COMMUNICATION AND SIGNAL PROCESSING (CSP)GROUP

Courses (all are 3 Credit courses)

EEE 6214: Information Theory

Contents: Overview on: Entropy and Mutual Information, Differential entropy, Entropy Rates of Stochastic Processes, Source Coding.
Channel Capacity: Definition channel capacity, Examples of channel capacity, Symmetric channels, Channel coding theorem, Joint source channel coding theorem.
The Gaussian Channel: Definition, Coding theorem for Gaussian channel, Band-limited channel, Parallel Gaussian channel, Channels with colored Gaussian noise, Gaussian channels with feedback.
Rate Distortion Theory: Definition, Calculation of rate distortion function, Rate distortion theorem, Achievability of the rate distortion function, Characterization of the rate distortion function.
Network Information Theory: Capacity of Gaussian multiple user channels, Capacity of Multiple access channel, Achievability of the capacity region for the multiple access channel, Slepian-Wolf theorem, Broadcast channel.

EEE 6202: Advanced Telecommunication Engineering

Basics of telecommunication systems, channel models and noise, challenges. Entropy and data compression, source coding for voice, data, image and video. Line coding and baseband transmission, optimum receivers, performance of digital modulations under AWGN, eye diagram and ISI, Nyquist's criterion, synchronisation techniques, frequency and time-domain equalizers. error detection and correction techniques. Advanced multiplexing and multiple access techniques: OFDM, DWDM, CSMA/CA, NOMA. Queuing theory, Grade of Service (GoS), traffic shaping, traffic scheduling. Telecommunication backbone and access networks: IP networking, intelligent networks, SONET and SDH, MPLS, NGN, FTTx, Ethernet, PON, DSL, ADSL, VDSL, HFC, WLAN, WMAN, 3G/4G cellular networks. Emerging technologies: 5G, Internet of things (IoT), cognitive radio networks, vehicular and unmanned aerial vehicular networks, mesh networks, and ad hoc networks.

EEE 6203: Advanced Digital Signal Processing

Spectral estimation of random processes: classical methods, model based high resolution methods, super resolution techniques, spectral estimation in noisy condition, applications: estimation of sinusoids in noise, speech enhancement, quantitative tissue characterization, ECG/PPG signal analysis; adaptive filters: single and multichannel filters, non-blind and blind techniques, time and frequency domain approaches, convergence analysis, variable-step size single and multichannel LMS filters, constrained adaptive filters, applications in noise and echo cancellation; multi-rate signal processing with applications; non-stationary signal decomposition techniques and theirs applications.

EEE 6204: Optical Fiber Communications

Introduction to optical communication, Different types of fibers, specialty fibers
Wave Equation and Coupling Modes in optical waveguide and NLSE
Fiber loss, Chromatic dispersion, Birefringence and PMD Chromatic dispersion compensation, Higher order dispersion
Fiber nonlinearities: SPM, XPM, FWM
Optical transmitters and receivers, Optical Amplifiers, Optical Filters
Advanced Optical Modulation and Detection Schemes, Receiver noise analysis, BER calculation, Sensitivity calculation, Sensitivity degradation
Introduction to Soliton transmission
Optical networks, PON, SONET/SDH, OFDM, OTDM and WDM transmission systems.

Courses (all are 3 Credit courses)
EEE 6206: Optical Networks Optical networking: principles and challenges; evolution of optical networks, wavelength routed network, wavelength division multiplexing (WDM) network, sub-carrier multiplexing optical networks. Optical switching elements, optical cross-connects (OXC), multiplexers/demultiplexers, add-drop multiplexer, wavelength routers, optical wavelength converters, WDM network test beds. Network architecture, IP over WDM. Broadcast and select network, MAC protocol for optical networks: Aloha, Slotted Aloha, Modified slotted Aloha, OTDMA and WDMA, WDM ring network, OADM based network, Reconfigurable ring network, Wavelength assignment and routing algorithms Optical access networks: passive optical networks, radio-over-fiber networks, fiber-to-the-home/premise networks. Optical metro and core networks: SDH/SONET, GMPLS, Gigabit Ethernet, optical flow/burst/label/packet switching. Optical networking operation, administration, management and planning techniques (OAM&P) including: wavelength assignment & routing, multicast, grooming, fault management, connection management, performance management and network resource optimization. All-optical networks.
EEE 6207: Broadband Wireless Communications Overview of broadband wireless communications, multiple access techniques - TDMA, FDMA. Spread spectrum communications - direct sequence spread spectrum (DSSS), FHSS, THSS, modulator and demodulator structure, probability of error, jamming margin, decoding, performance in the presence of interference, PN sequence, CDMA, MC-CDMA, UWB transmission. Multi-user detection: multiple access interference, detector performance measure - BER, asymptotic efficiency, near-far resistance; detectors - matched filter detector, de-correlator detector, MMSE detector, SIC, PIC, MAP and MLSE detectors. Propagation in mobile radio channels; channel models, fading - large scale and small scale fading, flat fading and frequency selective fading channel, fast fading and slow fading channel; delay spread, Doppler spread and angle spread; channel autocorrelation functions, scattering function, correlated and uncorrelated scattering(US), WSS and WSSUS model. Multiple antenna systems, capacity of SISO, SIMO, MISO and MIMO systems, ergodic capacity, outage capacity, STBC, OSTBC, QOSTBC, spatial multiplexing (SM) scheme, SM detection techniques, diversity and diversity combining techniques. Multi-carrier communications; Orthogonal FDM (OFDM), OFDM transceivers. Special issues of OFDM - cyclic prefix, timing offset, frequency offset, synchronization, peak power problem, Broadband wireless standards
EEE 6208: Advanced Multimedia Communications Multimedia communications: definition, data types and digital representation, linear and non-linear multimedia; standards; applications and challenges. Compression techniques: Limpelziv and Huffman coding; DPCM, ADPCM, LPC, parametric and sub-band coding, G.72x and MPEG-1/2/4 standards, GSM/CELP, G.729, G723.3, MP3; GIF, JPEG, JPEG-DCT, JPEG2000; motion JPEG, H.26x, MPEG- 1/2/4, MPEG-7, MPEG-21, hybrid coding and HDTV. Networks: OSI model, fixed IP, switched and enterprise networks; mobile IP, adhoc networking, wireless LAN and WAN, cellular networks, network security and remote access; SONET, SDH, SMDS, cable TV; high-speed PSTN - ADSL, VDSL, ISDN, H.221 framing. Internet and Multimedia: IP addressing, IPv4, IPv6, datagrams, ARP and RARP; NGI and Internet 2, media transcoding and conversion; entertainment networks, P2P systems, routing mechanisms; signaling and transport protocols - UDP, TCP/IP, FTP, SS7, RTP, RTCP, RTSP, SCTP, MSCTP, ICMP, DCCP, HDLC. Solutions for packet loss: error and flow control, channel coding, FEC, block and convolutional coding, interleaving; synchronization techniques; multimedia traffic for CS and PS networks; network QoS, traffic scheduling, resource reservation. Applications: email, audio and video transmission, media streaming, streaming servers and RTSP, MPEG transport stream, audio and video conferencing; VoIP and mobile IP protocols - SIP, MGCP, Megaco, H.32x; web radio; mobile-TV systems – DVB-H, MBMS, IMS, IP TV, P2P TV. Evolution and

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convergence: mobile and wireless multimedia, IMT-2000, FOMA, DoCoMo, WAP; multimedia information security, media encryption and watermarking; multimedia servers and databases. Modern trends: intelligent multimedia system, audio and video on demand, interactive television, virtual reality, animation techniques, IoT and Web technologies.
EEE 6209: Digital Image Processing Introduction to image processing. Image processing in color space. Multi-resolution image processing, scale-space analysis: discrete wavelet transforms, directional transforms, and compressed sensing. Image compression techniques and standards; image watermarking and fusion. Object segmentation and level sets. Morphological filters for image processing. Anisotropic diffusion, PDEs, shape representations, deformable models, image registration. Shape and texture analysis of objects in images; descriptors of objects. Pattern recognition; deep learning for vision-based artificial intelligence. Emerging applications of image processing.
EEE 6210: Digital Video Processing Formation and representation of video, spatio temporal video sampling, motion analysis and estimation: real versus apparent motion, optical flow, block- and mesh-based methods for motion estimation and region-based stochastic motion modeling, motion segmentation and layered video representations, video filtering: motion compensated filtering, noise reduction, signal recovery, deblurring, superresolution, mosaicing, deinterlacing and frame-rate conversion, video compression techniques and standards, content-based video indexing and retrieval, video communication: digital television, streaming over IP and wireless networks, error control and watermarking, stereo and multiview sequence processing.
EEE 6211: Digital Speech Processing Introduction to digital speech processing. Speech production and phonetics: speech organs, articulatory phonetics, acoustic theory of speech production, vocal tract models. Speech analysis: time and frequency domain analysis, Pre-processing and basic parameters of speech, Voice activity detector, Linear-predictive (LP) model, spectrum using LP, applications of LP , formant and pitch estimation, Cepstral analysis, Mel-frequency cepstrum. Speech coding: linear predictive coding (LPC), vocoders, vector quantization. Speech enhancement techniques, adaptive noise cancellation Speech synthesis: formant and LPC synthesizers, effect of different speeches and languages. Automatic speech and speaker recognition: feature extraction, hidden Markov models, noise robustness, measures of similarity, language and accent identification; Speech Emotion region.
EEE 6212: Genomic Signal Processing Fundamentals of molecular biology, genomics, and proteomics; DNA and microarray; genome sequencing; microarray technology and data pre-processing; gene feature selection; gene expression analysis; hidden Markov Model-based and time-frequency analysis of genomics and proteomic sequences, regulatory motif discovery; gene finding; gene clustering and classification; proteomic technologies, protein-proteininteractions and protein function prediction, modeling and inference for genetic regulatory networks, emerging applications of genomic signal processing.

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EEE 6615: Advanced Electromagnetic Theory*   Time varying and time harmonic fields. Wave propagation and polarization in different media. Electromagnetic theorems. Scattering of EM waves. Geometrical theorems of Diffraction and its applications. Integro-differential equations and its solutions. Derivation of Inverse Scattering Formulation: Microwave Imaging, Microwave antenna-theory and design: Aperture antennas, Horn Antennas, Broadband antennas: spiral & log periodic antennas. Advanced topics in EM theory: waveguide discontinuities and modal analysis, Excitation of Waveguides: electric and magnetic Currents, aperture Coupling, Periodic Structure: existence of Floquet modes. Introduction of EM software: HFSS, COMSOL or CST.   ***This course also belongs to EP group**
EEE 6616: Microwave Devices and Circuits   Circuit theory for wave guide systems. N port circuits: impedance matrix, admittance matrix, scattering matrix and transmission matrix, their properties. Different microwave transmission lines and microwave integrated circuits (MICs). Microwave passive devices: directional couplers, impedance transformers, hybrid junction / magic T, Wilkinson power divider, isolators, phase shifters, attenuators. Introduction to filters, filter design by image parameter and insertion-loss methods; design of different type of filters. Microwave active devices: amplifiers and oscillators.
EEE 6604: Antennas and Propagation   Basic antenna parameters. Antenna as an aperture: arrays of point sources and theory of pattern multiplications. Different antennas: dipoles, loop, thin linear antennas, helical antenna, biconical, spheroidal antennas, and reflector type antennas. Antenna's current distribution: self and mutual impedances. Banbinet`s principle and complementary antennas. Impedance calculation of slot antennas using Babinet's principle. Frequency independent antennas. Printed and smart antennas. Antenna Fabrication: 2D and 3D antennas. Antenna feeding: balanced vs. unbalanced feeding, matching. Antenna measurements. Use of antennas in broadcasting, microwave links, satellite communication and radio astronomy.
EEE 6606: Optical Waveguide Theory*   Types of optical waveguides: optical integrated circuits and guiding structures. Basics of optical waveguide analysis: basic equations for light waves, polarization of light, reflection and refraction, wave equations. Guided and radiation modes in dielectric slab waveguides. Coupled mode theory. Analytical solution for optical waveguides: WKB method, Marcatili's method, effective index method, equivalent network method. Nonlinear optical waveguides. Plasmonic waveguides. Computer aided design of integrated optical waveguide devices. Application of photonics to microwave devices.   ***This course also belongs to EP group**
EEE 6607: Speech Recognition   Introduction: history of automatic speech recognition (ASR), applications, statistical speech recognition, speech signal analysis for ASR, acoustic modeling: hidden Markov models (HMMs) and Gaussian mixture models (GMMs), context-dependent phone modeling, deep neural network (DNN) acoustic models, discriminative training, language models (LM), recurrent neural network (RNN) LM, large vocabulary continuous speech recognition (LVCSR), weighted finite state transducers (WFSTs), decoding, adaptation: noise adaptation, speaker adaptation/normalization, language model adaptation, robust ASR: robust features, noise reduction, microphone arrays, multilingual systems, advanced topics: using prosody for ASR, audio-visual ASR, end-to-end systems, NN generative models and WaveNet.

Courses (all are 3 Credit courses)

EEE 6608: Machine Learning and Pattern Recognition*

Introduction to algorithms and principles involved in machine learning. Linear regression, logistic regression. Discriminative learning. Fundamentals of representing uncertainty, learning from data, supervised learning. Support vector machines and kernel trick. Model selection and feature selection. Combining features, classifiers, and boosting. Ensemble methods. Clustering and unsupervised learning. Expectation maximization regularization. Hidden Markov models. Learning from Bayesian networks. Probabilistic inference. Collaborative filtering. Reinforcement learning. Neural networks representation and learning. Deep neural network and manifold learning. Design and analysis of machine perception systems. Design and implementation of a technical project applied to real-world problems of images, text, and robotics.

***This course also belongs to the Interdisciplinary group**

EEE 6609: Deep Learning

Machine learning review, challenges motivating deep learning, universal function approximators, deep learning models: feed forward deep neural networks (DNN), hidden layers, backpropagation, convolutional neural networks (CNN), recurrent neural networks (RNN), long short-term memory (LSTM) networks, memory networks and Boltzmann machines, deep learning toolboxes: Theano, Caffe, Keras, Tensorflow, neural network regularization: dropout, model averaging, batch normalization, data augmentation, visualization, neural network optimization: stochastic mini-batch gradient descent, momentum, early stopping, weight decay, Nesterov momentum, AdaGrad, RMSProp, Adam, unsupervised neural learning: autoencoders, generative models, neural reinforcement learning, Distillation and model compression, applications of deep learning in natural language processing, image classification, detection, segmentation, image to sentence generation, robotics.

EEE 6610:Wireless and IP Networking

Wireless Networking: Radio propagation: Path-loss, fading, noise, link-budget. Cellular networks: Architectures, frequency reuse, capacity, co-channel interference, MAC, admission control, user association, resource allocation, load balancing, handover management, energy efficiency, heterogeneous networks, C-RAN, CoMP, carrier aggregation, FFR, SFR, Massive MIMO, Relay, DAS, CRN, DTNs, M2M, D2D, IoT, All-IP Networks; Network standards: GSM to LTE, 5G. Wireless LAN, MAN and PAN: Architectures, IEEE 802.11 family, standards, MAC protocols, power savings, Bluetooth, Zigbee, WiMAX, RFID. Wireless sensor networks and satellite networking.

IP Networking: Switching methods, OSI and TCP/IP models, switch, bridge, routers, gateways. Link Layer: Framing, flow control, error control, MAC, Ethernet generations, Bridged Ethernet. Network layer: Datagrams, IP addressing, IP4 and IP6, NAT, ARP, Mobile IP, routing strategies and protocols. Transport layer: TCP, UDP, RTP, congestion management. Application layer: DNS, Telnet, FTP, SMTP, WWW. Traffic shaping. Packet scheduling - FIFO, PQ, RR, WFQ, RED. QoS: Differentiated services, integrated services, MPLS, network management. VoIP: QoS, architecture, H.323, SIP.

EEE 6611: Sensor Networks

Applications, challenges, metrics, architecture, sensor nodes, cluster heads, anchor, protocol stack, basics of RF communication, popular protocols (802.11, 802.15, Bluetooth). Coverage: Area, point, barrier and k-coverage. Medium Access Control (MAC) Aspects: Contention-free, Contention-based, Hybrid and Self-organizing MAC. *Routing:*Data-centric, proactive, on-demand, hierarchical, location-based andQoS-based routing. Time Synchronization: Reasons, challenges, protocols. Localization: Importance, issues, ranging techniques, range-based and range-free

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localization. Power Management: Sleep mode scheduling, active and idle power management, energy efficient MAC and routing. Data Collection and Processing: Discovery, data collectors, data aggregation, data transfer, data fusion, estimation. Underwater Sensor Networks: Applications, difference with terrestrial SNs, architectures, transmission media and propagation models (acoustic, optical, EM, magnetic), localization, intruder detection and tracking, AUV and submarine navigation. Industrial Sensor Networks: Standards - Zigbee, Wireless HART, UWB, IETF 6LoWPAN, ISA-100, Wi-Fi – Low power, Bluetooth Low Energy.
EEE 6612:Random Processes in Communications Introduction to independent increment processes; Brownian motion and Wiener process; Ito integral, Point processes, Poisson processes, and spectral representations; Series expansion of random processes; Linear systems with random inputs; Linear estimation and orthogonality principle; State space theory; Wiener filters, Kalman filters, Optimum receivers, matched filters, correlation receiver and signal detection; Random processes in nonlinear systems with noise, and phase lock loop systems.
EEE 6213: Applied Probability Theory & Random Processes Applications of probability theory, random variables and stochastic processes; tools relevant to both modelling uncertainty and inferencing in the presence of uncertainty; probabilistic methods applicable to problems in electrical and electronic engineering arena such as power systems, electronic systems, communication systems and networks, biomedical systems, etc.
EEE 6613:Signal Detection and Estimation Theory Introduction to random processes. Hypothesis testing: Bayesian, minimax, Neyman-Pearson, and composite. Signal detection in discrete-time deterministic and stochastic signals; performance analysis, sequential and distributed detections, nonparametric and robust detection. Parameter estimation: Bayesian and nonrandom parameter estimation. Minimum-variance unbiased estimators, properties of estimators, ML, MMSE, MAP and MAE-based parameter estimation, EM algorithm. Estimation in discrete time: general linear estimation theory, Kalman-Bucy filtering, Wiener Kolmogorov filtering. Contemporary techniques for signal estimation and detection.
EEE 6614: Satellite Communication Systems Radio Regulations, ITU-R/T, IFRB. Frequencies and interference management. The Origin of Satellites, Communications Via Satellite, Characteristic Features of Communication Satellites. Satellites: Space and ground segments, earth stations, bus and payloads, antennas and coverage, transparent and non-transparent transponders, Orbits and Orbital Errors, Control and operation of Satellite systems, Satellite Power Systems, Satellite Links: Link Equations, Carrier to Noise and Interference Ratio. Communication Networks and Systems: Various modulation techniques, Multiple Access techniques, Capacity Comparison of Multiple-Access techniques, Channel Coding and Error Correction Coding Techniques. Satellite System and Special Services: Mobile Satellite Systems, The Internet and Satellites, Direct Broadcast Satellite System.