statement**
21MATXXX.1	Analyzing solvability of the linear system of equations and applying matrix algebra in solving a system of linear Equations
21MATXXX.2	Understanding concepts of vector space and the link between linear transformation and matrix.
21MATXXX.3	Understanding the concepts of Gram-Schmidt orthogonalization, Least squares and Singular value decomposition.
21MATXXX.4	Understanding different types of Optimization Techniques in engineering problems. Learning
21MATXXX.5	Understanding gradient based Optimizations Techniques in single variables as well as multi-variables

CO Code	PO1	PO2	PO3	PO4	PO5
21MATXXX.1	2	1			
21MATXXX.2	1	1			
21MATXXX.3	1	1			
21MATXXX.4		1			
21MATXXX.5	2	1			

21ES601 EMBEDDED SYSTEM PROGRAMMING 3-0-2-4

Version control system, benefits, Types of Version Control Systems, Centralized Version Control Systems, Distributed Version Control Systems. Coding standard and guidelines. Code documentation. Functions, Pointers, Structure, Data Structures- Stacks and Queues, Linked List.

Introduction to Object oriented design pattern. Basic elements, mutable and immutable type, tuples, list, and dictionaries. Control statements, loops, Functions, modules, Exception and assertions. Classes, Access Modifiers, dunder/magic methods, object-oriented programming, abstraction, inheritance, encapsulation, polymorphism, Code testing.
Porting to microcontrollers, Code Analysis and Performance tuning

TEXTBOOKS/REFERENCES:

1. Jon Loeliger, Matthew McCullough,"*Version Control with Git"*, O'Reilly Media, Inc 2nd Edition,2012
2. Zed A. Shaw, *"Learn Python 3 the Hard Way",* Addison-Wesley, 2016
3. Robert Martins, *"Clean Code" ,* Pearson Education, second edition,2012
4. Xavier Rival and Kwangkeun Yi , "*Introduction to Static Analysis an Abstract Interpretation Perspective"*, MIT Press, January 2020

CO Code	Course outcome statement
21ESXXX.1	Understand the basics of version control system and documentation.
21ESXXX.2	Develop structured programming using C.
21ESXXX.3	Develop code using object-oriented concepts.
21ESXXX.4	Analyze programs for real world applications.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1	2	2	2	
21ESXXX.2	2	2	2	2	
21ESXXX.3	2	2	3	2	
21ESXXX.4	3	1	3	3	1

21ES602 EMBEDDED SYSTEM DESIGN USING ARM 3-0-2-4

An introduction to Embedded Processors – RISC verses CISC- CPU Performance Metrics –Benchmark - RISC processor design. ARM Architecture – Programming Model, Pipelined data path design - Pipeline Hazards, Addressing Modes, ARM Instruction set – Thumb2 Instruction - ARM Programming - Floating Point data representation - Vector Floating Point Unit, Interrupts & Exception Handling- DSP Extensions - Assembly programming. Memory system design - Memory Management unit - Cache Memory - Virtual Memory. Introduction to ARM based Microcontrollers – Peripherals – Ports, Timers, PWM, ADC, UART, SPI, I2C - Application development – Bare - metal Programming, Rapid Prototyping with libraries - Case studies. ARM advanced CPU cores, Comparison with other architectures like PowerPC, DSP, PIC, MSP, FPGA etc.

TEXTBOOKS/REFERENCES:

1. Steve Furber, "*ARM System-on-Chip Architecture*", Pearson India, 2015.
2. Joseph Yiu, "*The Definitive Guide to ARM® Cortex®-M3 and Cortex®-M4 Processors*", Third Edition, Newnes, 2013.
3. Rob Toulson and Tim Wilmshurst, "*Fast and Effective Embedded Systems Design: Applying the ARM mbed*", Newnes, 2012.
4. Andrew Sloss, Dominic Symes and Chris Wright, "*ARM System Developer's Guide: Designing and Optimizing System Software*", Morgan Kaufumann Publisher, 2011.
5. ARM Microcontroller User Manual.

CO Code	Course outcome statement
21ESXXX.1	Understand the architecture of ARM Processor.
21ESXXX.2	Analyze the instruction set of ARM Processor.
21ESXXX.3	Understand the interface of peripherals in ARM Microcontroller.
21ESXXX.4	Develop an Embedded application using ARM Microcontroller.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1		2	3	
21ESXXX.2	2		3	3	
21ESXXX.3	2		2	3	
21ESXXX.4	3	2	3	2	2

21ES603 SIGNAL AND IMAGE PROCESSING 3-0-2-4

Review of Frequency and time domain analysis -Discrete Fourier Transforms, Fast Fourier Transform. Digital Filters-IIR Filters–Bilinear transformation. FIR filters– Windowing method- Application to real time signals: simulated, audio with noise filtering and analysis of signals.
Elements of Visual Perception- Image Sensing and Acquisition-Simple Image Formation
- Image Sampling and Quantization—Image Quality-Introduction to colour image-, Introduction to color image – RGB and HSI Models. Image transform: Fourier transform, DFT, Hadamard Transform. Filters-Image enhancement in Spatial domain: Introduction to image enhancement, basic grey level transforms, Histogram, Histogram-processing equalization, Matching & color histogram, Enhancement using arithmetic/logic
Smoothening Spatial Filtering, Sharpening Spatial Filtering, Enhancement in spatial domain:
Algorithms in thresholding- Edge Detection, Hough Transform, Region based segmentation, Morphological-dilation and erosion, opening and closing (Qualitatively). Shape Identification, Texture Identification, Colour Identification Selection of sensors and Processors for real time implementation, Applications in Real Time Scenario using Rasperry Pi Processor.

TEXTBOOKS/REFERENCES

1. Mitra S. K, *"Digital Signal Processing, A Computer-Based Approach"*, Third Edition,McGraw Hill, 2005.
2. Ifeachor E. C and Jervis B. W, *"Digital Signal Processing: A Practical Approach"*,Second Edition, Addison Wesley, 2002.
3. Steven W Smith, *"The Scientist and Engineer's Guide to DSP"*, Newnes, 2002.
4. Rafael C. Gonzalez and Richard E. Woods, *"Digital Image Processing"*, Third Edition, Prentice Hall, 2008.
5. AshwinPajankar, *"Raspberry Pi Computer Vision Programming"*, Packt Publishing, May 2015.

CO Code	Course outcome statement
21ESXXX.1	Understand discrete/ and fast fourier transforms for signal analysis.
21ESXXX.2	Comprehend digital filters for signal modification applications
21ESXXX.3	Understand image sensing techniques, image representations and image transforms.
21ESXXX.4	Illustrate image enhancement techniques in spatial and frequency domain on real time problems.
21ESXXX.5	Develop image processing techniques for embedded applications

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1		1	1	1
21ESXXX.2	2		1	1	1
21ESXXX.3	2		2	1	1
21ESXXX.4	2		2	1	1
21ESXXX.5	3	3	2	1	2

21ES681 APPLICATION LAB FOR EMBEDDED SYSTEM 0-0-2-1

Introduction to various software tools such as MATLAB/LabVIEW/Visual studio. Implement simple real-world applications in embedded platforms.

CO Code	**Course outcome statement**
21ESXXX.1	Comprehend the requirements of embedded system application.
21ESXXX.2	Analyse the feasibility of embedded system application.
21ESXXX.3	Develop prototype for embedded application.
21ESXXX.3	Validate the performance of embedded application.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	3	2	1		1
21ESXXX.2	3	2	1	1	1
21ESXXX.3	3	2	2	2	2
21ESXXX.4	3	2	2	2	2

21RM609 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

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, 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

CO Code	**Course outcome statement**
21ESXXX.1	Understand types and methods of research, modelling and referencing
21ESXXX.2	Analyse experimental results
21ESXXX.3	Prepare and present research papers
21ESXXX.4	Knowledge on IPR and ethics in publication

CO Code	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**
21ESXXX.1	1	3	1		
21ESXXX.2	1	3	2		
21ESXXX.3	2	3	2		
21ESXXX.4	2	3	1		

21ES611 REAL TIME OPERATING SYSTEM 3-0-2-4

Overview of concepts of GPOS, GPOS functionalities, Evolution of operating systems. Introduction to real-time systems, RTOS basic architecture, RTOS vs. GPOS. Architecture of OS (Monolithic, Microkernel, Layered, Exokernel and Hybrid kernel structures). POSIX Standards. RTOS Kernel services.
Task Management -tasks, process and threads, task attributes and types, preemption-context switching, task states and transition, task control block. Introduction to real-time task scheduling, clock-driven and priority-driven scheduling, uniprocessor scheduling algorithms- RM-response time analysis, DM, EDF-processor demand analysis, Least Laxity First (LLF), and introduction to multiprocessor scheduling concepts. Blocking, deadlock, priority inversion and solutions.
Task Communication and Synchronization - Semaphores and Mutex, Mailbox, Queue, Pipes. Timer Management, Interrupt handling, Memory Management-Cache and virtual memory, Input-Output handling. Familiarization of FreeRTOS – architecture, porting, Real time applications using RTOS.

TEXTBOOKS/REFERENCES:

1. Jane W.S. Liu, *"Real -Time Systems"*, First Edition, Pearson Education, 2000.
2. Cheng, A. M. K., *"Real-Time Systems: Scheduling, Analysis, and Verification"*, First Edition, Wiley, 2002.
3. Krishna, C. M., Shin, K. G., *"Real-Time Systems"*, First Edition, McGraw-Hill, 2017.
4. Richard Barry, *"Mastering the FreeRTOS™ Real Time Kernel A Hands-On Tutorial Guide"*, First Edition, Real Time Engineers Ltd., 2016.
5. Tanenbaum, *"Modern Operating Systems,"* Third Edition, Pearson Edition, 2009.

CO Code	**Course outcome statement**
21ESXXX.1	Understand the basic concepts in real time systems.
21ESXXX.2	Illustrate various services provided by the RTOS Kernel.
21ESXXX.3	Analyze various real-time scheduling algorithms.
21ESXXX.4	Design and develop real time applications using RTOS.

CO Code	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**
21ESXXX.1	1			2	
21ESXXX.2	1			1	
21ESXXX.3	2	1	2	2	
21ESXXX.4	3	2	3	3	2

21ES612 FPGA BASED SYSTEM DESIGN 3-0-2-4

Introduction to FPGAs – Design flow – Circuit Fabrics – LUTs and IO Blocks – FPGA Technology overview – Digital Design for FPGAs - High Level System Architecture and Specification: Behavioural modelling and simulation - Hardware description languages – Design of combinational and sequential subsystems – Case Study of RTL Design for FPGAs – Interpreting Synthesis and Implementation reports

Design of data path and controller subsystems – FIFOs - Memory controllers – Platform FPGAs - DSP blocks – FPGA Block RAMs - Synthesis issues – System Level synthesis from high level languages

Block-based design flow – Case study of block-based design of a digital system – FPGA processor fabrics and bus interfaces – FPGA based embedded design flow

TEXTBOOKS/ REFERENCES

1. Michael D. Ciletti, *"Advanced Digital Design with Verilog HDL"*, Second Edition, Pearson Higher Education, 2011.
2. Stephen Brown and Zvonko Vranesic, *"Fundamental of Digital Logic with VHDL Design"*, Third Edition, McGraw Hill, 2009.
3. Samir Palnitkar, "Verilog HDL, A Guide to Digital Design and Synthesis", Second Edition, Pearson Education, 2003.
4. T. R. Padmanabhan and B. Bala Tripura Sundari, *"Design Through Verilog HDL"*, Wiley Interscience, 2004
5. Wayne Wolf, *"FPGA-Based System Design"*, Prentice Hall India Pvt. Ltd., 2005.

CO Code	**Course outcome statement**
21ESXXX.1	Understand synthesizable HDL modelling of digital subsystems.
21ESXXX.2	Formulate architecture of systems at the RTL abstraction.
21ESXXX.3	Implement digital systems in FPGA platforms and evaluate them based on tool reports
21ESXXX.4	Employ custom and block design to realize embedded systems for FPGA implementation.

CO Code	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**
21ESXXX.1	2		2	1	
21ESXXX.2	2		2	1	
21ESXXX.3	3	1	3	2	1
21ESXXX.4	3	2	3	2	2

21ES613 MACHINE LEARNING FOR EMBEDDED APPLICATIONS 2-0-2-3

Introduction to Machine learning, different forms of learning: supervised and unsupervised learning, classification and regression, parametric and nonparametric models, curse of dimensionality, linear and logistic regression. Support vector machines for regression and classification. Neural Networks, Introduction to Convolutional Neural Network (CNN)

Motion Classification and Anomaly Detection. Edge Impulse, Data Collection, Feature Extraction from Motion Data, Feature Selection in Edge Impulse, Machine Learning Pipeline, Model Training in Edge Impulse, deploy a Trained Model to embedded platform, Anomaly Detection.

Audio classification and Keyword Spotting. Audio Data Capture, Audio Feature Extraction (MFCC), Implementation Strategies and Sensor Fusion, CNN training for sound classification.

TEXTBOOKS / REFERENCES:

1. Trevor Hastie, Robert Tibshirani, Jerome Friedman, *"The Elements of Statistical Learning: Data Mining, Inference, and Prediction"*, Second Edition, Springer, 2009.
2. Pete Warden, Daniel Situnayake, *"TinyML: Machine Learning with TensorFlow Lite on Arduino and Ultra-Low-Power Microcontrollers"*, O'Reilly Media; 1st edition (16 December 2019)
3. Christopher M. Bishop, *"Pattern Recognition and Machine Learning"*, Springer, 2nd edition 2011.
4. Tom M. Mitchell, *"Machine Learning"*, McGraw-Hill, 1st edition 1997.
   https://www.coursera.org/learn/introduction-to-embedded-machine-learning#syllabus
   https://sites.google.com/g.harvard.edu/tinyml/home
   https://www.udemy.com/course/getting-started-with-embedded-ai-hands-on-experience/

CO Code	Course outcome statement
21ESXXX.1	Understand the fundamentals of machine learning
21ESXXX.2	Familiarise supervised and unsupervised machine learning models.
21ESXXX.3	Implement trained ML model on an embedded platform
21ESXXX.4	Validate open-source deep learning model on an embedded platform

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1	1	1	1	1
21ESXXX.2	2	1	1	1	
21ESXXX.3	2	2	3	3	2
21ESXXX.4	2	2	3	3	2

21ES614 **INTERNET OF THINGS** **3-0-2-4**

Introduction to IoT - Definitions, frameworks and key technologies. Functional blocks of IoT systems: hardware and software elements- devices, communications, services, management, security, and application. Challenges to solve in IoT.

Basics of Networking & Sensor Networks - Applications, challenges - ISO/OSI Model, TCP/IP Model. Sensor network architecture and design principles. IoT technology stack -overview of protocols in each layer. Communication Protocols. Communication models, Application protocols for the transfer of sensor data. Infrastructure for IoT: LoRa-Wan, 6LoWPAN, 5G and Sigfox. Operating systems and programming environments for embedded units (Contiki).

Introduction to Cloud, Fog and Edge Computing- Modern trends in IoT – Industrial IoT, Wearable. Applications of IoT - Smart Homes/Buildings, Smart Cities, Smart Industry, and Smart Medical care, Smart Automation etc.

TEXTBOOKS/REFERENCES:

1. Andrew S. Tanenbaum and David J. Wetherall, *"Computer Networks"*, 5th Edition, Pearson Education, 2011.
2. Holger Karl and Andreas Willig, *"Protocols and Architectures for Wireless Sensor Networks"*, John Wiley and Sons Ltd., 2005.
3. Olivier Hersent, David Boswarthick and Omar Elloumi, *"The Internet of Things: Key Applications and Protocols"*, Wiley, 2012.
4. Rayes, Ammar, Salam, Samer *"Internet of Things from Hype to Reality"* 2nd edition
5. Boris Adryan, Dominik Obermaier, Paul Fremantle *"The Technical Foundations of IoT"* Artech House 2nd edition.

CO Code	Course outcome statement
21ESXXX.1	Understand the concepts and principles of IoT.
21ESXXX.2	Implement communication protocols related to IoT and machine to machine communication (M2M)
21ESXXX.3	Familiarize key technologies in an IoT framework.
21ESXXX.4	Develop IoT based solution for real world applications.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1		1	3	
21ESXXX.2	3	1	2	3	
21ESXXX.3	1		1	3	2
21ESXXX.4	3	1	3	1	2

21ES631 DISTRIBUTED COMPUTING 3-0-0-3

Introduction to distributed computing systems (DCS), DCS design goals, Fundamental issues, System architecture, Distributed and Centralized architecture. Distributed Coordination: Temporal ordering of events, Lamport's logical clocks, Vector clocks; Ordering of messages, Physical clocks, Global state detection, Process synchronization, Modelling of distributed real-time systems. Basics of real time systems: Functional, Temporal and Dependability requirements.

Real time communication, Requirements of real time communication system, Flow Control-Explicit and Implicit, Thrashing, Inter-process communication: Message passing communication, Remote procedure call, Group communication, Deadlocks in distributed systems, Load scheduling and balancing techniques, Consistency Models, Fault Tolerance.

Introduction to Distributed System Models, High-Performance Computing, Grid Computing, Cloud Computing, Many-core Computing, Many-Task Computing, Data-Intensive Computing, Parallel architectures, and Multithreaded programming. Introduction to GPU architecture and programming. Usage of tools for GPU Programming.

TEXTBOOKS/REFERENCES:

1. G. Coulouris, J. Dollimore, T. Kindberg, G. Blair, *"Distributed Systems: Concepts and Design,"* Addison Wesley, Fifth edition, 2012.
2. Kai Hwang Jack Dongarra Geoffrey Fox, *"Distributed and Cloud Computing" From Parallel Processing to the Internet of Things*, 1st Edition, Morgan Kaufmann 2013.
3. Andrew S. Tanenbaum and Maarten van Steen. *"Distributed Systems: Principles and Paradigms" (DSPD)*, Prentice Hall, 2nd Edition, 2007
4. H Kopetz, *"Real Time Systems: Design Principles for Distributed Embedded Applications"*, Kluwer, Edition 2, 2011.
5. Rajkumar Buyya, Satish Narayana Srirama, *"Fog and Edge Computing: Principles and Paradigms"*, Wiley, 2019

CO Code	Course outcome statement
21ESXXX.1	Understand the basics of distributed computing systems.
21ESXXX.2	Analyze the significance of time and various time synchronization methods in distributed computing systems.
21ESXXX.3	Examine the significance and requirements of real time communication systems.
21ESXXX.4	Illustrate various distributed system models.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1		1	2	
21ESXXX.2	2		3	2	
21ESXXX.3	2		3	2	
21ESXXX.4	3	2	3	3	2

21ES632 HARDWARE SOFTWARE CO-DESIGN 3-0-0-3

Introduction to System Level Design –Generic Co-Design Methodology–Hardware-Software Co-Design Models and Architectures –Languages for System Level Specification, Design and Modelling

Design Representation for System Level Synthesis –Models of Computation–Architectural, Selection–Partitioning–Scheduling and Communication.

Hardware - Software Co-Simulation of Embedded Systems–Synthesis–Verification and Virtual Prototyping - Implementation Case Studies – Performance Analysis and Optimization – Re-Targetable Code Generation – FPGAs and Heterogeneous platforms

TEXTBOOKS/REFERENCES:

1. Patrick R. Schaumont, *"A Practical Introduction to Hardware/Software Co-design"* , Second Edition, Springer, 2013.
2. Jorgen Staunstrup and Wayne Wolf, *"Hardware/Software Co-design: Principle and Practice"*, Kluwer Academic Publishers, 1997.
3. Giovanni De Micheli, *"Readings in Hardware Software Co-design "*, Morgan Kaufmann, Academic Press, 2002.
4. Daniel D. Gajski, Frank Vahid, Sanjiv Narayan, Jie Gong, *"Specification and Design of Embedded Systems"*, Pearson Education publishing, 1994 edition, 2008 Impression

5. Vivado Design Suite User Guide: *Embedded Processor Hardware Design* UG898 (v2017.3) October 27, 2017.

CO Code	Course outcome statement
21ESXXX.1	Understand the need for hardware software co-design in the design flow process.
21ESXXX.2	Analyze hardware-software co-design problems for systems with moderate complexity.
21ESXXX.3	Apply hardware-software co-design methods and techniques for embedded systems.
21ESXXX.4	Apply different levels of abstractions and models for verification of embedded co-design.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1		2	1	
21ESXXX.2	2	1	3	2	
21ESXXX.3	3	1	3	2	
21ESXXX.4	3	2	3	2	2

21ES633 EMBEDDED SYSTEM DESIGN PROCESS 2-0-2-3

Embedded system design cycle, Requirement analysis, planning, design, development, testing, prototyping, deployment. Development methodologies, System modelling. - Modelling –Continuous Dynamics, Discrete Systems, Hybrid Systems.
System components – Hardware - sensors & actuators, ADC, DAC, serial communication interfaces, software- application and system software.
Error analysis, signal processing and conditioning for interfacing purposes: digital and analogue quantities, noise reduction and digital filters.

TEXTBOOKS/REFERENCES:

1. D. Patranabis, *"Sensors & Transducers"*, Prentice Hall India,2005.
2. Ramón Pallás-Areny, John G. Webster, *"Sensors and Signal Conditioning"*, 2nd Edition WILEY, 2012.
3. Gerald D. Everett, Raymond McLeod, *"Software Testing: Across the Entire Software Development Life Cycle"*, *W*iley ,second edition
4. Roger S. Pressman, Bruce R. Maxim, *"Software Engineering: a practitioner's approach"*, Boston, Ninth edition.
5. Glenford J. Myers, Corey Sandler, Tom Badgett, *"The Art of Software Testing,"* Wiley ,3rd Edition.

CO Code	Course outcome statement
21ESXXX.1	Understand the basics of embedded system development life cycle.
21ESXXX.2	Familiarize modelling of embedded system.
21ESXXX.3	Understand the operation of various sensors and actuators.
21ESXXX.4	Develop interfaces for sensors and actuators.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1	1	1	3	
21ESXXX.2	2	1	2	3	
21ESXXX.3	1	1	1	3	2
21ESXXX.4	3	1	3	1	1

21ES634 EMBEDDED SYSTEMS FOR AUTOMOTIVE APPLICATIONS 2-0-2-3

Automotive Fundamentals – Vehicle functional domains and requirements – Automotive Electrical subsystems- The systems approach to control and automotive instrumentation – Sensors and Actuators in various vehicle domains. Systems in Power Train Electronics: Engine Management Systems in Chassis control: ABS, ESP,TCS, Active Suspension Systems, Cruise Control and Adaptive Cruise control systems – Body Electronic systems – Automotive Safety systems HVAC – Electric Hybrid Vehicles and their configurations- Drive-by-wire systems – Autonomous and Connected Vehicles and their challenges- Introduction to Embedded Automotive Protocols: CAN, LIN, Flex-Ray, MOST-AUTOSAR standard and its applications - OSEK VDX Open Systems in Automotive Networks.

TEXTBOOKS/REFERENCES:

1. William B. Ribbens, *"Understanding Automotive Electronics – An Engineering Perspective"*, Eight Edition, Elsevier Inc., 2017.
2. Robert Bosch GmbH, *"Bosch Automotive Electrics and Automotive Electronics -Systems and Components, Networking and Hybrid Drive"*, Fifth Edition, Springer Vieweg, 2007.
3. Najamuz Zaman, *"Automotive Electronics Design Fundamentals"*, Springer, 2015.
4. V. A. W. Hillier and David R. Rogers, "Hillier's Fundamentals of Motor Vehicle Technology on Chassis and Body Electronics", Fifth Edition, Nelson Thrones, 2007.
5. Tom Denton, *"Automobile Electrical and Electronic Systems"*, Fifth edition, Routledge, 2017.

CO Code	Course outcome statement
21ESXXX.1	Understand various automotive subsystems

21ESXXX.2	Introduce Automotive sensors and actuators
21ESXXX.3	Develop automotive control systems in embedded platform.
21ESXXX.4	Understand various automotive communication protocols and software architecture

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1				1
21ESXXX.2	1		1		1
21ESXXX.3	2	1	2	1	2
21ESXXX.4	2	1	2	1	2

21ES635 EMBEDDED SYSTEMS FOR ROBOTICS 2-0-2-3

Robots and Embedded Systems-Sensors, Microcontrollers and Actuators in Robots - Control - On-Off Control, PID Control, Velocity Control and Position Control, Recent Trends in Robotics-Milli/Micro/Nano Robot- Human-robot interaction.

Industrial Robots - Evolution of robotics, Robot anatomy, 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. Introduction to Robot dynamics & Control.

Mobile Robots, Concepts of Localization, and path planning. Autonomous robots- Swarm and Collaborative robots. Robot Operating System: architecture, sensors, actuators and platforms supported.

TEXTBOOKS/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"*, Fourth Edition, Pearson, 2018.
4. Anis Koubaa, *"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 Code	Course outcome statement

21ESXXX.1	Understand the architecture and components of robotic systems.
21ESXXX.2	Develop the kinematic models of manipulators
21ESXXX.3	Develop the inverse kinematic models for manipulators.
21ESXXX.4	Implement algorithms in autonomous mobile robot path planning, localization and control.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1	1			
21ESXXX.2	2		2	2	2
21ESXXX.3	2		2	2	2
21ESXXX.4	2		2	3	2

21ES636 EMBEDDED SYSTEMS IN BIOMEDICAL APPLICATIONS 3-0-0-3

Overview of biomedical devices – Origin of bio potentials – bio potential electrodes – bio potential amplifiers, System Theory for Physiological Signals: Filters, Modeling – Embedded systems in Patient monitoring: ECG, EEG, EMG, Blood pressure, respiration, pulse oximeters, diagnostic devices.
Non-invasive Diagnosis Using Sounds from Within the Body, Non-invasive Measurement of Blood Pressure, Measurement of Electrical Potentials and Magnetic Fields from the Body Surface and Plethysmography. Healthcare and the Wireless Sensor Network, Smart m-Health Sensing, m-Health and Mobile Communication Systems, Data Collection and Decision Making. m-Health Computing m-Health 2.0, Social Networks, Health Apps, Cloud and Big Health Data, m-Health and Global Healthcare and the Future of m-Health – case study.

TEXTBOOKS/REFERENCES:

1. John G. webster, Amit J. Nimunkar, *"Medical Instrumentation - Application and Design"*, Fifth Edition, John Wiley and Sons, 2020.
2. Subhas Chandra Mukhopadhyay and Aime Lay-Ekuakille, *"Advances in Biomedical Sensing, Measurements, Instrumentation and Systems"*, Springer, 2010.
3. Aime Lay-Ekuakille and Subhas Chandra Mukhopadhyay, *"Wearable and Autonomous Biomedical Devices and Systems for Smart Environment - Issues and Characterization"*, Springer, 2010.
4. Robert B. Northrop, *"Noninvasive Instrumentation and Measurement in Medical Diagnosis"*, CRC Press, 2019.
5. Roberts. H. Istepanian and Bryan Woodward, *"m-Health Fundamentals and Applications"*, Wiley, 2017.

CO Code	Course outcome statement
21ESXXX.1	Understand the basics of Bio Potentials and Physiological Signals.
21ESXXX.2	Familiarise Patient Monitoring System using Embedded Systems.
21ESXXX.3	Study of Embedded Systems in Patient Assistive Devices.
21ESXXX.4	Analyse the application of Embedded systems in surgical devices, medical imaging, clinical laboratory equipment etc.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1				
21ESXXX.2	1	1	1		1
21ESXXX.3	1	1	1		1
21ESXXX.4	1	1	1	1	

21ES637 VIDEO PROCESSING 3-0-0-3

Introduction, Analog video and NTSC television, Spatio-temporal sampling; Sampling structure conversion (without using motion), Motion Analysis, Real versus apparent motion, Spatial-temporal constraint methods (optical flow equation), Block-matching methods, Mesh-based methods, Region-based (parametric) motion modeling, Motion segmentation and layered video representations.
Motion-compensated (MC) filtering, Noise reduction, Signal recovery and general inverse problems, Restoration (deblurring), Super resolution, Mosaicking, Deinterlacing, Frame-rate conversion (MC-Interpolation).
Video Watermarking, Video Compression, Frame-based compression (principles behind MPEG-1/2), Scalable or layered frame-based compression, Object-based compression (principles behind MPEG-4). Surveillance - Video indexing, summarization, and retrieval, Object detection and tracking, Video Analytics.

TEXTBOOKS / REFERENCES:

1. Y. Wang, J. Ostermann, and Y. Q. Zhang, *"Video Processing and Communications"*, Prentice Hall, 1st edition, 2002.
2. M. Tekalp, *"Digital Video Processing"*, Prentice Hall, 2nd edition, 2005.
3. J. W. Woods, *"Multidimensional signal, image and video processing and coding"*, Academic Press / Elsevier, 2nd edition, 2012.
4. Linda G. Shapiro and George C. Stockman, *"Computer Vision"*,. Prentice-Hall, Inc., 1st edition, New Jersey, 2001.

CO Code	Course outcome statement

21ESXXX.1	Understand the attributes of video data.
21ESXXX.2	Familiarise the various motion analysis schemes.
21ESXXX.3	Develop applications for video restoration, super resolution, and Mosaicking.
21ESXXX.4	Apply video processing techniques for watermarking and compression.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1		2		
21ESXXX.2	1	1	2	1	1
21ESXXX.3	3	1	3	2	1
21ESXXX.4	3	2	3	2	1

21ES638 GPU ARCHITECTURE AND PROGRAMMING 2-0-2-3

Review of Traditional Computer Architecture – Basic five stage RISC Pipeline, Cache Memory, Register File, SIMD instructions, GPU architectures - Streaming Multi Processors, Cache Hierarchy, The Graphics Pipeline, Introduction to CUDA programming.
Multi-dimensional mapping of dataspace, Synchronization, Warp Scheduling, Divergence, Memory Access Coalescing, Optimization examples: optimizing Reduction Kernels, Optimization examples: Kernel Fusion, Thread and Block.
OpenCL basics, OpenCL for Heterogeneous Computing, Application Design: Efficient Neural Network Training/Inferencing.

TEXTBOOKS / REFERENCES:

1. Jason Sanders and Edward Kandrot, *"CUDA by Example: An Introduction to General-Purpose GPU Programming"*, Addison-Wesley, 1st edition, 2010
2. Benedict Gaster,Lee Howes, David R. Kaeli, *"Heterogeneous Computing with OpenCL"* Morgan Kaufmann; 1st edition, 2011
3. David Kirk and Wen-meiHwu, *"Programming Massively Parallel Processors"*, Morgan Kaufmann, 3rd edition, 2010
4. John L.Hennessy and David A. Patterson, *"Computer Architecture -- A Quantitative Approach"*, Morgan Kaufmann, 5th edition, 2011

CO Code	Course outcome statement
21ESXXX.1	Understand the fundamentals of parallel programming.

21ESXXX.2	Familiarise the various OpenCL device architectures.
21ESXXX.3	Analyze OpenCL case studies.
21ESXXX.4	Develop an application using GPU.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	2	1	2	1	
21ESXXX.2	2	1	2	1	1
21ESXXX.3	3	2	3	2	1
21ESXXX.4	3	2	3	3	2

21ES639 ADVANCED IMAGE PROCESSING AND COMPUTER VISION 2-0-2-3

Review of Image Processing - Image Formation, Capture and Representation, Linear Filtering, Correlation, Convolution. Visual Features and Representations: Edge Detection, Object Boundary and Shape Representations, Interest or Corner Point Detectors, Histogram of Oriented Gradients, Scale Invariant Feature Transform, Speeded up Robust Features, Saliency. Visual Matching: Bag-of-words, VLAD; RANSAC, Hough transform; Pyramid Matching; Optical Flow
Basics of Artificial Neural Network for Pattern Classification, Convolutional Neural Networks
Applications – Medical Image Segmentation, Motion Estimation and Object Tracking, Face and Facial Expression Recognition, Image Fusion, Gesture Recognition, Remote sensing etc.

TEXTBOOKS / REFERENCES:

1. Ralph Gonzalez, Richard Woods, Steven Eddins, *"Digital Image Processing Using MATLAB"*, McGraw Hill Education, 2nd edition, 2017.
2. Richard Szeliski ,*"Computer Vision: Algorithms and Applications"*, Springer, 2010.
3. Laurene Fausett, *"Fundamentals of Neural Networks Architectures, Algorithms and Applications"*, Pearson, 1st edition, 2004
4. Forsyth & Ponce, "Computer Vision-A Modern Approach," Pearson Education, 2nd edition 2015.
5. M.K. Bhuyan, *"Computer Vision and Image Processing: Fundamentals and Applications"*, CRC Press, 1st edition, 2019

CO Code	Course outcome statement
21ESXXX.1	Familiarise the fundamentals of image processing.

21ESXXX.2	Understand neural networks for Image classification problems.
21ESXXX.3	Apply advanced image processing techniques.
21ESXXX.4	Design solutions for real-world image processing problems.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1	1	1	1	
21ESXXX.2	2	1	1	1	1
21ESXXX.3	2	2	2	2	2
21ESXXX.4	3	2	3	2	2

21ES640 CRYPTOGRAPHY AND NETWORK SECURITY 3-0-0-3

Classical Encryption Techniques – Symmetric Cipher Model – Steganography – AES Cipher -Symmetric Cipher – Multiple Encryption and triple DES – Blocks Cipher – stream Cipher – Confidentiality using symmetric encryption – Placement of encryption function – random number generation – Introduction to number theory – Cryptosystems – message authentication and Hash functions – requirements – functions – course – Hash and MAC algorithms – secure Hash algorithms – Digital signatures and authentication protocols – standard – authentication applications – overview architecture – web security - socket layer and transport layer security – Intruders – Detection – Malicious software – viruses and related threats –denial of service - counter measures – firewalls – design principles – trusted systems - firmware security - IoT security.

TEXTBOOKS / REFERENCES:

1. William Stallings, *"Cryptography and Network Security – Principles and Practices"*, Seventh Edition, Prentice Hall, 2017.
2. Douglas R Stinson, *"Cryptography: Theory and Practice"*, Fourth Edition, Chapman and Hall/CRC, 2018.
3. Arshdeep Bahga, Vijay Madisetti, *"Internet of Things – A hands-on approach"*, Universities Press, 2015.
4. Mark Ciampa, *"Security+ Guide to Network Security Fundamentals"*, Fifth Edition, Cengage Learning, 2014.

CO Code	Course outcome statement
21ESXXX.1	Understand various encryption techniques.

21ESXXX.2	Understand the number theory in cryptographic schemes.
21ESXXX.3	Illustrate various authentication protocols.
21ESXXX.4	Analyse various software threats and counter measures.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1		1		1
21ESXXX.2	2		1		1
21ESXXX.3	2	1	1	1	2
21ESXXX.4	2	2	2	1	2

21ES641 WEB TECHNOLOGIES AND APPLICATIONS 3-0-0-3

Web essentials: Creating a website – Working principle of a website – Browser fundamentals – Authoring tools – Types of servers: Application Server – Web Server – Database Server; Scripting essentials: Need for Scripting languages – Types of scripting languages – Client-side scripting
Server-side scripting – PHP – Working principle of PHP – PHP Variables – Constants – Operators – Flow Control and Looping – Arrays – Strings – Functions – File Handling – PHP and MySQL – PHP and HTML – Cookies – Simple PHP scripts. XML-Documents and Vocabularies-Versions and Declaration-Namespaces- DOM based XML processing Event-oriented Parsing: XML-Documents and Vocabularies-Versions and Declaration - Namespaces - DOM based XML processing Event-oriented Parsing
Application essentials: Creation of simple interactive applications – Simple database applications – Multimedia applications – Design and development of information systems – Personal Information System – Information retrieval system – Social networking applications.

TEXTBOOKS / REFERENCES:

1. Robin Nixon, *"Learning PHP, MySQL, JavaScript, CSS & HTML5"*, Fifth Edition, O'REILLY, 2018.
2. Jeffrey C. Jackson, *"Web Technologies--A Computer Science Perspective"*, Pearson Education, 2006.
3. Robert. W. Sebesta, *"Programming the World Wide Web"*, Eighth Edition, Pearson Education, 2015.
4. Bates, *"Web Programming: Building Internet Applications"*, Third Edition, Wiley, 2010.
5. R. Kelly Rainer, Casey G. Cegielski, Brad Prince, *"Introduction to Information Systems"*, Eighth Edition, Wiley Publication, 2019.

CO Code	Course outcome statement
21ESXXX.1	Comprehend the concepts of responsive web design.
21ESXXX.2	Apply markup and scripting languages to design and validate dynamic web pages.

21ESXXX.3	Evaluate the appropriateness of client/server applications.
21ESXXX.4	Develop client/server applications with database.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1				1
21ESXXX.2	2			1	1
21ESXXX.3	2	1	1	1	2
21ESXXX.4	2	1	1	1	2

21ES642 MOBILE APPLICATION DEVELOPMENT 2-0-2-3

Introduction to mobile application development platforms, Application Development-Layouts, Views, Resources, Activities, Intents, Background tasks, Connecting to the Internet, Fragments, Preferences. User Interaction – input, menu items, custom views, User Experience – themes and styles, lists and adapters, material design, adaptive layouts, accessibility, localization, debugging the UI Storing Data, SQLite database, Sharing Data, content resolvers and providers, loaders to load data.
Services, background work, alarms, broadcast receivers, Notification, widgets, location-based services and Google maps. transferring data efficiently, publishing app, Multiple form factors, sensors, Google cloud messaging, monetizing mobile app.

TEXTBOOKS / REFERENCES:

1. Phillips, Stewart, Hardy and Marsicano, *"Android Programming (Big Nerd Ranch Guide)"*, Fourth Edition, Big Nerd Ranch Guides, 2019.
2. Hellman, *"Android Programming – Pushing the limits"*, First Edition, Wiley, 2013.
3. Tejinder Randhawa, *"Mobile Applications Design, Development and Optimization"*, Springer International Publishing, 2021.
4. Joseph Annuzzi Jr., Lauren Darcey, and Shane Conder, *"Advanced Android Application Development"*, Fourth Edition, Addison-Wesley Professional, 2014.

CO Code	Course outcome statement
21ESXXX.1	Understand Android programming.
21ESXXX.2	Develop Android programs.

21ESXXX.3	Develop mobile applications with cloud services.
21ESXXX.4	Analyse various services of mobile applications development.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1				1
21ESXXX.2	2	1		2	2
21ESXXX.3	2	1	1	2	2
21ESXXX.4	2	1	1	2	2

21ES643 ADVANCED MOBILE AND WIRELESS NETWORKS 3-0-0-3

Wireless networking - Physical layer- OFDM and 802.11 PHY, Multi-antenna systems and MIMO, Overview of 802.11n/ac PHY. MAC layer- CSMA/CA and Wi-Fi MAC overview, Wide bandwidth channel access techniques (802.11n/ac), Energy efficiency and rate control.

Multi-gigabit wireless networks - GSM, 3G/4G, UMTS, CDMA, HSDPA, QoS Management. Next generation (5G) wireless technologies- Upper Gigahertz and Terahertz wireless communications - Millimeter wave networking, Directionality and beam forming, Mobility and signal blockage, IEEE 802.11ad (60 GHz WLAN) MAC and PHY overview. Visible light communication - High-speed networking using LEDs, IEEE 802.15.7 PHY and MAC overview. Sensing through visible light, Visible light indoor localization and positioning, WiFi fingerprinting - protocols and challenges, Non-WiFi localization.

Future mobile networks - Drone networking- multi-UAV networks, architectures and civilian applications, Communication challenges and protocols for micro-UAVs. Connected and autonomous cars- Wireless technologies for Vehicle-to-Infrastructure (V2I) and Vehicle-to-Vehicle (V2V) communications, Automotive surrounding sensing with GHz and THz signals.

TEXTBOOKS / REFERENCES:

1. Theodore S. Rappaport, *"Wireless Communications: Principles and Practice"*, Second Edition, Pearson Education, 2009.
2. Matthew Gast, *"802.11n/ac: A Survival Guide"*, First Edition, O'Reilly Media, 2013.
3. Pei Zheng Larry Peterson Bruce Davie Adrian Farrel, *"Wireless Networking Complete"*, First Edition, Morgan Kaufmann, 2009.
4. William Lee, *"Wireless and Cellular Telecommunications"*, Third Edition, McGraw Hill, 2006.
5. Saad Asif, *"5G Mobile Communications Concepts and Technologies"*, First Edition, CRC Press, 2018.

CO Code	Course outcome statement

21ESXXX.1	Understand the capabilities of WiFi based communication systems.
21ESXXX.2	Comprehend next generation 5G communication networks.
21ESXXX.3	Familiarise different localization techniques in communication networks.
21ESXXX.4	Design wireless networks for real world applications.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1				1
21ESXXX.2	1			2	2
21ESXXX.3	1			2	2
21ESXXX.4	2	1	1	2	2

21ES644 MULTI CORE ARCHITECTURES 2-0-2-3

Review of Computer Design - Measuring performance Instruction level parallelism - Branch prediction techniques - Static & Dynamic scheduling – Speculation - Limits of ILP. Thread-level parallelism, Multi-issue, and Multi-core processors – Homogenous and Heterogenous multicore systems
Shared and Distributed memory -Transaction Memory issues Memory hierarchy design - Cache coherence, Memory wall problem - Advanced Cache Memory design - Virtual Memory, Storage Systems - Ware-house Scale Computers
Power optimization- Dynamic Voltage Frequency Scaling - Multi-core architectures for embedded systems – Fault Tolerant aspects for multi core systems- Programming environments for multi-core.

TEXTBOOKS / REFERENCES:

1. Peter S. Pacheco, *"An Introduction to Parallel Programming,"* Morgan Kauffman/Elsevier, 2011.
2. Yan Solihin, *"Fundamentals of Parallel Multicore Architecture"*, CRC Press, 2016.
3. Georgios Kornaros, *"Multi-core Embedded Systems"*, CRC Press, Taylor and Francis Group, First edition, 2019.
4. Victor Alessandrini, Morgan Kaufmann, *"Shared Memory Application Programming, Concepts and Strategies in Multicore Application Programming", 1*st Edition 2015.
5. Darryl Gove, *"Multicore Application Programming for Windows, Linux, and Oracle Solaris"*, Pearson, 2011.

CO Code	Course outcome statement
21ESXXX.1	Understand instruction level and thread level parallelism and branch prediction techniques.
21ESXXX.2	Develop static and dynamic scheduling algorithms.
21ESXXX.3	Analyse memory hierarchy design and cache coherency problem.
21ESXXX.4	Discuss concepts on multi-issue and multi-core processors with power optimization.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1				1
21ESXXX.2	2	1		2	2
21ESXXX.3	2	1	1	2	2
21ESXXX.4	2	1	1	2	2

21ES645 FAULT TOLERANT SYSTEM 3-0-0-3

Goals and Applications of Fault Tolerant Computing - Reliability, Availability, Safety, Dependability, Long Life, Critical Computation, High Availability Applications, Fault Tolerance as a Design Objective. Fault Models - Faults, Errors, and Failures, Causes and Characteristics of Faults, Logical and Physical Faults, Error Models.

Fault Tolerant Design Techniques: Hardware redundancy, Software Redundancy, Time redundancy and Information redundancy. Check pointing, Fault tolerant networks, Reconfiguration-based fault tolerance.

Reliability Evaluation Techniques - Failure Rate, Mean Time to Repair, Mean Time Between Failure, Reliability Modelling, Fault Coverage, M-of-N Systems, Markov Models, Safety, Maintainability, Availability. Case studies of fault tolerant systems and current research issues - Space Shuttle, Tandem 16 Non-Stop System, Recovery oriented computing, Fault tolerant platforms for Automotive Safety-Critical, Reliability and Fault tolerance in Collective Robot Systems.

TEXTBOOKS / REFERENCES:

1. Israel Koren and C. Mani Krishna, *"Fault Tolerant Systems"*, Elsevier, 2nd edition, 2020.
2. D. K. Pradhan, *"Fault-Tolerant Computing, Theory and Techniques"*, Prentice-Hall, 1998

3. M. L. Shooman, *"Reliability of Computer Systems and Networks Fault Tolerance Analysis and Design,"* Wiley, 2003
4. Elena Dubrova, *"Fault-Tolerant Design,"* Springer-Verlag New York, 2013.
5. Barry W. Johnson, *"Design and Analysis of Fault-Tolerant Digital System"*, Addison, 2009.

CO Code	Course outcome statement
21ESXXX.1	Understand basics of fault tolerance and fault models
21ESXXX.2	Discuss various forms of redundancies and fault tolerant design techniques
21ESXXX.3	Develop concepts on system reliability
21ESXXX.4	Comprehend different fault tolerant design concepts.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1				1
21ESXXX.2	2	1		2	2
21ESXXX.3	2	1	1	2	2
21ESXXX.4	2	1	1	2	2

21ES646 EMBEDDED SYSTEMS IN SMART GRID 2-0-2-3

Smart grid definition. Smart grid vs conventional grid. Smart Grid technologies- Power system and ICT in Generation, Transmission and Distribution. Basic understanding of power systems. Management aspects (Utility, Operator, Consumer). Evolution of automation in power system. Smart Grid features- Distributed generation, storage, DD, DR, AMI, WAMS, WACS). Sensors - CT, PT; Embedded Devices - IED, PMU, PDC, CT, PT, relays, DR Switch; Algorithms; Communication- Standards, Technology, and protocols. IoT applications in power system – Case study 1 generation control, load management, dynamic pricing etc.; IoT for domestic prosumers. Case Study 2 -Smart microgrid simulator (SMGS), DR, DD, Energy storage, Communication.

TEXTBOOKS / REFERENCES:

1. James Momoh, *"Smart Grid: Fundamentals of Design and Analysis"*, Wiley. IEEE Press, March 2012.
2. Janaka Ekanayake, Nick Jenkins, Kithsiri Liyanage, Jianzhong Wu and Akihiko Yokoyama, *Smart Grid: Technology and Applications"*, Wiley, February 2012.
3. Nouredine Hadjsaïd and Jean Claude Sabonnadière, *"Smart Grids"*, Wiley ISTE, May 2012.
4. Ali Keyhani and Muhammad Marwali, *"Smart Power Grids"*, Springer, 2011.

5. Vijay Madisetti and Arshdeep Bahga, *"Internet of Things: A Hands-on Approach"*, Hardcover – Import, 2014.

CO Code	Course outcome statement
21ESXXX.1	Understanding the basics of power system management and its automation.
21ESXXX.2	Explore the features of Smart grid.
21ESXXX.3	Learn different Sensors and embedded devices used in smart grid.
21ESXXX.4	Examine the different communication standards, technologies and protocols for smart grid.
21ESXXX.5	Investigate the IoT applications in Smart grid.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1				1
21ESXXX.2	2	1		2	2
21ESXXX.3	2	1	1	2	2
21ESXXX.4	2	1	1	2	2

21ES647 DESIGN FOR IoT AND CLOUD COMPUTING 2-0-2-3

Embedded Systems: Rise of embedded systems and their transition to intelligent systems and to Internet of Things -RFIDs, NFC, Web of Things - Embedded Systems Design: power and energy consumption; hardware design elements, software platforms –OS and applications, code optimization, validation and robust code generation; system integration, debugging and test methodology; tools for coding, debugging, optimization, and documentation; measurement of system performance, Creating virtual prototypes - hardware software emulation. IoT Reference Architectures, Introduction to Node Red, Visual Prototyping with Arduino and connectivity to IoT platforms, Applications: Healthcare and home automation examples. Cloud Computing: Infrastructure as a Service (IaaS), Cloud Database, Cloud storage. Platform as a Service (PaaS) for Web Rapid Application Development (RAD), Distributed Storage, Distributed Computing frameworks. Connectivity to remote server database, data access-storage processing. Development of cloud server and web applications.

TEXTBOOKS / REFERENCES:

1. Barry, P., and Crowley, P., *"Modern Embedded Computing"*, Morgan Kaufmann, 2012.
2. Vijay Madisetti and Arshdeep Bahga, *"Internet of Things: A Hands-on Approach"*, Hardcover Import, 2014.

3. Thomas Erl, *"Cloud Computing: Concepts, Technology & Architecture"*, Prentice Hall, May 2013.
4. Michael J. Kavis, *"Architecting the Cloud: Design Decisions for Cloud Computing Service Models (SaaS, PaaS, &IaaS)"*, Wiley CIO Series, January 2014.
5. George Reese, *"Cloud Application Architectures: Building Applications and Infrastructure in the Cloud"*, O'Reilly, 2009.

CO Code	Course outcome statement
21ESXXX.1	Understand the challenges and requirement of IoT framework.
21ESXXX.2	Distinguish applications from ubiquitous computing, IoT and WoT.
21ESXXX.3	Discuss the issues in system integration, debugging, testing and analysing the system performance.
21ESXXX.4	Design an IoT application.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1				1
21ESXXX.2	2	1		2	2
21ESXXX.3	2	1	1	2	2
21ESXXX.4	2	1	1	2	2

21ES648 INTELLIGENT SYSTEMS DESIGN 3-0-0 -3

Intelligent Systems – Definition, Need and role of embedded engineers. Architectures of intelligent systems – Automation, sensors, artificial intelligence techniques, actuators. Intelligent agents – definition, applications of intelligent agents in science, technology, business and commercial. Supporting technologies - Data mining, knowledge management, control and automation. Types of systems – Expert Systems, Recommendation Systems, Cognitive Systems, Swarm intelligent systems, Hybrid computing systems. Behaviour Oriented Design (BOD) – Definition, Extension to object-oriented design, process of specifying agency, specifying the agent's priorities using POSH dynamic plans.

TEXTBOOKS/REFERENCE BOOKS:

1. Karray F, Karray FO, De Silva CW, *"Soft computing and intelligent systems design: theory, tools, and applications"*. Pearson Education; 2009.
2. Larry Bielawski, Robert Lewand, *"Intelligent Systems Design: Integrating Expert Systems, Hypermedia, and Database Technologies"*, First Edition, Wiley Professional Computing.
3. Alexander M. Meystel, James S. Albus, *"Intelligent Systems: Architecture, Design, and Control"*, First Edition, Wiley – Interscience Publication, 2002.

4. Anindita Das, "Artificial *Intelligence and Soft Computing for Beginners"*, 2nd Edition, Arizona Business Alliance, 2014

CO Code	Course Outcome Statement
21ESXXX.1	Understand the need and scope of intelligent systems and the role of embedded engineers in the design of such systems.
21ESXXX.2	Familiarize the components of intelligent systems especially intelligent agents and its applications.
21ESXXX.3	Analyze the various types of intelligent systems.
21ESXXX.4	Understand Behaviour Oriented Design and process of defining agents.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1		2	3	1
21ESXXX.2	2	1	2	3	1
21ESXXX.3	1		1	2	1
21ESXXX.4	2	1	2	3	2

21ESXXXX
DISSERTATION
0-0-0-10

The students are made to choose a suitable problem, comprehend and analyse the problem after detailed literature survey.

CO Code	Course outcome statement
21ESXXX.1	Identify a topic based on recent literature in embedded systems.
21ESXXX.2	Formulate the framework for implementation.
21ESXXX.3	Choose computational and analytical tools for implementation
21ESXXX.4	Communicate technical content orally and document the findings.

CO Code	PO1	PO2	PO3	PO4	PO5
21ESXXX.1	1	1	1		1
21ESXXX.2	2	2	1		1
21ESXXX.3	2	2	3	2	2
21ESXXX.4	2	3	2		

21ES799 **DISSERTATION II** **0-0-0-16**

The students are made to work on the problem selected and comprehend and analyse the results.

CO Code	**Course outcome statement**
21ESXXX.1	Plan the project implementation with embedded system domain knowledge
21ESXXX.2	Implementation of project methodology in software/hardware aspects
21ESXXX.3	Analyse the results and perform comparative analysis with existing frameworks.
21ESXXX.4	Prepare technical reports, research papers, and disseminate knowledge

CO Code	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**
21ESXXX.1	1	2	2	2	2
21ESXXX.2	2	2	2	2	2
21ESXXX.3	2	2	2	2	2
21ESXXX.4	2	3	2	3	3