Description of Selected Courses

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Ph.D. (2024–Present): University of Washington (UW)

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B.Sc. in Mathematics (2017–2022): Isfahan University of Technology (IUT)

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* I took this graduate-level course during my undergraduate studies.

Chapter 1

Selected Graduate Courses

1.1 University of Washington, U.S.

1.1.1 Statistical Learning: Modeling, Prediction, and Computing (STAT 535)

Topics

Statistical learning over discrete multivariate domains, exemplified by graphical probability models. Emphasizes the algorithmic and computational aspects of these models. Includes additional topics in probability and statistics of discrete structures, general purpose discrete optimization algorithms like dynamic programming and minimum spanning tree, and applications to data analysis.

Textbooks

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1.1.2 Statistical Learning: Modeling, Prediction, and Computing (STAT 538)

Topics

Reviews optimization and convex optimization in its relation to statistics. Covers the basics of unconstrained and constrained convex optimization, basics of clustering and classification, entropy, KL divergence and exponential family models, duality, modern learning algorithms like boosting, support vector machines, and variational approximations in inference.

Textbooks

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1.1.3 Numerical Optimization (MATH 516)

Topics

Methods of solving optimization problems in finitely many variables, with or without constraints. Steepest descent, quasi-Newton methods. Quadratic programming and complementarity. Exact penalty methods, multiplier methods. Sequential quadratic programming. Cutting planes and nonsmooth optimization.

Textbooks

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1.1.4 Medical Imaging (MATH 583)

Topics

Textbooks

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1.1.5 Machine Learning for Big Data (STAT 548)

Topics

Machine learning and statistical techniques for analyzing datasets of massive size and dimensionality. Representations include regularized linear models, graphical models, matrix factorization, sparsity, clustering, and latent factor models. Algorithms include sketching, random projections, hashing, fast nearest-neighbors, large-scale online learning, and parallel learning (Map-Reduce, GraphLab).

Textbooks

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1.1.6 Causal Modeling (STAT 566)

Topics

Construction of causal hypotheses. Theories of causation, counterfactuals, intervention vs. passive observation. Contexts for causal inference: randomized experiments; sequential randomization; partial compliance; natural experiments, passive observation. Path diagrams, conditional independence, and d-separation. Model equivalence and causal under-determination.

Textbooks

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1.1.7 Topology of Manifolds (MATH 544)

Topics

General topology, the fundamental group, covering spaces, topological and differentiable manifolds, vector fields, flows, the Frobenius theorem, Lie groups, homogeneous spaces, tensor fields, differential forms, Stokes's theorem, deRham cohomology.

Textbooks

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1.1.8 Localization Techniques in High-Dimensional Geometry

Topics

Concentration of measure in different settings (Euclidean, Riemannian and discrete) and the main open problems surrounding it, proof techniques involving different types of localization, applications of localization techniques in geometry, probability statistics, and theoretical computer science. After taking the course, students will have the necessary background in order to both conduct research around open problems in concentration of measure, find new applications to existing localization techniques and perhaps also develop new localization techniques.

Textbooks

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1.1.9 Mathematics of A.I. (MATH 583)

Topics

The field of mathematics is experiencing transformative changes driven by the confluence of the symbolic reasoning of interactive theorem provers and the statistical reasoning of superpowered machine learning algorithms. This course will survey the dynamic interplay between mathematics and artificial intelligence (AI). What are the mathematical foundations of AI, and conversely how can AI accelerate mathematical research? We will learn the foundations of neural networks, build simple neural networks from scratch, and also build advanced models using the Python library PyTorch. We will cover theoretical results such as the Universal Approximation Theorem (asserting that the functions computed by feed-forward neural networks are dense in the space of continuous functions) as well as recent results on the theoretical limitations of neural networks and transformers. We will also survey the history of symbolic AI, otherwise known as good old-fashioned AI, and we will cover one of its greatest successes, namely, interactive theorem provers. We will learn how to formalize mathematical theorems using the Lean Theorem Prover. Finally, we will survey the state-of-the-art of autoformalization, which is the automation (or at least partial automation) of the formalization process. We will cover various search algorithms for proof generation including how various tactics (such as exact?, simp, ring, linarith, and omega) are implemented in Lean as well as explore applications of reinforcement learning algorithms in the style of Alphazero. A large component of this course are group projects, each focused on an exploratory question within one of the themes of Math AI.

Textbooks

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1.1.10 Statistical Inference 1 (STAT 512)

Topics

Review of random variables; transformations, conditional expectation, moment generating functions, convergence, limit theorems, estimation; Cramer-Rao lower bound, maximum likelihood estimation, sufficiency, ancillarity, completeness. Rao-Blackwell theorem. Hypothesis testing: Neyman-Pearson lemma, monotone likelihood ratio, likelihood-ratio tests, large-sample theory. Contingency tables, confidence intervals, invariance. Decision theory.

Textbooks

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1.1.11 Statistical Inference 2 (STAT 513)

Topics

Review of random variables; transformations, conditional expectation, moment generating functions, convergence, limit theorems, estimation; Cramer-Rao lower bound, maximum likelihood estimation, sufficiency, ancillarity, completeness. Rao-Blackwell theorem. Hypothesis testing: Neyman-Pearson lemma, monotone likelihood ratio, likelihood-ratio tests, large-sample theory. Contingency tables, confidence intervals, invariance. Decision theory.

Textbooks

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1.1.12 Optimization: Fundamentals and Applications (MATH 515)

Topics

Maximization and minimization of functions of finitely many variables subject to constraints. Basic problem types and examples of applications; linear, convex, smooth, and nonsmooth programming. Optimality conditions. Saddlepoints and dual problems. Penalties, decomposition. Overview of computational approaches.

Textbooks

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1.1.13 Optimal Transport (MATH 581C)

Topics

The modern theory of Monge-Kantorovich optimal transport is a very popular area right now in mathematics and its applications to statistics and ML. This is due to the interaction of the geometric intuition of classical OT with random particle systems and statistical analysis, mostly via what is known as entropic regularization. This two quarter long graduate topics course will serve as an introduction to this rich and useful theory.

Prerequisites: Basic measure theory, topology, functional analysis. Some knowledge of probability, including Brownian motion, will be very useful. Notes will be provided.

Textbooks

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1.1.14 Microlocal Analysis and Semiclassical Analysis (MATH 583C)

Topics

Microlocal analysis comprises techniques developed from the 1950s on-ward based on the Fourier transform related to the study of variable coefficients, linear and non- linear partial differential equations. This includes distributions, pseudodifferential operators, wave front sets, Fourier integral operators, and paradifferential operators. It has applications in many fields including inverse problems, general relativity, quantum mechanics, quantum field theory, spectral theory etc. Semiclassical analysis is a branch of mathematical physics and analysis that studies the behavior of quantum systems in the limit where Planck's constant goes to zero. It serves as a bridge between classical mechanics and quantum mechanics, offering approximations of quantum phenomena using classical concepts. We will give applications of Microlocal Analysis and Semiclassical Analysis to Inverse Problems.

Textbooks

- Peter Hintz "An introduction to Microlocal Analysis, Springer Verlag, GTM 304.

1.2 University of Calgary, Canada

1.2.1 Statistical Inference (STAT 721)

Topics

Statistical models, likelihoods, maximum likelihood estimators, likelihood ratio, Wald and score tests, confidence intervals, bounds and regions, Bayesian estimation and testing, basic large sample theory, estimating equations, jack-knife, bootstrap and permutation.

Textbooks

- Dennis D Boos, L. A Stefanski, Essential Statistical Inference Theory and Methods, Springer Texts in Statistics, 2013.

1.2.2 Theory of Probability 1 (STAT 701)

Topics

Probability spaces, integration, expected value, laws of large numbers, weak convergence, characteristic functions, central limit theorems, limit theorems in Rd, conditional expectation, introduction to martingales.

Textbooks

- Rick Durrett, Probability: Theory and Examples: Cambridge University Press, 2019.

1.2.3 Generalized Linear Models (STAT 635)

Topics

Exponential family of distributions, binary data models, loglinear models, overdispersion, quasi-likelihood methods, generalized additive models, longitudinal data and generalized estimating equations, model adequacy checks.

Textbooks

- Annete J. Dobson, Adrian G. Barnett, An Introduction to Generalized Linear Models, Third Edition, Chapman & Hall/CRC Texts in Statistical Science, 2008

1.2.4 Asymptotic Statistical Inference (STAT 601.01)

Topics

This course focuses on approximation techniques and asymptotic methods in statistics. Topics include different modes of convergence, Slutsky's theorem, Berry-Esséen theorem, Edgeworth expansions, Delta method, Liapounov's theorem, asymptotic (relative) efficiency and robustness of estimation and testing, asymptotics of likelihood based estimation and testing, nonparametric estimations based on U- and Vstatistics.

Textbooks

- E. L. Lehmann, Elements of Large-Sample Theory, Springer Texts in Statistics, 1999

1.2.5 Nonparametric Statistics (STAT 601.02)

Topics

This course focuses on non-parametric estimation and hypotheses testing. Topics include properties (such as efficiency and robustness) of nonparametric methods vs parametric methods, estimations and tests based on binomial distribution, estimations and tests based on ranks, tests for contingency tables, nonparametric linear regression, nonparametric density estimation (such as kernel estimation) and goodness-of-fit tests (such as Kolmogorov-Smirnov test), re-sampling methods, etc.

Textbooks

- W. J. Conover, Practical Nonparametric Statistics, 3rd Edition, John Willey & Sons, Inc. 1999

1.3 Isfahan University of Technology, Iran

1.3.1 Real Analysis 1*

Topics

Measure Theory: Sigma-Algebra and their generators, Dynkin system, Contents, Premeasure, Measure, Lebesgue Premeasure, Extending a Premeasure to a measure, Lebesgue measure and measures on real numbers, Measurable operators, Operatory properties of Lebesgue measure. Integration Theory: Measurable functions, Simple functions, Nonnegative measurable functions integration, Integrability, Almost everywhere properties, Lp Spaces, Convergence theorems and their applications, Radon Nikodym Theorem, Signed measures, Integration with respect to an operatory measure, Convergence in measure, Equi-Integrable.

Textbooks

- Measure and Integration Theory, Heinz Bauer, Translation to Persian by Dr. Rasoul Nasr Isfahani
- Gerald B. Folland, Real Analysis: Modern Techniques and Their Applications, 2nd Edition, Willey, 2007.

Chapter 2

Selected Undergraduate Courses

2.1 Mathematical Courses

2.1.1 Introduction to Mathematics

Topics

An introduction to propositional logic and the logic of predicates, First order logic, Axiomatic set theory and its justification by alluding to some mathematical paradoxes such as Russel's paradox, The Boolean algebra of sets, Indexed family of sets, Union and intersection of a family, Cartesian product of two sets, Relation, equivalence relations and their link to partitions of sets, The set of equivalence classes, Combination of two relations, Function, restriction and extension of functions, One-to-one and on-to function, Left inverse and right inverse functions, Inverse function, Equipotence, finite and infinite sets, Countable and uncountable sets, Countability of rationals and uncountability of real numbers, Cardinal numbers, Ordering on cardinal numbers, Schroder-Bernstein theorem, Main operations on cardinal numbers such as addition and multiplication

Textbooks

- Ian Stewart, David Tall, The Foundations of Mathematics, Oxford University Press, 2007
- Herbert Kenneth Kunen, The Foundations of Mathematics, College Publications, 2009
- Shwu-Yeng T. Lin, You-Feng Lin, Set theory with applications, Book Publishers, 1985

2.1.2 Calculus 1

Topics

Sequence of Real numbers, Convergence of a sequence, Monotone convergence theorem, The squeeze theorem, Numerical Series, Convergence and divergence of numerical series, Convergence tests of series with nonnegative terms, Arbitrary terms series, Cauchy product of two series, Power series, Radius of Convergence of a power series, Definition of the Exponential function in terms of series and its properties, Continuity and limiting behavior of the Exponential function, Hyperbolic functions, Logarithm function and its properties, Other Exponential and Logarithmic functions, Reviewing the concept of derivative of a function, Derivative of Transcendental functions, Principal theorems of differentiation, Derivative of a composite function, Rolle's theorem, Mean value theorem, Cauchy mean value theorem, Finite Taylor expansion, L'Hopital's rule, Differentiation's application in limiting behavior of a function, Primitive function (Indefinite Integrals), Integration methods, Change of variables , Integration by parts, Trigonometric change of variables, Partial fraction decomposition, Particular change of variables, Reimann integral, Integrability of continuous and continuous by parts functions, Properties of definite integrals, Integral mean value theorem, The fundamental theorem of calculus, Improper integrals, Derivative and integral of Power series, Taylor expansion, The field of imaginary numbers, The complex plane, Complex numbers in polar form,Solving equations with algebraic methods.

Textbooks

- Aghasi M., Mashkouri M., Bahrami F., Taherian Gh., Calculus of one variable real functions, Department of Mathematical Sciences, Isfahan University of Technology
- Naderi, A., Zohouri Zangeneh H. (2004), Single Variable Calculus, IUT Publishing Co., Isfahan, Iran

2.1.3 Calculus 2

Topics

Multivariate functions, The level set of a function, Cylindrical surfaces, Surfaces of revolution, Quadratic surfaces, Limits and continuity of multivariate functions, Limits via paths, Implicit derivatives, Differentiability, Chain rule, Directional derivatives, Parametric curves and the tangent vector to a curve, Tangent plane of a surface and its normal line, Relative, absolute and local extrema of multivariate functions, Double integrals, Computing double integral on regions of the plane, Change of variables in double integrals, Change of variables in polar coordinate, Triple integrals, Computing triple integrals on regions of the space, Change of variables in triple integrals, Triple Integration with Cylindrical and Spherical Coordinates, Line integral with respect to the arc length, Line integral with respect to the position vector, Green's theorem (In plane), Integration over surfaces, Gauss's theorem (Divergence), Stokes' theorem.

Textbooks

- Richard A. Silverman, Modern Calculus and Analytic Geometry, Dover Publications; Illustrated edition (June 20, 2012) - Seasons 11 to 15
- Calculus problem set (Download from Mathematics Department Website)

2.1.4 Mathematical Analysis 1

Topics

Field of real numbers, Least/greatest upper bouns , Archimedean property, Density of rational/ irrational numbers, Real Sequences, Convergence and divergence, Upper/ lower limit of a bounded sequence, Cauchy sequence, Convergence and divergence of a series, Cauchy's criterion for convergence, Convergence tests, Rearrangement of a series, Metric space, Open and closed sets, Compact sets, Connected sets, Sequences in a metric space, Cauchy sequences and complete metric spaces, Continuity, Topological properties of continuous functions, Continuity and Compactness/connectedness, Uniform continuity, Derivative of functions, Intermediate value theorem for derivative, Reimann integrable functions, Lebesgue criterion for Riemann integrability, Riemann–Stieltjes integral

Textbooks

- S.K. Berberian (1994), A first course in real analysis, Springer-verlage New York
- Self-Reading: Real Analysis: a first course, by Gordon, Russel A. Seasons 1,2,3, 6, and 8.

2.1.5 Mathematical Analysis 2

Topics

Metric spaces: Normed linear spaces, Open and closed sets, Interior and closure of a set, Compact sets, Connected sets, Sequences and convergence, Completeness, Continuity, Continuity and compact/connected sets, Uniform convergence. Sequence of functions, Relation between uniform convergence and continuity/differentiability/integrability, Weierstrass approximation theorem, Stone-Weierstrass theorem, Compact subsets of C(X), Arzela-Ascoli lemma, Series of functions, Weierstrass M test, Abel's test for uniform convergence. Power series, Fourier series.

Textbooks

- Rudin W. (1976), Principles of Mathematical Analysis, McGraw-Hill Publishing Company; 3rd Ed.
- Ulger A. (2006), Real Analysis

2.1.6 Complex Analysis

Topics

Complex Numbers: Algebraic operations, Absolute value, Conjugate, Polar s, Roots, Topological concepts (Metrics and Connectedness), Elementary functions, Analytic functions and Cauchy-Riemann equations, Harmonic functions, Contour integrals, Cauchy-Goursat theorem, Cauchy integral formula and its applications, Liouville's theorem, The Fundamental Theorem of Algebra, Power/Taylor/ Laurent series, Maximum modulus principle, Zeros and singular points, Isolated Singular points, Rouche's theorem, Hurwitz's theorem, Cauchy's residue theorem and its application in evaluation of improper integrals, Linear fractional transformations, Conformal mapping.

Textbooks

- Berenstein, A.C. and Gay, R. (1991), Complex Variables, An Introduction, Springer-Verlag, New York
- Krantz, S.G. (2008), A Guide to Complex Variables, The Mathematical Association of America

2.1.7 Linear Algebra 1

Topics

Matrices, System of linear equations, Elementary row operations, Row reduced echelon matrices, Rank, Calculating the inverse of a matrix, Determinant, Vector spaces, Important examples of vector spaces, Subspace, Linea Independence and dependence, Basis and dimension, Sum of subspaces, Inner product spaces, Gram-Schmidt theorem, Orthogonal decomposition, Linear transformations, Change of basis matrix, Rank and nullity of a linear transformation, Eigenvalues and eigenvectors, Characteristic polynomial, Minimal polynomial, Primary or spectral decomposition theorem, Cayley Hamilton theorem, Triangular forms, Jordan forms.

Textbooks

- Meyer C. D. (2000), Matrix analysis and applied linear algebra, SIAM
- Strang, G. (2016), Introduction to linear algebra, 5th Ed., Thomson Learning Inc.

2.1.8 Linear Algebra 2

Topics

Inner product spaces, Direct sums of subspaces, LU Decomposition, Triangular forms, Jordan forms, Rational and Classic forms, Orthogonal direct sums, Quadratic forms, Bilinear forms, Hermitian matrices, Normal matrices, Positive definite matrices and their properties.

Textbooks

- T. S. Blyth and E.F. Robertson (2002), Further Linear Algebra, Springer undergraduate mathematics series

2.1.9 Introduction to Geometry

Topics

Euclidean Geometry, The Axiomatic method, Undefined terms, Euclid's first four postulates, The parallel postulate, Incidence geometry, Models, Isomorphism of models, Hilbert's axioms, Axioms of Betweenness, Axioms of congruence, Axioms of Continuity, Hilbert's Euclidean axiom of parallelism, Neutral geometry, Alternate interior angle theorem, Exterior angle theorem, Measure of angles and segments, Saccheri-Legendre theorem, History of parallel postulate, Angle sum of a triangle, Hyperbolic geometry, Similar triangles, Parallels which admit a common perpendicular, Limiting parallel rays

Textbooks

- Marvin J. Greenberg (2008), Euclidean and non-euclidean geometries: development and history-W.H freeman, 4th Ed.

2.1.10 Introduction to Combinatorics

Topics

Basic principles of counting, The pigeonhole principle, Permutations and combinations, Binomial coefficients, Inclusion and exclusion, Recursive relations, Ordinary and exponential generating functions, Zero and One matrices, Graph Theory, Degree, Degree sequence, Cycles, Paths, Complete graphs, Trees, Bipartite graphs, Eulerian and Hamiltonian graphs, Directed graphs and tournaments, Perfect and maximal matchings, Coloring, Planar graphs, Latin squares, Distinct representation systems (SDR), Philip Hall's theorem.

Textbooks

- Anderson, I. (1989), A first course in combinatorial mathematics, Second Edition, Oxford Applied Mathematics and Computing Science Series
- Brualdi, R. (2012), Introductory Combinatorics, 5th Ed., Pearson Education International

2.1.11 Graph Theory

Topics

Graphic sequence, Interval graphs, Edge graphs, Graph modeling, Paths and distance, Connectivity, Subgraphs, Graph isomorphism, Matrix representation of a graph, Counting the number of trees, Spanning trees, BFS, DFS, MST, Directed graphs, Tournaments, Eulerian/Hamiltonian graphs, Vertex-Edge connectivity, Cut edges and bonds, Cut vertices, Cayley's formula, Block decomposition, k-connected graphs, Menger's theorem, Planar graphs, Euler's formula, Minors, Subdivisions and Kuratowski's theorem, Duality, Independent sets, Touran's theorem,Ramsey's theorem, Edge colorings, Chromatic number, Greedy algorithms, Brooks' theorem, Hajo's conjecture, Critical graphs, Four color theorem, Matchings, Matchings and coverings in bipartite graphs, Perfect matchings, Hall's marriage theorem, Konig's theorem, Matchings in general, Edge colorings, Factorisation, Vizing's theorem.theorem.

Textbooks

- Bondy J.A., Murty S.R. (1976), Graph theory with applications, The Macmillan press Ltd

2.1.12 Programming with Maple

Topics

Propositional logic, A logical or topological proof of compactness theorem, First-order logic, First-order structures and homomorphisms, Truth and deduction, Various deduction systems (Hilbert system and sequent calculus), Interpolation theorem, Gödel's soundness and completeness theorem, Introductory model theory including compactness, Löwenheim-Skolem theorems, Quantifier elimination, Non-standard analysis, Mathematical implications of compactness theorem, Computability and recursiveness, Church-Turing Thesis, Gödel's incompleteness theorem, Introductory complexity theory and p-vs-np problem.

Textbooks

- Enderton, H, Enderton, H.B. (2001), a mathematical introduction to logic, 2nd Ed., Elsevier
- Mendelson, E. (2009), Introduction to Mathematical Logic, 5th Ed., CRC Press.

2.1.13 Numerical Analysis

Topics

Sources of error, Computer representation of numbers and its properties, Propagation of error in function evaluation, Well-posed problem and stability, Approximating functions by Taylor expansion and its error estimation, Existence and uniqueness of nonlinear equations, Bisection method, False position method, Fixed point iteration method, Newton-Raphson method, Secant method, Error estimation and stopping criteria, Order of convergence and multiple roots, Horner algorithm and Newton method for finding the roots of polynomials, Interpolation problem, Lagrange interpolation method, Newton divided differences method, Forward and backward methods for equidistant points, Runge counter-example, Interpolation based on roots of Chebyshev polynomials, Discrete and continuous least squares for polynomials curve fitting, Trapezoidal, Simpson, Mid-point rules, Degree of precision of a quadrature rule, Newton-Cotes integration formulas, Gaussian quadrature, Richardson extrapolation and Romberg integration, Numerical differentiation and study of their order of convergence and degree of precision by Taylor expansion and interpolation, Instability in numerical differentiation

Textbooks

- Burden R.L., Faires J.D. (2015), Numerical Analysis, Cengage Learning, 10th Ed.
- Quarteroni A., Saleri F., Gervasio, P. (2014), Scientific Computing with MATLAB and Octave, Springer-Verlag Berlin, 4th Ed.

2.1.14 Point-set Topology

Topics

Topological spaces, Open and closed sets, Neighborhood of a point, Interior point and limit point, Closure of a set, Base and sub-base of a topology, Separable space, Countable spaces of first and second types, Hausdorff space, Continuous functions, Open mapping, Product space, Tychonoff's theorem , and some of its application such as Stone-Cech compactification, Imbedding and homeomorphism, Qoutient space and quotient mapping, Compactness and connectedness, Axioms of separability, Regular space, Normal space, Urison's lemma, Metric spaces, Metrizability theorems and paracompactness, Complete metric spaces, Function spaces, Ascoli's theorem.

Textbooks

- Munkres, J.R. (2000) Topology, A first course, Second edition, Prentice Hall, Incorporated. 2)
- Engelking, R. (1989) General topology, Second edition, Sigma series in pure mathematics, Verlag, Berlin. 3)
- Willard, S. (2012) General topology, Dover publications Inc. Mineola, New York. 4)
- Simmons, G.F. (1983) Introduction to topology and modern analysis, Krieger publishing Co., Melbourne

2.2 Statistical Courses

2.2.1 Probability 1

Topics

Probability, Random experiment (Compound and Sample), Different concepts of probability, Probability function, Uniform probability space (Classic probability model), Computing methods of probability in finite cases, Basic counting methods, Rules of counting, Ordered samples and permutations, Unordered samples and combinations, Ordered partitions and distinct permutations, Conditional probability, Compound experiments, Conditional probability application and Bayes' rule, Stochastic independence, Random variables, Cumulative distribution function, Discrete random variables, Continuous random variables, The distribution of a function of a random variable, Binomial distribution, Geometric distribution, Hyper-Geometric distribution, Negative-Binomial distribution, Poisson distribution, Discrete uniform distribution, Uniform distribution, Exponential distribution, Gamma distribution, Chi-Squared distribution, Normal distribution, Beta distribution, Cauchy distribution, Concentration and dispersion, Expectation, Expectation of a function of a random variable, Properties and applications of expectation, Moment generating functions, Variance, Multivariate distributions, Discrete and continuous Multivariate random variables, Multinomial distribution, Bivariate normal distribution, Independent random variables, Covariance, Correlation coefficient, Distribution of a function of a multivariate random variable, Distribution function method, Change of variables method, T-Distribution, F-Distribution, Chi-Squared Distribution, Discrete and continuous conditional distribution of multivariate random variables

Textbooks

- Ross S.M. (2014), A first course in probability, 9th Ed., Pearson Education Limited
- Ghahramani S. (1996), Fundamentals of Probability; with stochastic processes,Prentice Hall
- G.R. Grimmett and D. Stirzaker (2000), Probability and Random Processes, 3rd Ed., Oxford.

2.2.2 Probability 2

Topics

Moment generating function, Probability generating function and its relation with the moments, Distribution of transformation of joint random variables (Moment generating method and change of variables method), Order statistics, Distribution function of an order statistic, Joint distribution of two or more order statistics, Sample range and Sample median distribution, Conditional distribution applications, Expectation of conditional distributions and their applications (Including total expectation and forecasting), Conditional variance and studying them for bivariate normal distribution, Limit theorems, Convergence in distribution, Second order convergence, Convergence in probability, Weak law of large numbers, Central limit theorem, Important inequalities in probability (Jensen's inequality, Markov's inequality, Chebyshev's inequality).

Textbooks

- Ross S.M. (2014), A first course in probability, 9th Ed., Pearson Education Limited
- Ghahramani S. (1996), Fundamentals of Probability; with stochastic processes,Prentice Hall
- G.R. Grimmett and D. Stirzaker (2000), Probability and Random Processes, 3rd Ed., Oxford.

2.2.3 Statistical Methods

Topics

Random Sample, Sample distributions and CLT, Point estimation, Unbiasedness, MSE, Interval estimation, Pivotal quantity, Large sample interval estimation, Hypothesis test, Simple hypothesis tests, Test statistics, Decision rule, First and second kind of errors, One/Two-sided hypothesis tests, P-value, Large sample hypothesis tests, Hypothesis tests for comparing means and variances of two independent populations, Statistical inference about the difference of means of pairwise observations, Goodness-of-fit test, Contingency tables, Concept of linear dependence and Simple linear regression.

Textbooks

- Statistical concepts and methods Gouri K. Bhattacharyya, Richard A. Johnson, John wiley and Sons, 1977 - Translated to Farsi, 1st and 2nd vol.

2.2.4 Mathematical Statistics 1

Topics

Review of distribution theory, Exponential family of distributions, Location family, Scale and location-scale family, Estimation methods, Concept of estimate and estimator, Moments method, Maximum likelihood method, Properties of ML estimators, Consistency, Minimum variance unbiased estimators, Unbiased estimators, Cramer-Rao inequality and Fisher information, Bayes' Statistic, Lost function, Risk function, Prior and posterior distribution, Conjugate prior, Bayesian estimation.

Textbooks

- Mood A.M., Graybill F.A. and Boes D.C. (1973), Introduction to the theory of Statistics,McGraw Hill, 3rd Ed.
- Parsian A. (2019), Basic concepts of mathematical statistics, Isfahan University of Technology, 4th Ed.

2.2.5 Mathematical Statistics 2

Topics

Methods of finding interval estimators, Pivotal quantity, General method, Distribution function method, Equal-Tailed and Shortest-length confidence intervals, Unbiased confidence intervals, Large sample confidence intervals, Confidence intervals for the difference of means and proportion of variances of two dependent-independent populations, quantiles, Simple hypothesis tests, Test statistic, Test errors, Power function, P-value, Powerful test, Randomized hypothesis test, Likelihood ratio test, Comparing two tests, UMPT, Compound hypotheses, MLR property, UMP in one-sided tests, Generalized likelihood ratio test, Asymptotic distribution of LRT, Relation between hypothesis tests and confidence intervals, Goodness-of-fit test, Chi-Squared test, Bayes' Statistic, Lost/Risk function, Prior and posterior distribution, Conjugate prior, Bayesian estimation.

Textbooks

- Mood A.M., Graybill F.A. and Boes D.C. (1973), Introduction to the theory of Statistics,McGraw Hill, 3rd Ed.
- Parsian A. (2019), Basic concepts of mathematical statistics, Isfahan University of Technology, 4th Ed.

2.2.6 Regression 1

Topics

Simple linear regression, Estimating the least squares of parameters, Interpretation of Regression coefficients, Dividing the population into subpopulations, Regression coefficients' hypothesis test, Regression coefficients confidence intervals, Predicting the response for new observations, Prediction interval for new observations, Coefficient of determination, Regression through the centre, MLE, Correlation coefficient and its test, Regression model with stochastic regressor variables, Multiple linear regression, Estimating the model parameters, Interval estimation for regression coefficients and mean of response, Regression models with orthogonal model matrix, Point and interval Prediction for the new observations, Normalized regression coefficients, Multiple coefficient of determination, Multinomial regression models, Test for significance of regression, Partial regression coefficient, Generalization of linear hypothesis test, Interpretation of regression coefficients.

Textbooks

- Montgomery, Douglas C., Elizabeth A. Peck, G. Geoffrey Vining (2012), Introduction to linear regression analysis, Wiley; 5th Ed.
- Alvin C. Rencher, G. Bruce Schaalje (2008), Linear models in statistics, Wiley-Interscience; 2nd Ed.

2.2.7 Sampling Methods 1

Topics

Deterministic sampling, Probability sampling, Sampling frame, Sampled population, Total error of census, Sampling and non-sampling errors, Simple random sampling, Sample selection (With or without replacement), Estimators of population, Confidence intervals, Determining the sample size, Stratification sampling, Total sum, mean and proportion estimators, Selecting the strata, Stratification sampling vs simple random sampling, Posterior stratification, Sampling with varying probabilities, Stratification with probability proportional to size, Methods of selecting the sample with varying probabilities, Lahiri's method and cumulative method, Sampling with varying probability without replacement and the parameters' estimators

Textbooks

- Amidi A. (2005), Sampling theory and its applications, 3rd Ed., IUP, Tehran
- C.E. Sarndal, B.Swensson, J. Wretman, Model assisted survey sampling

2.2.8 Stochastic Processes

Topics

Bernoulli processes, Number/times of success, Sums of random variables process, Poisson processes, Arrival times, Compound poisson process, Markov chains, Zero-state distribution, Hitting times, Transition matrix, Recurrent and transient states, Absorption probabilities, Branching processes and queueing, Decomposition of location space, Stationary distributions, Birth and death chains, Irreducible chains, Null and non-null recurrent states, Mean number of visits to a fixed recurrent state, Monte Carlo method, Continuous-time markov processes, Jump processes, Jump process applications in birth and death processes and queueing.

Textbooks

- Karlin, S. Taylor, H. M. (1975), A First Course in Stochastic Processes, 2nd Ed.
- Cinlar, E. (1975), Introduction to Stochastic Processes
- Karlin, S. Taylor, (2011), An Introduction to Stochastic Modeling, Academic Press, 4th Ed.

2.2.9 Introduction to Computer Programming

Topics

An Introduction to the course, Hardware at a glance, Solving problems using computers (Flowchart and pseudo-codes), Introduction to C, Decision control structures (conditions and loops), Compilation and execution, Bitwise operators, Integer and float conversions, Associativity of operators, Decisions using switch, The goto keyword, Functions and Pointers (call by value and call by reference), Passing values between functions, Function declarations and prototypes, Data types, Arrays, Strings, Structures.

Textbooks

- Yashavant P. Kanetkar (2004), Let Us C: Authentic guide to C programming language, 5th Ed.

Bibliography