Foundations of Machine Learning
Books: The Elements of Statistical Learning, Trevor Hastie, Robert Tibshirani, Jerome Friedman; Pattern Recognition and Machine Learning, Christopher Bishop
Content: Supervised classification: perceptron, support vector machine, loss functions, kernels, neural networks and deep learning, Supervised regression: linear regression, least square linear regression model, Bayes Linear Regression, non-linear regression, ridge regression, lasso regression, SVM regression, Unsupervised learning: clustering - K-Means, Expectation-Maximization - Mixture of Gaussian

Advanced Machine Learning
Books: Probabilistic Graphical Models: Principles and Techniques, by Daphne Koller and Nir Friedman. Deep Learning by Ian Goodfellow, Yoshua Bengio and Aaron Courville.
Content: probabilistics graphical models (directed and undirected), inference methods like junction trees, belief propagation, and other approximate methods, sampling methods like MCMC, variational auto-encoders, GANs, neural architectures for sequence and graph-structured predictions

Reinforcement Learning (Foundations of Intelligent and Learning Agents)
Books: Reinforcement Learning: An Introduction, Richard S. Sutton and Andrew G. Barto
Content: Agency, intelligence, and learning, Exploration and multi-armed bandits, Markov Decision Problems and planning, policy improvement, policy iteration, value iteration, Monte Carlo Methods, TD Learning and Bootstrapping, Q-learning, SARSA, policy gradient methods, search, case studies: Chess, Go

Speech Processing
Content: Speech production and acoustic phonetics, speech perception.;Speech analysis: time and frequency domain techniques for pitch and formant estimation, cepstral and LPC analysis.;Speech synthesis: articulatory, formant, and LPC synthesis, voice response and text-to-speech systems.;Applications: data compression, vocoders, speech enhancement, speech recognition, speaker recognition, aids for the speech and hearing impairments.

Automatic Speech Recognition
Content: Introduction to statistical ASR, Weighted Finite State Transducers and their algorithms, Acoustic models, Hidden Markov models, Deep neural network-based models, Pronunciation models, Acoustic Features and Speech Production Basics, Language models (Ngram models, RNN-LMs), Decoding search problem (Viterbi algorithm, etc.), Pronunciation Modeling, Speaker Adaptation, Conversational Agents, Speech Synthesis, Parametric Speech Synthesis

Image Processing
Books: Rafael C. Gonzalez, Richard E. Woods - Digital Image Processing
Content: Digital image fundamentals, Histogram manipulation, Spatial filtering, Frequency filtering and wavelets, Color spaces and color processing, Compression, Morphological processing, Segmentation, Shape detection, Image descriptors, Image recognition

Advanced Image Processing (in progress - Spring 2020)
Content: Image transforms and statistics of natural images, Dictionary learning and sparse representations in image processing, Principal Components Analysis (PCA), Singular Value Decomposition (SVD) and Independent Components Analysis (ICA); Sparse PCA, Concept of overcomplete dictionaries, Greedy pursuit algorithms: matching pursuit (MP), orthogonal matching pursuit (OMP) and basis pursuit (BP), Popular dictionary learning techniques: Method of Optimal

Directions (MOD), Unions of Orthonormal Bases, K-SVD, Non-negative sparse coding – along with applications in image compression, denoising, inpainting and deblurring, Sparsity-seeking algorithms: iterative shrinkage and thresholding (ISTA), Compressed Sensing (CS), Concept and need for CS, Theoretical treatment: concept of coherence, null-space property and restricted isometry property, proof of a key theorem in CS, Algorithms for CS, Applications of CS: Rice Single Pixel Camera and its variants, Video compressed sensing, Color and Hyperspectral CS, Applications in Magnetic Resonance Imaging (MRI). Low-rank matrix estimation and Robust Principal Components Analysis: concept and application scenarios in image processing, statement of some key theorems, and proofs.

Medical Image Computing
Content: Introduction to imaging modalities, mathematical imaging models, noise and artifact models, sampling, signal modelling and fitting X ray, computed tomography (CT), positron emission tomography (PET), magnetic resonance imaging (MRI) (including diffusion MRI, functional MRI), ultrasound, microscopy. Visualization Methods: sectioning, multimodal images, overlays, rendering surfaces and volumes, using glyphs for PET-CT imaging, diffusion tensor imaging. Image reconstruction Methods: image models, sampling, problem formulations, algorithms for MRI, CT. Image denoising Methods: Bayesian estimation, nonlinear smoothing for MRI, CT. Image segmentation Methods: clustering, Bayesian estimation, graph partitioning, classification. Anatomical shape analysis Methods: descriptors, learning shape models, hypothesis testing. Image registration Methods: similarity, transformation for anatomical atlas, co-registration, motion correction.

Digital Signal Processing
Books: A.V. Oppenheim and Schafer, Discrete Time Signal Processing, Prentice Hall, 1989.
Content: Discrete time signals: Sequences, representation of signals on orthogonal basis, Sampling and reconstruction of signals,Discrete systems: attributes, Z-Transform, Analysis of LSI systems, Frequency analysis, Inverse Systems, Discrete Fourier Transform (DFT),Fast Fourier Transform algorithm, Implementation of Discrete Time Systems. Design of FIR Digital filters: Window method, Park-McClellan's method. Design of IIR Digital Filters: Butterworth, Chebyshev and Elliptic Approximations, Lowpass, Bandpass, Bandstop and High pass filters. Effect of finite register length in FIR filter design. Parametric and non-parametric spectral estimation. Introduction to multirate signal processing. Application of DSP to Speech and Radar signal processing.

Analytical Signal Processing
Content: Compressed sensing, finite rate of innovation signals and their sampling methods, graph signal processing and its applications, phase retrieval problems, distributed sampling problems, machine learning for signal processing, role of quantization and other nonlinearities in signal processing systems, signal approximation methods

Estimation and Identification
Books: Linear Estimation, Ali H. Sayed, Babak Hassibi, and Thomas Kailath
Content: Introduction to linear least square estimation : a geometric approach.Wiener filter, Levinson filter, updating QR filter and the Kalman filter.Filter implementation structures : lattice, ladder and the systolic QR.Stochastic realization theory (modelling given the covariance). Modelling given the raw data. Spectral estimation.;Recursive least squares identification algorithms: Levinson-type, Kalman-type and the QR-type.

Probability and Random Processes
Books: Sheldon M. Ross, Introduction to Probability and Statistics for Engineers and Scientists; Robert Gallager, Stochastic Processes

Content: Review of Basic Probability, Joint distributions, functions of random variables, moments of random variables, Conditional distribution, densities and moments, Characteristic functions of a random variable, Markov, Chebyshev and Chernoff bounds; Random sequences and modes of convergence (everywhere, almost everywhere, probability, distribution and mean square), Limit theorems, Strong and weak laws of large numbers, central limit theorem. Random process. Stationary processes and filtering. Wide sense stationarity. Gaussian Processes. Mean and covariance functions. Autocorrelation function. Power spectral density.

Markov Chains and Queuing Systems (in progress - Spring 2020)
Content: Review of probability, Renewal Processes: Basic definitions, recurrence times, rewards and renewal reward theorem, point processes, Poisson process, Wald's equation, Blackwell's theorem.; Discrete time Markov chains: definitions and properties, matrix representation, Perron-Frobenius theory.; Continuous time Markov chains: basic definitions, Q-matrix, birth-death processes, quasi birth death processes.; Embedded Markov processes, semi Markov processes, reversible Markov chains.; Random walks; Fundamental queueing results: Little's theorem, invariance of the mean delay, Conservation law.;Markovian queues: Jackson and BCMP networks, numerical Algorithms.; M/G/1 & G/M/1 queues and G/G/1 queues; Advanced queueing models: priority, vacation and retrials in queues.

Signals and Systems
Books: Alan V. Oppenheim and Alan S. Willsky with S.H. Nawab, Signals and Systems, Second Edition, PHI (Indian reprint: 2014), B.P. Lathi, Principles of Signal Processing and Linear Systems, Oxford University Press, International Version 2009.
Content: Signals and their properties and simple operations, description and properties of LTI systems, Fourier series representation of periodic signals, Fourier transform, Sampling and Analog to Digital Conversion, Laplace transform

Data Analysis and Interpretation
Books: Sheldon M. Ross, Introduction to Probability and Statistics for Engineers and Scientists
Content: Review of Basic Principle of Counting, Permutation and Combination, Axioms of Probability Conditional Probability and Independence, Random Variables, Joint Distribution of Random Variables, Expectation and Conditional Expectation, Moment Generating Functions, Statistics: Sufficient, Complete, Estimators: MVUE, MLE, Central Limit Theorem, Law of Large Numbers

Computer Graphics
Content: Introduction: What is Computer Graphics? Geometric Manipulation: Transformations, Matrices, Homogeneous Coordinates. Elementary 3D Graphics: Plane projections, Vanishing points, Specification of a 3D view. Visibility: Image and object precision, z-buffer algorithms, area based algorithms. Basic Raster Graphics: Scan conversion, filling, and clipping. Rendering: Lighting, Radiosity, Raytracing.

Data Structures and Algorithms
Books: T. Cormen, C. Leiserson, R. Rivest, C. Stein, Introduction to Algorithms, 2nd edition
Content: Introduction to data structures, abstract data types, analysis of algorithms. Creation and manipulation of data structures: arrays, lists, stacks, queues, trees, heaps, hash tables, balanced trees, tries, graphs. Algorithms for sorting and searching, order statistics, depth-first and breadth-first search, shortest paths and minimum spanning tree.

Matrix Computations

Books: David S. Watkins, Fundamentals of Matrix Computations, 3rd Edition, Wiley-Interscience, 2010.
Content: Fundamentals: Flops count, memory management, matrix-vector multiplication. Gaussian elimination: Basic Gaussian elimination without pivoting, LU decomposition, the condition of LU decomposability. Gaussian elimination with pivoting. Positive definite matrices, Cholesky factorization. Comparison between the two methods. A brief discussion on sparsity. Sensitivity and round-off errors: Vector norms, matrix norms. Condition number. Perturbation, residual, round-off errors. Backward stability. Error propagation in Gaussian elimination. Backward error analysis in Gaussian elimination.
QR decomposition: Orthogonal matrices, rotators and reflectors. Solution of the least squares problem, the full-rank case. Gram-Schmidt process. Condensed QR decomposition. Updating the QR decomposition. SVD: Introduction. Algorithm. Applications. Sensitivity. Eigenvalues and eigenvectors: The power method. Unitary similarity transform, Schur's theorem, normal matrices, spectral theorem of normal matrices. Hessenberg and tridiagonal matrices, reduction to these forms. The QR algorithm. A brief discussion on sparsity. Iterative methods: Steepest descent, conjugate gradient.

Control Systems
Books: Franklin G.F., Powell J.D., Emami-Naeini A., Feedback Control of Dynamic Systems, Pearson, Upper Saddle River, New Jersey, 5th edition, 2006.
Content: Examples of control systems, feedback control systems. Mathematical modelling of: electrical systems, mechanical systems, electro-mechanical systems. Laplace transforms, transfer functions, electrical analogues of other dynamical systems. State-space modelling of dynamical systems. Block diagrams, block diagram reductions. Signal flow graph, Mason's gain formula. Linearity, time-invariance versus nonlinearity and time-variance. Linearization. Distributed parameter systems. Time response of dynamical systems: Obtaining solutions from mathematical models. Poles and zeros and their effects on solutions. Step response of standard second order systems, time-domain specifications and their formulae. Stability: Definition of stability. Routh-Hurwitz test. Lyapunov theory. Properties of feedback: Basic idea of feedback control systems. Error analysis. P, PI, PD, PID controllers. Design of controllers: The root-locus technique, steps in obtaining a root-locus. Design of controllers using root-locus. Pole placement with state feedback, controllability. Pole placement with output feedback, observability, Luenberger observer. LQR control. Frequency domain analysis: Bode plot, Nyquist plot, Nyquist stability criterion, gain and phase margins, robustness. Design of compensators: Lead compensator, lag compensator, lead-lag/lag-lead compensators, their design.

Game Theory and Applications
Content: basics of static games and dynamic games with perfect and imperfect information, simultaneous moves, sequential move and hybrid games, strict and weak domination of strategies, pure and mixed strategies, Nash Equilibrium, Kakutani's Fixed Point Theorem, routing and congestion games, mechanism design, Hotelling's model of spatial competition, problem of the commons, rubinstein stahl bargaining model with finite and infinite horizon, repeated games and infinitely repeated games, discounting, Bayesian games and Bayes Nash Equilibrium, auction theory.

Computer Networks
Books: Computer Networks, Andrew S. Tanenbaum
Content: Internet architecture and the layering abstraction. Application layer: network application architectures and examples. Socket programming. Transport layer: transport protocol design, analysis of TCP. Network layer: addressing, routing, forwarding, interdomain routing. Router design and scheduling. QoS and resource allocation. Traffic engineering, network address translation and

other practical topics. Link layer: channel access, switching, VLANs, MPLS. PHY layer basics: framing, encoding, modulation.

Operating Systems
Books: Operating System Concepts, Abraham Silberschatz, Peter Baer Galvin, Greg Gagne, Ninth Edition
Content: Operating-System Structure, Processes, Threads, Process Synchronization, CPU Scheduling, Deadlocks, Main Memory, Virtual Memory, Mass-Storage Structure, File-System Interface, File-System Implementation, I/O Systems

Microprocessors
Books: Kenneth J. Ayala, The 8051 Microcontroller, Architecture, Programming and Applications, Penram International Publishing, 1996
Content: General purpose processor; elements of hardware and software architectures; introduction to concepts of data and control paths, registers and memory organization. Instruction set basics and assembly language programming: instruction structure and addressing modes, instruction encoding, and study of 8085A instruction set, hardware architecture and interrupts. Introduction to microcontrollers. 8051 hardware and instruction set architecture, timers/counters, interrupts and serial interface (including multi-processor communication). Interfacing basics using examples of I/O devices: parallel port, serial ports, keypad, display, etc. Introductory discussion on processor performance evaluation and design using a RISC ISA (including concepts of pipelining, pipelining hazards, cache, virtual memory and parallelism).

Discrete Structures
Books: Discrete Mathematics and its applications, by Kenneth H Rosen.
Content: Propositions and predicates, proofs and proof techniques. Sets, relations and functions, cardinality, basic counting. Posets and lattices: Dilworth’s theorem, inversion and distributive lattices. Graph theory: paths, cycles, trees, connectivity. Group theory : Lagrange’s theorem, homomorphisms, applications.

Error Correcting Codes
Content: Linear block codes : Systematic linear codes and optimum decoding for the binary symmetric channel; Generator and Parity Check matrices, Syndrome decoding on symmetric channels; Hamming codes; Weight enumerators and the MacWilliams identities; Perfect codes.;Introduction to finite fields and finite rings;factorization of (X^n-1) over a finite field; Cyclic Codes.; BCH codes; Idempotents and Mattson-Solomon polynomials; Reed-Solomon codes, Justeen codes, MDS codes, Alterant, Goppa and generalized BCH codes; Spectral properties of cyclic codes. ;Decoding of BCH codes: Berlekamp's decoding algorithm, Massey's minimum shift register synthesis technique and its relation to Berlekamp's algorithm. A fast Berlekamp - Massey algorithm.; Convolution codes; Wozencraft's sequential decoding algorithm, Fann's algorithm and other sequential decoding algorithms; Viterbi decoding algorithm.

Random Graphs
Content: Erods-Renyi graphs, basic structural properties, emergence of giant connected component and full connectivity, applications. Random Geometric Graphs, structural and connectivity properties, applications Scale-free and small-world networks, generative models and properties, applications, Random processes on graphs, such as random walks, epidemic spread, and opinion dynamics.