M.TECH. EMBEDDED SYSTEMS

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Almost all Electronics, Electrical and Mechanical systems are now controlled by a controller, which is embedded as a part of the complete system. Such a system is called an Embedded System. Examples are tele-communication systems, chemical-processing plants, transportation systems such as aircrafts and automobiles, bio-medical instruments and home appliances like microwave ovens and washing machines. The characteristics of embedded systems are that they are designed to do some specific tasks often in real time satisfying certain performance requirements. It is achieved through the controllers and software called firmware stored in read only memory of the controller.

The vast majority of control systems built today are embedded, that is, they rely on built-in, special-purpose microcontrollers (digital computers) to close their feedback loops. Some systems may contain large number of controllers. In such settings, controllers often use shared networks to communicate with each other and with large numbers of sensors and actuators scattered throughout the system. The design of embedded controllers and the intricate, automated communication networks that support them raises many new problems- theoretical and practical- about network protocols, compatibility of operating systems, and ways to maximize the effectiveness of the embedded hardware. This course will address many such questions and aspects of embedded and networked control.

CURRICULUM
First Semester

CourseCode	Type	Course	L T P	Cr
18MA604	FC	Applied Mathematics for Embedded Systems	3 1 0	4
18ES601	FC	Embedded System Programming	3 0 2	4
18ES602	FC	Signal and Image Processing	3 0 2	4
18ES603	FC	Embedded Processor Architectures and Design	3 0 2	4
18RM600	SC	Research Methodology	2 0 0	2
	E	Live in Labs * / Elective – I		3
18HU601	HU	Amrita Values Program**		P/F
18HU602	HU	Career Competency I**		P/F
			Credits	**21**

**** Non-credit course**

Second Semester

CourseCode	Type	Course	L T P	Cr
18ES621	SC	Distributed Computing	3 0 0	3
18ES622	SC	Internet of Things	3 0 2	4
18ES623	SC	Real Time Operating Systems	3 0 2	4
18ES624	SC	FPGA-Based System Design	3 0 2	4
	E	Elective – II		3
	E	Elective – III		3
18ES625	SC	Embedded Systems Applications Lab	1 0 2	2
18HU603	HU	Career Competency II	0 0 2	1
			Credits	**24**

Third Semester

CourseCode	Type	Course	L T P	Cr
18ES798	P	Dissertation		8
			Credits	**8**

Fourth Semester

CourseCode	Type	Course	L T P	Cr
18ES799	P	Dissertation		12
			Credits	**12**

Total Credits: 65

List of Courses

Foundation Core

Course Code	Course	L T P	Cr
18MA604	Applied Mathematics for Embedded Systems	3 1 0	4
18ES601	Embedded System Programming	3 0 2	4
18ES602	Signal and Image Processing	3 0 2	4
18ES603	Embedded Processor Architectures and Design	3 0 2	4

Subject Core

Course Code	Course	L T P	Cr
18RM600	Research Methodology	2 0 0	2
18ES621	Distributed Computing	3 0 0	3
18ES622	Internet of Things	3 0 2	4
18ES623	Real Time Operating Systems	3 0 2	4
18ES624	FPGA Based System Design	3 0 2	4
18ES625	Embedded Systems Application Lab	1 0 2	2

Electives
Groups of Streams

I. Embedded Applications

Course Code	Course	L T P	Cr
18ES701	Embedded Systems for Automotive Applications	3 0 0	3
18ES702	Advanced Mobile and Wireless Networks	3 0 0	3
18ES703	Embedded Systems in Biomedical Applications	3 0 0	3
18ES704	Embedded Systems in Robotics	3 0 0	3
18ES705	Embedded Systems in Smart Grid	3 0 0	3
18ES706	Design of Internet of Things and Cloud Computing	2 0 2	3
18ES707	Special Topics in Embedded Systems	3 0 0	3

II. Architecture and Programming

18ES708	Multi-Core Architectures	3 0 0	3
18ES709	Fault Tolerant Systems	3 0 0	3
18ES710	GPU Architecture and Programming	2 0 2	3
18ES711	Soft Computing	3 0 0	3
18ES712	Hardware Software Co-Design	3 0 0	3
18ES713	Object Oriented Programming	3 0 0	3
18ES714	Machine Learning	3 0 0	3
18ES715	Deep Learning	2 0 2	3

III. Controls and Systems

18ES716	Cryptography and Network Security	3 0 0	3
18ES717	Speech and Language Processing	3 0 0	3
18ES718	Advanced Digital Signal Processing and Processors	3 0 0	3
18ES719	Modern Control Systems	3 0 0	3
18ES720	Video Processing	3 0 0	3

Project Work

Course Code	Course	L T P	Cr
18ES798	Dissertation		8
18ES799	Dissertation		12

18MA604 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, Quasi-convex 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.

TEXT BOOKS / 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 LievenVandenberghe D, "Convex Optimization", Cambridge University Press, 2004.

18ES601 EMBEDDED SYSTEM PROGRAMMING 3-0-2-4

GNU Tools, Development and debugging Tools. Review of general C programming and data types, arrays, functions, pointers, structure, enum, files. Introduction to Embedded C, Interfacing C with Assembly. Embedded programming issues - Reentrancy, Portability, Optimizing and testing embedded C programs. Embedded Applications using Data structures, Linear data structures– Stacks and Queues, Linked List. Object Oriented programming introduction and basics, Scripting Languages for Embedded Systems - Shell scripting, Programming basics of Python. Software architecture of Embedded System.

TEXT BOOKS / REFERENCES:

1. Behrouz A. Forouzan and Richard F. Gilberg, "Computer Science: Structured Programming Approach Using C", Third Edition, Course Technology Inc., 2006.
2. Kirk Zurellm, "C Programming for Embedded Systems", CRC Press, 2000.
3. David E Simon, "An Embedded Software Primer", Pearson Education Asia, 2005.
4. Simon Monk , "Programming the Raspberry Pi: Getting Started with Python", The McGraw-Hill Companies, 2013.
5. Michael Dawson, "Python Programming for the Absolute Beginner", Third Edition, Cengage Learning, 2010.

18ES602 SIGNAL AND IMAGE PROCESSING 3-0-2-4

Signal Processing: 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.

Image Processing: Elements of Visual Perception- Image Sensing and Acquisition-Simple Image Formation- Image Sampling and Quantisation—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 operations, Spatial filtering, Smoothing spatial filtering, Sharpening spatial filtering.Image Enhancement in frequency domain: Smoothing frequency domain filtering, Sharpening frequency domain filtering.(Qualitatively)
Segmentation & Morphological operations: segmentation and threshold function, Different algorithms in thresholding, Line detection, Edge detection,Hough transform, Region based segmentation, Morphological-dilation and erosion, opening and closing.(Qualitatively). Selection of sensors and Processors for real time implementation.Shape Identification, Texture Identification, Colour Identification 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.

18ES603 EMBEDDED PROCESSOR ARCHITECTURES AND DESIGN 3-0-2-4

An introduction to Embedded Processors – RISC verses CISC- CPU Performance MetricsBenchmark- Integer and Floating Point data representation - RISC processor design
ARM Architecture – Programming Model, Pipelined data path design - Pipeline Hazards, Addressing Modes, ARM Instruction set - Thumb Instruction Set- ARM Programming - Vector Floating Point Unit, Interrupts & Exception Handling- DSP Extensions, Mixed C and Assembly programming, Memory system design- Cache Memory, Memory Management unit - Virtual Memory. Introduction to ARM based Microcontrollers – Peripherals – Interfacing – Application development – Case studies. ARM advanced CPU cores, Comparison with other architectures like PowerPC, DSP, PIC, MSP, FPGA, etc.

TEXT BOOKS / REFERENCES:

1. Steve Furber, “ARM System-on-Chip Architecture”, Pearson India, 2015.
2. Andrew Sloss, Dominic Symes and Chris Wright, “ARM System Developer's Guide: Designing and Optimizing System Software”, Morgan Kaufumann Publisher, 2011.
3. David A. Patterson and John L. Hennessy, “Computer Organization and Design – The Hardware/Software Interface”, ARM Edition, Morgan Kaufmann Publisher, 2010.
4. William Hohl and Christopher Hinds, “ARM Assembly Language: Fundamentals and Techniques”, Second Edition, CRC Press, 2016.
5. ARM Microcontroller User Manual.

18ES621 DISTRIBUTED COMPUTING 3-0-0-3

Basics of real-time systems: Functional, Temporal and Dependability requirements, Introduction to distributed computing systems (DCS), DCS design goals, Transparencies, Fundamental issues, System architecture, Composability, Scalability, Extensibility, Complexity, 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: Distributed mutual exclusion algorithms, Performance matrix.

Modeling distributed real-time systems, Real time communication, Requirements of real time communication system, Flow control-Explicit and Implicit, Thrashing, Inter-process communication: Message passing communication, Remote procedure call, Transaction communication, Group communication; Broadcast atomic protocols, 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 toGPU architecture and programming.Usage of tools for GPU Programming.

TEXT BOOKS / REFERENCES:

1. G. Coulouris, J. Dollimore, T. Kindberg, G. Blair, *“Distributed Systems: Concepts and Design,”* Addison Wesley, 2011.
2. Kai Hwang Jack Dongarra Geoffrey Fox, *“Distributed and Cloud Computing”* From Parallel Processing to the Internet of Things, 1st Edition, Morgan Kaufmann 2011.
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, 1997.

18ES622 INTERNET OF THINGS 3-0-2-4

Introduction to IoT - Definitions, frameworks and key technologies. Challenges to solve in IoT - Embedded systems architecture: Key hardware and software elements. Low power and very low power embedded systems, peripherals and sensors in embedded systems, peripheral interfacing - SPI, I2C& CAN.

Evolving IoT standards - Basics of Networking & Sensor Networks - Applications, challenges - ISO/OSI Model, TCP/IP Model, Network Devices and Applications.Communication Protocols - Wired and Wireless LAN, Bluetooth, Zigbee, WiMax, etc. Communication models (Request-Response, Publish-Subscribe etc),IOT Protocols – MQTT, CoAP, HTTP REST, Web Sockets etc.

System design of an IoT - Sensor network architecture, scenarios, optimization goals, design principles & Protocol Stack, Hardware and software protocol stacks modifications for IoT - MAC, Routing and application layers, performance considerations. Modern trends in IOT – Wearable, industrial standards.Applications of IoT - Smart Homes/Buildings, Smart Cities, Smart Industry, and Smart Medical care, Smart Automation etc.

TEXT BOOKS / REFERENCES:

1. Andrew S. Tanenbaum and David J. Wetherall, "Computer Networks", 5th Edition, Pearson Education, 2011.
2. Steve Rackley, "Wireless Networking Technology - From Principles to Successful Implementation", Newness (Elsevier), 2007.
3. Holger Karl and Andreas Willig, "Protocols and Architectures for Wireless Sensor Networks", John Wiley and Sons Ltd., 2005.
4. Olivier Hersent, David Boswarthick and Omar Elloumi, "The Internet of Things: Key Applications and Protocols", Wiley, 2012.
5. Vijay Madisetti and ArshdeepBahga, "Internet of Things: A Hands-on Approach", Hardcover – Import, 2014.

18ES623 REAL TIME OPERATING SYSTEMS 3-0-2-4

Overview of concepts of GPOS, GPOS functionalities, Introduction to real-time systems,RTOS basic architecture, RTOS vs GPOS.Architecture of OS (Monolithic, Microkernel, Layered, Exo-kernel and Hybrid kernel structures).Evolution of operating systems, POSIX Standards.

RTOS Kernel, Kernel services: Task Management -tasks, process and threads, task attributes and types - task states and transition, task control block, Introduction to real-time task scheduling, uniprocessor and multiprocessor scheduling concepts - RM, DM, EDF, Least Laxity First (LLF), clock-driven and priority-driven scheduling, preemption-context switching, blocking, priority inversion and solutions, response time analysis, processor demand analysis,Worst case execution time calculation, scheduling for fault-tolerance.

TimerManagement, Interrupt handling, MemoryManagement, Input-Output handling, Task Communication and Synchronization - Semaphores and Mutex, Mailbox, Queue, Pipes, RPC, deadlock. Comparison and study of RTOS: FreeRTOS and µCOS – Case studies: RTOS for fault Tolerant Applications, picking RTOS for your project, RTOS trends in next 5 years.

TEXT BOOKS / REFERENCES:

1. Jane W.S. Liu, "Real -Time Systems", Pearson Education, 2000.
2. Cheng, A. M. K., "Real-Time Systems: Scheduling, Analysis, and Verification", Wiley, 2002.
3. Krishna, C. M., Shin, K. G. "Real-Time Systems", McGraw-Hill, 1997.
4. Jean J Labrosse, "MicroC/OS-II-The Real-Time Kernel", 2nd edition, CMP Books, 2002.
5. Tanenbaum,*"Modern Operating Systems,"* 3/e, Pearson Edition, 2007.

18ES624 FPGA-BASED SYSTEM DESIGN 3-0-2-4

HDL – Role of HDL - HDL for Design Synthesis - Design Flow – Programmable logic: Simple PLDs, CPLDs ,FPGA HDL - A Simple Design – HDL elements - Data flow – behavioural – structural modeling - Creating Combinational and Synchronous Logic - Designing FIFO - Test Benches - State Machine Designs - Design Examples - Memory Controller - Mealy State Machines - Design Considerations - Hierarchy in Large Designs - Functions and Procedures – Subprograms.

General principles of circuit synthesis - Synthesis and Design Implementation - Synthesis and Fitting CPLDs, FPGAs- Resource Sharing - Creating Test Benches – Implementation technology – PLD's, Custom Chips, Standard Cell and Gate arrays – FPGA Architectures – SRAM based FPGAs – Permanently programmed FPGAs – Circuit design of FPGA fabrics – Architecture of FPGA fabrics – Logic Implementation of FPGAs - Physical design for FPGAs.

TEXT BOOK / REFERENCES

1. Stephen Brown and ZvonkoVranesic, "*Fundamental of Digital Logic with VHDL Design*", Second Edition, McGraw Hill, 2000.
2. Douglas L Perry, "*VHDL Programming by Example*", Fourth Edition, Tata McGraw Hill, 2002.
3. Wayne Wolf, "*FPGA-Based System Design*", Prentice Hall India Pvt. Ltd., 2004.
4. Samir Palnitkar, "*Verilog HDL,A Guide to Digital Design and Synthesis*", Second Edition, Pearson Education, 2003.
5. T. R. Padmanabhanand B. Bala Tripura Sundari, "*Design Through Verilog HDL*", Wiley-Blackwell, 2003.

18ES625 EMBEDDED SYSTEM APPLICATION LAB 1-0-2-2

Each student in consultation with the faculty in-charge will select a topic related to embeddedsystems and applications and develop an embedded product/system following the embedded system design principles.

18RM600 RESEARCH METHODOLOGY 2-0-0-2

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, 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

18ES701 EMBEDDED SYSTEMS FOR AUTOMOTIVE APPLICATIONS 3-0-0-3

Automotive Fundamentals – Vehicle functional domains and requirements – The systemsapproach to control and automotive instrumentation – Sensors and actuators in various vehicledomains. Systems in Power train Electronics: Engine Management Systems: Spark Ignition,Petrol/ Diesel Injection Systems, Transmission Systems. Systems in Chassis control: ABS, ESP,TCS, Active Suspension Systems, Cruise control and adaptive cruise control systems – Drive-bywiresystems. Body electronic systems: Power Generation/ Storage, starting motor systems,Vehicle wiring systems, HVAC, Automotive alarm systems, Vehicle immobilization &deactivation, Driver information systems, Parking systems, Central locking system – electricwindows – Occupants and driver safety systems: Seat belt lighteners and air-bags – DiagnosticsSystems. Electric/Hybrid Vehicles and their configurations – Autonomous Vehicles and their challenges. Introduction to Embedded automotive protocols: LIN, CAN,FlexRay, MOST - AUTOSAR standard and its applications – OSEK/VDX Open Systems in AutomotiveNetworks.

TEXT BOOKS / REFERENCES:

1. William B. Ribbens, "*Understanding Automotive Electronics - An Engineering Perspective*", Eight Edition, Elsevier Inc., 2017.
2. V. A. W. Hillier and David R. Rogers, "*Hillier's Fundamentals of Motor Vehicle Technologyon Chassis and Body Electronics*", Fifth Edition, Nelson Thrones, 2007.
3. Robert Bosch GmbH, "*Bosch Automotive Electricsand Automotive Electronics - Systems and Components,Networking and Hybrid Drive*", Fifth Edition, Springer Vieweg, 2007.
4. Joseph Lemieux, "*Programming in the OSEK/VDX Environment*", CMP Books, USA, 2001.
5. Tom Denton, "*Automobile Electrical and Electronic Systems*", Third Edition, Elsevier Butterworth-Heinemann, 2004.

18ES702 ADVANCED MOBILE AND WIRELESS NETWORKS 3-0-0-3

Overview of Wireless Systems, TeleTraffic Engineering-Service level, Usage, MeasurementUnits, Types, B Formulas, Overview of Digital Communication and Transmission, MultipleAccess Techniques, Architecture of Wireless Wide-Area Network, Mobility Management,Mobile Network and Transport Layer- TCP/IP Suite for Wireless Networks, Mobile IP, SIP,Wide Area Wireless Network Service- GSM,3G, UMTS, QoSMangament, HSDPA, FOMA,CDMA, Wireless Application Protocol, Bluetooth Protocol stack, Link Types, Security, ErrorCorrection, Topology, Applications, WiMax, 4G Systems, Software Defined Radio, CognitiveRadio.

TEXT BOOKS / REFERENCES:

1. Vijay K Garg, "*Wireless Communications and Networking*", Morgan Kaufmann, 2007.
2. Adreas F Molisch, "*Wireless Communications*", Second Edition, Wiley, 2011.
3. William Lee, "*Wireless and Cellular Telecommunications*", Third Edition, McGraw Hill,2005.
4. Martin Sauter, "*Beyond 3G - Bringing Networks, Terminals and the Web Together: LTE,WiMAX, IMS, 4G Devices and the Mobile Web 2.0*", Wiley, 2009.
5. EldadPerahia, "*Next Generation Wireless LANs: Throughput, Robustness, and Reliability in802.11n*", Cambridge University Press, 2008.

18ES703 EMBEDDED SYSTEMS IN BIOMEDICAL APPLICATIONS 3-0-0-3

Overview of biomedical devices – Origin of bio potentials – bio potential electrodes – biopotential amplifiers, System Theory for Physiological Signals: Filters, Modeling – Embeddedsystems in Patient monitoring: ECG, EEG, EMG, Blood pressure, respiration, pulse oxymeters, diagnostic devices.

Noninvasive Diagnosis Using Sounds from Within the Body, Noninvasive 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-Health2.0,Social Networks, Health Apps, Cloud and Big Health Data, m-Health and Global Healthcare and the Future of m-Health – case study.

TEXT BOOKS / REFERENCES:

1. John G. webster, "*Medical Instrumentation - Application and Design*", Fourth Edition, JohnWiley and Sons, 2010.
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 AutonomousBiomedical Devices and Systems for Smart Environment - Issues and Characterization*", Springer, 2010.
4. Robert B. Northrop, "*Noninvasive Instrumentation and Measurement in Medical Diagnosis*", CRC Press, 2002.
5. Roberts. H. Istepanian and Bryan Woodward, "*m-Health Fundamentals and Applications*", Wiley, 2017.

18ES704 EMBEDDED SYSTEMS IN ROBOTICS 3-0-0-3

Robots and Embedded Systems-Sensors - Sensor Categories, Binary Sensor, Analog versus Digital Sensors, Shaft Encoder; A/D Converter, Position Sensitive Device; Compass, Gyroscope, Accelerometer, Inclinometer, Digital Camera. Actuators - DC Motors, H-Bridge, Pulse Width Modulation, Stepper Motors, Servos. Control - On-Off Control, PID Control, Velocity Control and Position Control, Embedded Controllers, Interfaces, Operating System. Industrial Robots - Evolution of robotics, Robot anatomy, Design and control issues, 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, Concepts of Localization and path planning. Autonomous robots and Introduction to Robot Operating System.

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.

18ES705 EMBEDDED SYSTEMS IN SMART GRID 2-0-2-3

Smartgriddefinition.Smartgridvs conventional grid.SmartGrid technologies- Power system and ICT in Generation,Transmission and Distribution. Basic understanding of power systems.Managment 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,Energystorage,Communication.

TEXT BOOKS / REFERENCES:

1. James Momoh, “Smart Grid: Fundamentals of Design and Analysis”, Wiley-IEEE Press, March 2012.
2. JanakaEkanayake, Nick Jenkins, KithsiriLiyanage, Jianzhong Wu and Akihiko Yokoyama, “Smart Grid:Technology and Applications”, Wiley, February 2012.
3. NouredineHadjsaïd and Jean-Claude Sabonnadière, “Smart Grids”, Wiley-ISTE, May 2012.
4. Ali Keyhani and Muhammad Marwali, “Smart Power Grids 2011”, Springer, 2011.
5. Mini S. Thomas, John Douglas McDonald,"Power System SCADA and Smart Grids", CRC Press, April 2015.
6. Vijay Madisetti and ArshdeepBahga, “Internet of Things: A Hands-on Approach”,Hardcover – Import, 2014.

18ES706 DESIGN FOR INTERNET OF THINGS 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: Partitioning to hardware and software; principles of co-design; performance of these systems - estimation of speed, throughput, power and energy consumption; hardware design elements -design, validation, and testing tools; 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. Wolf, M., *Computers as Components*, Third Edition, Morgan Kaufmann, 2012.
3. VijayMadisetti and ArshdeepBahga, “Internet of Things: A Hands-on Approach”, Hardcover – Import, 2014.
4. Thomas Erl, "Cloud Computing: Concepts, Technology & Architecture", Prentice Hall, May 2013.
5. Michael J. Kavis, "Architecting the Cloud: Design Decisions for Cloud Computing Service Models (SaaS, PaaS, &IaaS)", Wiley CIO Series, January 2014.
6. George Reese, "Cloud Application Architectures: Building Applications and Infrastructure in the Cloud", O'Reilly, 2009.

18ES707 SPECIAL TOPICS IN EMBEDDED SYSTEMS 3-0-0-3

System analysis-user and market requirement, project specifications, structured analysis. System Modelling, Preliminary design – Hardware and Software Partitioning, Component Selection - Selecting the right sensors, processors, interfacing circuits, actuators, software modules and development environments, Testing and Debugging, User interface design and prototyping.Approaches to implementation-top down, bottom up, threads.

Major trends in embedded system - Processor - Single core, Multi-core, Multi-processor, Pervasive or ubiquitous or context-aware computing, Artificial Intelligence, Virtual and Augmented Reality, Embedded software, IoT, Computer/Machine vision, Cyber-physical systems.

Applications and Use cases - Wearable Electronics, Smart Healthcare, Automotive Embedded Systems, Smart agriculture, Consumer electronics like PDA, mobile phones, Smart homes/environments, Smart Community, Smart citiesandSmart grids, Virtual assistants, Robotics, Smart Security/Surveillance systems,Autonomous systems.

TEXTBOOKS/REFERENCES

1. Wayne Wolf, "Computers as Components, Second Edition: Principles of Embedded Computing System Design", 2nd Edition, The Morgan Kaufmann Publishers, 2008.
2. E. A. Lee and S. A. Seshia, Introduction to Embedded Systems - A Cyber-Physical Systems Approach, Second Edition, MIT Press, 2017.
3. A. K. Ganguly, "Embedded Systems: Design, Programming and Applications", Narosa, 2014.
4. Raj Kamal, "Embedded Systems - Architecture, Programming and Design", Tata-McGrawHill, 12th Reprint, 2007.
5. Raul A. Santos, Arthur Edwards Block, "Embedded Systems and Wireless Technology: Theory and Practical Applications", CRC Press, 2012.

18ES708 MULTI-CORE ARCHITECTURES 3-0-0-3

Review of Computer Design - Basics of Pipelining - Hazards, Measuring performance Instruction level parallelism - Branch prediction techniques - Static & Dynamic scheduling – Speculation - Limits of ILP. Thread-level parallelism, Multi-issue and Multi-core processors - Shared and Distributed memory Multiprocessor Architectures - Transaction Memory issues Memory hierarchy design - Cache coherence, Memory wall problem - Advanced Cache Memorydesign - Virtual Memory, Storage Systems - Ware-house Scale Computers - Power optimizationin multi-core systems - Multi-core architectures for embedded systems – Programmingenvironments for multi-core.

TEXT BOOKS / REFERENCES:

1. J.L. Hennessy and D.A. Patterson, "*Computer Architecture: A Quantitative Approach*", FifthEdition, Morgan Kaufmann, 2011.
2. GeorgiosKornaros, "*Multi-core Embedded Systems*", CRC Press, Taylor and Francis Group,2010.
3. J.P. Shen and M.H. Lipasti, "*Modern Processor Design: Fundamentals of SuperScalarProcessors*", McGraw Hill, 2005.
4. David Culler, J.P. Singh and Anoop Gupta, "*Parallel Computer Architecture: AHardware/Software Approach*", Morgan Kaufmann, 1998.
5. DezsoSima, Terence Fountain and Peter Kacsuk, "*Advanced Computer Architectures: A Design Space Approach* ",Pearson, 2005.

18ES709 FAULT TOLERANT SYSTEMS 3-0-0-3

Hardware fault tolerance, software fault tolerance, information redundancy, check pointing, fault tolerant networks, reconfiguration-based fault tolerance, and simulation techniques. Students will gain familiarity with the core and contemporary literature in the area for dependable computing. Dependability concepts: Dependable system, techniques for achieving dependability, dependability measure, fault, error, failure, and classification of faults and failures. Fault Tolerance Strategies: Fault detection, masking, containment, location, reconfiguration, and recovery. Fault Tolerant Design Techniques: Hardware redundancy, software redundancy, time redundancy and information redundancy. Dependable communication: Dependablechannels, survivable networks, fault-tolerantrouting. Fault recovery, Stable storage and RAID architectures, and Data replication and resiliency. Case studies of fault tolerant multiprocessor and distributed systems.

TEXT BOOKS / REFERENCES:

1. Israel Koren and C. Mani Krishna, "Fault Tolerant Systems", Elsevier.2007.
2. P. Jalote, "Fault Tolerance in Distributed Systems", Prentice-Hall Inc. 1994.
3. D. K. Pradhan, "Fault-Tolerant Computing, Theory and Techniques", Prentice-Hall, 1998.
4. Los Alamitos, CA, "Fault-Tolerant Computing, Theory and Techniques", IEEE ComputerSociety Press, 1996.
5. Barry W. Johnson, "Design and Analysis of Fault-Tolerant Digital System", Addison, 1989.

18ES710 GPU ARCHITECUTRE AND PROGRAMMING 2-0-2-3

Introduction to Parallel Programming - Introduction to OpenCL - OpenCL Device Architectures - Basic OpenCL – examples - Understanding OpenCL - Concurrency and Execution Model - Dissecting a CPU/GPU - OpenCL Implementation - OpenCL case study: Convolution, Video Processing, Histogram and Mixed Particle Simulation - OpenCL Extensions - OpenCL Profiling and Debugging – WebCL.

TEXT BOOKS / REFERENCES:

1. Benedict R Gaster, Lee Howes, David, R. Kaeli, PerhaadMistry and Dana Schaa, "Heterogeneous Computing with OpenCL", Second Edition, Elsevier, 2012.
2. AaftabMunshi, Benedict Gaster, Timothy G. Mattson, James Fung and Dan Ginsburg, "OpenCL Programming Guide", Addison-Wesley Professional, 2011.

3. RyojiTsuchiyama, Takashi Nakamura, TakuroIizuka and Akihiro Asahara, “The OpenCL Programming Book ”, Fixstars Corporation, 2010.
4. Matthew Scarpio, “OpenCL in Action: How to Accelerate Graphics andComputations”, Manning Publications, 2011.

18ES711 SOFT COMPUTING 3-0-0-3

Neural Networks (NN) – Supervised and Unsupervised Learning – Hopfield – RBF Networks – Principal Component Analysis – PNN – Kohonen Self Organizing Networks – Learning Vector Quantization – Hebbian Learning – Adaptive Resonance Theory – Genetic Algorithms (GA) – Standard GA – Schema Theory – Building Block Hypothesis – Introduction to Support Vector Machines – Classification and Regression – Typical Applications Integrating Various Soft Computing Tools. Introduction to evolutionary algorithms-Ant Colony Optimization and swarm intelligence.

TEXT BOOKS / REFERENCES:

1. Simon Haykin, “*Neural Networks and Learning Machines*”, Third Edition, Pearson Education, 2009.
2. K.F. Man, K.S. Tang and S. Kwong, “*Genetic Algorithms: Concepts and Applications*”, IEEE Transactions on Industrial Electronics, Vol-3, 1996.
3. Thomas S.Parker and Leon O Chua, “*CHAOS: A Tutorial for Engineers*”, IEEE Proceedings, Vol-75, No.8, 1987.
4. Jan Komorowski, Lech Polkowski and AndrzejSkowron, “*Rough Sets: A Tutorial*”, http://Folli.Loria.Fr/Cds/1999/Library/Pdf/Skowron.Pdf

18ES712 HARDWARE SOFTWARE CO-DESIGN 3-0-0-3

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

18ES713 OBJECT ORIENTED PROGRAMMING 3-0-0-3

Introduction to object oriented software design, Comparison of programming methodologies, Object Basics, Java Environment, Classes and Object, Data Members, Access Specifiers, Arrays within a Class, Array of Objects, Constructors, Default Constructors, Destructors, Static Members, Constant Members, Object Oriented Design with UML, Class s , object diagrams and sequence diagrams. Overview of Streams, Bytes vs. Characters, File Object, Binary Input and Output, Reading and Writing Objects, Method Overriding, Polymorphism, Super, Interfaces and Abstract Classes, Packages, Use case diagrams and activity diagrams. Introduction to Threads, Creating Threads, Thread States, Runnable Threads, Coordinating Threads, Interrupting Threads, Runnable Interface Applets: Applet Architecture- Parameters to Applet - Embedding Applets in Web page, Component diagrams and Deployment diagrams.

TEXT BOOK / REFERENCES:

1. Naughton P. and Schildt H., "*Java2 Complete Reference*", Eighth Edition, Tata GrawHill, 2011.
2. Ali Bahrami, "*Object Oriented Systems Development*", Second Edition, McGraw-Hill, 2008.
3. Grady Booch and Robert A. Maksimchuk, "*Object-oriented Analysis and Design with Applications*", Third Edition, Addison Wesley, 2006.
4. Jaime Nino, Fredrick a Hosch, "*An Introduction to Programming and Object Oriented Design Using Java*", Wiley India PrivateLimited, 2010.

18ES714 MACHINE LEARNING 3-0-0-3

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, Basics of probability theory and probability distributions, information theory, Bayesian learning, Neural Networks, Gaussian Mixture models and the EM algorithm, Factor analysis, Principal components analysis, Independent Component Analysis, Kernels and kernel functions, Support vector machines for regression and classification, Decision trees, CART, Ensemble Methods: Boosting - Adaboost, Gradient Boosting; Bagging - Simple methods, Random Forest, 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.

18ES715 DEEP LEARNING 2-0-2-3

Probability and Information Theory , Basics of classical Machine Learning techniques, algorithmic differentiation-forward and backward. Introduction to Neural Networks, Backpropagation, Multi-layer Perceptrons . Overview of Computer vision Problems, Deep Learning for computer vision, Deep Feedforward Networks , Regularization for Deep Learning Optimization for Training Deep Models , Convolutional Networks , object detection and segmentation, Visualization and understanding, Generative models, Variationalautoencoders, Sequence Modeling: Recurrent and Recursive Nets. Long short term memory networks (LSTM) . Applications in security and Autonomous navigation.

TEXTBOOKS/REFERENCES

1. Ian Goodfellow, YoshuaBengio and Aaron Courville, “Deep Learning”, MIT Press, 2017

18ES716 CRYPTOGRAPHY AND NETWORK SECURITY 3-0-0-3

Classical Encryption Techniques – Symmetric Cipher Model – Steganography – AESCipherSymmetric Cipher – Multiple Encryption and triple DES – Blocks Cipher – stream Cipher – Confidentiality using symmetric encryption – Placement of encryption function – randomnumber generation – Introduction to number theory – Cryptosystems – message authenticationand Hash functions – requirements – functions – course – Hash and MAC algorithms – secureHash algorithms – Digital signatures and authentication protocols – standard – authenticationapplications – Electronic mail security - S/MIME-IP security – overview-architecture – websecurity - socket layer and transport layer security – Intruders – Detection – Malicious software– viruses and related threats – counter measures – firewalls – design principles – trusted systems.

TEXT BOOKS / REFERENCES:

1. William Stallings, “Cryptography and Network Security – Principles and Practices”, Fourth Edition, Prentice Hall, 2003.
2. Douglas R Stinson, “Cryptography: Theory and Practice”, Third Edition, Chapman and Hall/CRC, 2005.

18ES717 SPEECH AND LANGUAGE PROCESSING 3-0-0-3

Introduction to Linguistics – natural language and formal language – regular expressions and finite state automata – words and their parts – morphology – parsing – word tokenization – pronunciation and spelling – N grams and language models – Transliteration – Transliteration using sequence labeling – Part of speech tagging – POS tagging using SVM – chunking – shallow parsing – context free grammars – Parsing using context free grammars – probabilistic and lexicalized parsing, CFG parser – Parsing techniques – structured output learning – generalized linear classifiers in NLP.

TEXT BOOKS / REFERENCES:

1. Daniel Jurafsky and James H Martin, "*Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics and Speech Recognition*", Second Edition, Prentice Hall, 2008.
2. Christopher D. Manning and HinrichSchutze, "*Foundations of Statistical Natural Language Processing*", MIT Press, 1999.
3. Sandra Kubler, Ryan McDonald and JoakimNivre, "*Dependency Parsing Synthesis Lecturers on Human Language Technologies*", Morgan and Claypool Publishers, 2009.

18ES718 ADVANCED DIGITAL SIGNAL PROCESSING AND PROCESSORS 3-0-0-3

Multirate Digital Signal Processing - Decimation, Interpolation, Cascade Equivalents, Fractional Sampling Rate Alteration, Applications- acquisition of high quality data, high resolution spectral analysis and design and analysis of narrowband digital filtering. Architecture of TMS320C6748 DSP - Instruction set – Addressing modes - Peripherals - Assembly language and C programming – Integrated Development Environment - Code Composer Studio.Digital Signal Processing implementation using TMS320C6748 DSP for digital filters - Levinson Durbin Algorithm Embedded Target for TMS320C6748 DSP Platform using MATLAB - Simulink.Application development using MATLAB – Simulink - Real-TimeWorkshop and hardware.

TEXT BOOKS / REFERENCES:

1. Vaidyanathan P. P, "Multirate Systems and Filter Banks", Prentice Hall, 1993.
2. TMS320C6748 DSP. Technical Reference Manual.
3. Andy Bateman and Iain Paterson-Stephens, "The DSP Handbook, Algorithms,Applications and Design Techniques", Prentice-Hall, 2002.
4. RulphChassaing, "DSP Applications Using C and the TMS320C6x DSK", John Wiley and Sons, 2002.
5. B Venkataramani and M Bhaskar, "Digital Signal Processors: Architecture,Programming and Applications", Tata McGraw Hill, 2002.

18ES719 MODERN CONTROL SYSTEMS 3-0-0-3

State Variable Analysis and Design: Introduction, concept of state, state variables and state model, state modeling of linear systems, linearization of state equations. State Space representation using physical variables, Phase variables and Canonical variables. Derivation of transfer function from state model, diagonalization, Eigen values, Eigen vectors, generalized Eigen vectors. Solution of state equation, state transition matrix and its properties, computation using Laplace transformation, power series method, CayleyHamilton method, concept of controllability and observability, methods of determining the same. Pole Placement Techniques: Stability improvements by state feedback, necessary and sufficient conditions for arbitrary pole placement, state regulator design, and design of state observer, Controllers- P, PI, PID. Non-linear systems: Introduction, behavior of non-linear system, common physical non linearity-saturation, friction, backlash, dead zone, relay, multivariable 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.

TEXT BOOKS/ REFERENCES:

1. Ogata, "*Modern Control Engineering*". Fifth Edition, Prentice Hall, 2009.
2. Franklin and Powell, "*Feedback Control of Dynamics Systems*". Fourth Edition, PrenticeHall, 2002.
3. Joseph DiStefano III, Allen J. Stubberud and Ivan J. Williams "*Feedback and Control Systems*",*Second Edition*, Schaum's Outline Series, Mcgraw-Hill, 2014.
4. David G. Luenberger, "*Introduction to Dynamic Systems: Theory, Models, and Applications*", Wiley, 1979.
5. Richard C. Dorf and Robert H. Bishop, "*Modern Control Systems*", Eleventh Edition Prentice Hall, Pears Education, 2008.

18ES720 VIDEO PROCESSING 3-0-0-3

Introduction - Image Representation - Image Digitization, Geometric Transformations, Linear image filtering and correlation- Image Smoothing - Edge Detectors - Corner Detectors. Noise reduction, Image Segmentation, Morphological image processing, Digital video processing.

TEXT BOOKS / REFERENCES:

1. Daniel Jurafsky and James H Martin, "*Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics and Speech Recognition*", Second Edition, Prentice Hall, 2008.
2. Christopher D. Manning and HinrichSchutze, "*Foundations of Statistical Natural LanguageProcessing*", MIT Press, 1999.
3. Sandra Kubler, Ryan McDonald and JoakimNivre, "*Dependency Parsing Synthesis Lecturers on Human Language Technologies*", Morgan and Claypool Publishers, 2009.

18ES798 DISSERTATION 8

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

18ES799 DISSERTATION 12

During fourth semester each student should work further on the topic of the minor project oranew topic under the supervision of a faculty member. By the end of fourth semester thestudenthas 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.