

Department of Computer Science
University of Delhi
Delhi-110007
Ph.D. Course Work & Syllabi

Algorithmic Graph Theory

Introduction to graphs, Paths, cycles and trails
Max-flow min-cut theorem, computing max s-t flows and min-cut
Edge and Vertex Connectivity and Menger's theorem
Maximum matching, Hall's theorem, algorithms for computing maximum matching in weighted and unweighted graphs.
Edge and vertex coloring of graphs. Independent sets
Planar graphs and algorithms for checking for planarity.

Approximation Algorithms

NP-Hardness and Approximation algorithms
TSP
Linear programming and duality (Vertex Cover and Matching)
LP rounding (set cover/vertex cover)
Dual fitting (greedy set cover)
Local search technique(Facility Location)
Primal-Dual approximation algorithms in graph connectivity and network design
Iterative Rounding

Theory of NP-Completeness

Introduction to the Theory of NP-completeness
Cook's Theorem, CSP
Clique Problem
Vertex Cover and Independent Set
Sequencing Problems: Hamiltonian Cycle Problem and TSP
Subset-Set problem
Graph Coloring
Scheduling Problems

Swarm Intelligence

Introduction to Swarm Intelligence
Particle Swarm Optimization
Ant Colony Optimization
Job Scheduling on Computational Grid (PSO application)
PSO for Data Mining
ACO for Data Mining
Solving the Traveling Salesman Problem using Ant Colonies
Swarm-based Network Management
Multi-objective optimization
Swarm-bots

Human Computer Interaction

The course needs to focus on survey of work on interactive systems, explore the current and future research areas in interaction techniques and the design, prototyping, and evaluation of user interfaces. Topics include user interface toolkits; design methods; evaluation methods; ubiquitous and context-aware computing; tangible interfaces;

Research papers on these topics need to be discussed with the background that the student is registered in Ph. D and needs to understand the way papers present the work, conduct the experimental studies and prepare summary on these followed by presentations.

Goals of HCI, Basic interaction Design Cognitive Psychology of HCI, Graphic Design and Human Interaction: Design for Social Inclusion, Human computer interaction methods, Usability evaluation

Combinatorial Optimization

Introduction: Optimization problems, neighborhoods, local and global optima, convex sets and functions, simplex method, degeneracy; duality.

Graph Algorithms: Primal-Dual algorithm and its application to shortest path, Max-flow problems (Ford and Fulkerson labeling algorithms, Dijkstra's algorithm, Ford-Warshall algorithms), bipartite matching algorithm, spanning tree algorithms.

Information Hiding Techniques

Principles of Steganography and Watermarking Information Hiding-Data hiding in images- LSB encoding, BPCS Steganography, Lossless data hiding, data hiding by quantization, Patchwork, Transform domain method, Robust data hiding in JPEG image, DCT based watermarking, Robust welvet based watermarking, Data hiding in binary image, The Zhao-Koch method, The Wu lee method, The CPT method, The TP method, Data hiding in Fax image, Spread Spectrum model Steganalysis- Steganalysis introduction and terminology, Detecting hiding information, Extracting hiding information, Disabling hidden information

Information Security

Symmetric Key Cryptography-classical Encryption Techniques, Block Ciphers , data encryption Standard(DES), Triple DES, Modes of DES, Advanced Encryption Standard, Stream Cipher and RC4 Public key cryptography- DH key exchanged, RSA, Elliptic Curve Cryptography, Message Authentication and Hash Function, Cryptographic hash function , Non Cryptographic Hash function ,Birthday problem, birthday attack, tiger hash, HMAC ,CMAC Digital Signatures Cryptanalysis- Enigma, RC4 as used in WEP , Linear and Differential Cryptanalysis attacks on RSA Security Protocols- SSH, SSL, IPsec, Kerberos, WEP,GSM Firewalls

Special Topics in Computer Networks

Real-time and non-real-time applications: Quality of Service (QoS) requirements of real-time applications – bandwidth, delay and delay variation parameters, Quality of service metrics, guaranteed and best-effort services.

IEEE Wireless LAN (WLAN) standard: 802.11 and 802.11e standards, WLAN services-association, disassociation, re-association, distribution, integration, authentication, deauthentication and data delivery services.

WLAN centralized protocol functions: Point Coordination Functions (PCF), Hybrid Coordination Function (HCF), HCF Controlled Channel Access (HCCA); HCCA admission control mechanisms, HCCA parameterized QoS.

WLAN distributed protocol functions: Distributed Coordination Functions (DCF), Enhanced Distributed Channel Access (EDCA), EDCA priority based QoS.

Performance analysis of WLAN distributed protocol functions: Random variables and random process, Markov chain model of DCF and EDCA protocols, Throughput and delay analysis.

Readings:

1. Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications IEEE Std. 802.11™-2007.
2. G., Bianchi, IEEE 802.11-saturation throughput analysis, IEEE Communication Letters, vol. 2, pp. 318–320, Dec. 1998.
3. G., Bianchi, Performance analysis of the IEEE 802.11 distributed coordination function, IEEE J. Selected Areas in Communication, vol. 18, 535-547, Mar. 2000.
4. S., Choi, J.D., Prado, S., Shankar, and S., Mangold, IEEE 802.11e contention-based channel access (EDCF) performance evaluation, in *Proc. IEEE ICC'03*, vol. 2, May 2003, pp. 1151–1156.
5. S., Mangold, S., Choi, G.R., Hiertz, O., Klein, and B., Walke, Analysis of IEEE 802.11e for QoS support in wireless LANs, IEEE Wireless Communications, December 2003, pp.40-50.
6. Y., Xiao, A Simple and Effective Priority Scheme for IEEE 802.11, IEEE Communications Letters, vol. 7, no. 2, February 2003.
7. X., Chen, H., Zhai, X., Tian, and Y., Fang, Supporting QoS in IEEE 802.11e Wireless LANs, IEEE Transactions on Wireless Communications, Vol.5, No. 8, August 2006 pp-2217-2227.

Special Topics in Data Mining

Classification Techniques: Models and Patterns, Performance Measures, Forms of Knowledge, Decision Trees, Linear Regression, Neural Networks, k-Nearest Neighbors, Naïve Bayesian Classifiers, Support Vectors Machines, Ensemble Methods.

Clustering Techniques: Clustering Concepts, Clustering Vs Classification, Clustering Techniques, Partitioning Methods, Comparing k-Means and k-Medoids, Expectation-Maximization, Hierarchical Methods, Density-Based Methods, Grid-Based Methods, Dealing with Large Data.

Use of the techniques for web usage mining, user tracking and profiling, web content and structure mining, web personalization, text mining, spatial mining, bioinformatics and other scientific applications.

Readings:

1. D.J.Hand, Heikki Mannila, Padhraic Smyth, Principles of Data Mining, MIT Press 2001,22
2. Trevor Hastie, Robert Tibshirani, Jerome H. Friedman, The Elements of Statistical Learning, Springer, 2001.
3. Soumen Chakrabarti, Mining the Web, Morgan Kaufmann, 2002.
4. Sushmita Mitra, Tinku Acharya, Data Mining: Multimedia, Soft Computing, and Bioinformatics, Wiley, 2003, ISBN: 978-0-471-46054-1.
5. Ronen Feldman, James Sanger, The Text Mining Handbook, Cambridge University Press, 2006.
6. John Wang, Encyclopedia of Data Mining, IGI Global, 2008.

Special Topics in Theoretical Computer Science

(NP - Completeness and Approximation)

Introduction to NP_completeness and Approximation.

Problems from first principle: Satisfiability SAT, 3SAT.

Graphs: Clique, Covering, Graph Partitioning, Subgraph problem, Graph Isomorphism, Graph Coloring, Hamiltonian Cycle Problem, TSP.

Network Design Problems: Steiner tree, Spanning Trees, Cuts and Connectivity, Routing and Flow Problems.

Sets and Partitions: Set partition and Covering, Subset sum.

NP-hard problems: Clustering Problems like k-means clustering, co-clustering, connected kmeans clustering. More new problems as they are added to the class of NPC or NPH.

Approximation algorithms for the above problems.

Readings:

1. M. R. Garey and D. S. Johnson, Computers and Intractability: A Guide to the Theory of NP-Completeness (Series of Books in the Mathematical Sciences), 1979.
2. Teofilo F. Gonzalez, Handbook of NP-Completeness: Theory and Applications 2009.
3. Vijay V. Vazirani, Springer-Verlag, Approximation Algorithms, France, 2006.
4. Teofilo F. Gonzalez, Handbook of Approximation Algorithms and Metaheuristics (Chapman & Hall/Crc Computer and Information Science Series) 2007.

5. Mokhtar S. Bazaraa, John J. Jarvis, and Hanif D. Sherali, Linear Programming and Network Flows by 2004.
6. Part of the course will be covered by research papers.

Special Topics in Information Security

Information hiding: Introduction, Background, and Applications of Information hiding: Data hiding, applications of data hiding.

Steganography: Frameworks of secret communication, Security of steganography systems, Information hiding in noisy data, Adaptive & non-adaptive algorithms, Active and malicious attackers, Information hiding in written text, Invisible communication. Data hiding in still images : LSB encoding, BPCS steganography, Lossless data hiding, Data hiding by quantization, Patchwork, Transform domain methods, Robust data hiding in JPEG images, frequency domain watermarking Detecting malicious tempering, Robust wavelet based watermarking, Kundur-Hatzinakos watermarking, Data hiding in binary images, Zhao-koch method, Wu-Lee method, CPT method, TP method, Data hiding in fax images.

Watermarking: Introduction, Watermarking principals, Applications, Requirements and algorithmic design issues, Evaluation and standards of watermarking.

Fingerprinting: Introduction, Terminology and requirements, Classifications, Research history, fingerprinting schemes, Statistical fingerprinting, and Collusion-secure fingerprinting.

Readings:

1. I.J.Cox, M.L.Miller, J.A.Bloom, J.Fridrich, T.Kalker, Digital Watermarking and Steganography, Morgan Kaufman 2008.
2. F.Y.Shih, Digital Watermarking and Steganography Fundamentals and Techniques, CRC press 2008.
3. Stefon Katzeubeisser, F.A.Petitolos, Information Hiding Techniques for Steganography and digital watermarking, Aatech House London 2008.

Special Topics in Soft Computing

Rough Sets: Information Systems, decision tables, indiscernibly relation, set approximation, approximation of family of sets, analysis of decision tables.

Type-2 Fuzzy Sets: Notion of uncertainty of membership in a fuzzy set, foot print of uncertainty, embedded fuzzy sets, operations on type-2 fuzzy sets, type-2 fuzzy relations, type reduction, type-2 fuzzy inference system.

Fuzzy Clustering: Limitations of hard partitioning and need for fuzzy clustering, FCM, PCM, GK, and FMLE algorithms, cluster validity measures

Projected Clustering: The problem of high dimensionality in clustering, use of projected clustering methods to address the problem of high dimensionality - grid based, density based, centroid based, and hierarchical approaches.

Rough Set Based Methods: Information granulation using rough sets, decision rules in rough set models, classification, and clustering methods based on rough sets.

Neuro Fuzzy Systems: Neuro fuzzy systems of Mamdani, logical, and Takagi-Sugeno type, flexible neuro fuzzy systems.

Readings:

1. L. Rutkowski, Computational Intelligence, Methods and Techniques, Springer, 2008
2. J. Valente de Oliveira, W. Pedrycz, Advances in Fuzzy Clustering and its Applications, John Wiley & Sons, 2007.
3. J. Stepaniuk, Rough-Granular Computing in Knowledge Discovery and Data Mining, Springer, 2008.
4. F. Hopner, F. Hoppner, F. Klawonn, Fuzzy Cluster Analysis: Methods for Classification, Data Analysis and Image Recognition, John Wiley & Sons, 1999.

Special Topics in Database Systems

Introduction to Web Data Management and XML.

A Survey of Web Data Management Systems: Web Query Systems; Web Information Integration Systems; Web Data Restructuring.

XML Basics: Semi-structured Data, XML Schemas, XML indexing, XSLT, XHTML, DOM and SAX parsers.

XML Query Languages: Xquery, Xpath, XsLT, XSQL.

Node and Link Objects: Representing Metadata of Web Documents and Hyperlinks, Metadata Associated with HTML and XML Documents, Representing Structure and Content of Web Documents, Representing Structure and Content of Hyperlinks, Node and Link Objects, Node and Link Structure Trees.

Databases Modeling: Recent Approaches in Modeling Web Data, Storage of XML data in databases, publishing data from databases in XML. Use of Tools for storing and retrieving data from XML Databases.

Readings:

1. Sourav Bhowmick, Sanjay Madria, and Wee Keong Ng, Web Data Management A Warehouse Approach, Springer.
2. Kevin William, Professional XML Databases, Wrox publications.

Special Topics in Artificial Intelligence (Multiagent Systems)

Intelligent Agents: Environments, Intelligent Agents, Agents and Objects, Agents and Expert Systems, Agents as Intentional Systems, Abstract Architectures for Intelligent Agents, Purely Reactive Agents, Perception, Agents with State, How to Tell an Agent What to Do, Utility Functions.

Practical Reasoning Agents: Practical Reasoning, Means-Ends Reasoning, The Blocks World, Implementing a Practical Reasoning Agent, Commitment to Ends and Means, The Procedural Reasoning System.

Reactive and Hybrid Agents: Brooks and the Subsumption Architecture. The Limitations of Reactive Agents, Hybrid Agents.

Multiagent Interactions: Utilities and Preferences, Multiagent Encounters, Dominant Strategies and Nash Equilibria, Competitive and Zero-Sum Interactions, The Prisoner's Dilemma.

Reaching Agreements: Mechanism Design, Auctions, Negotiation, Task-Oriented Domains, Worth-Oriented Domains, Argumentation.

Communication: Speech Acts, Agent Communication Languages, KIF, KQML, The FIPA Agent Communication Languages, Ontologies for Agent Communication, Coordination Languages.

Working Together: Cooperative Distributed Problem Solving, Coherence and Coordination, Task Sharing and Result Sharing, Task Sharing in the Contract Net, Result Sharing, Handling Inconsistency, Coordination, Multiagent Planning and Synchronisation.

Readings:

1. Michael Wooldridge, *An Introduction to MultiAgent Systems*, Wiley Series in Agent Technology, 2002.
2. G. Weiss. *Multiagent Systems--A Modern Approach to Distributed Artificial Intelligence*. MIT Press, Cambridge, MA, 3rd edition, 2001.
3. S. Russell and P. Norvig, *Artificial Intelligence: A Modern Approach* (2nd ed.), Pearson Education, 2006.
4. Rafael H. Bordini, Jomi Fred Hübner, Michael Wooldridge, *Programming Multi-Agent Systems in AgentSpeak using Jason*, Wiley Series in Agent Technology, 2007.
5. Lin Padgham, Michael Winikoff, *Developing Intelligent Agent Systems: A Practical Guide*, Wiley Series in Agent Technology, 2004.
6. Fabio Luigi Bellifemine, Giovanni Caire, Dominic Greenwood, *Developing Multi-Agent Systems with JADE*, Wiley Series in Agent Technology, 2007.

Special Topics in Computational Intelligence

(Rough Granular Computing)

Rough Sets in Approximation: Parameterized approximation space, uncertainty function, rough inclusion function, lower and upper approximations, properties of approximations such as accuracy and quality of approximation, learning approximation space from data discretization and approximation spaces, distances and approximation spaces; concept approximation.

Data Reduction: Reducts in the context of information systems and decision tables, significance of attributes and stability of reducts, representatives in information systems and decision tables.

Classification and Clustering Methods: Information granulation, decision rules in rough set models, evaluation of decision rules, nearest neighbour algorithms; self organizing system for information granulation, rough clustering and its evaluation.

Readings:

1. J. Stepaniuk, *Rough- Granular Computing in Knowledge Discovery and Data Mining*, Springer, 2008.
2. P. Doherty, W. Lukaszewicz, A. Skowron, A. Szalas: *Knowledge Engineering: A Rough Sets Approach*, Springer, 2006.
3. I. Duntsch, G. Gediga, *Rough Set Data Analysis: A Road to Non-invasive Knowledge Discovery*, Methodos Publishers, Bangor, 2000.
4. T. Y. Lin, N. Cercone, *Rough Sets and Data Mining - Analysis of Imperfect Data*, Kluwer Academic Publishers, Boston, 1997.

5. L. Polkowski, A. Skowron (eds.), Rough Sets in Knowledge Discovery 1: Methodology and Applications, Studies in Fuzziness and Soft Computing, vol. 18, Physica Verlag, Heidelberg, 1998.
6. L. Polkowski, A. Skowron (eds.), Rough Sets in Knowledge Discovery 2: Methodology and Applications, Studies in Fuzziness and Soft Computing, vol. 19, Physica Verlag, Heidelberg, 1998.
7. S. K. Pal, P. Mitra, Pattern Recognition Algorithms for Data Mining – Scalability

Deep Learning

From Machine Learning to Deep Learning: Understand the historical context and motivation for Deep Learning; Set up a basic supervised classification task and train a black box classifier on it; Train a logistic classifier “by hand” Optimize a logistic classifier using gradient descent, SGD, Momentum and AdaGrad.

Deep Neural Networks: Train a simple deep network, Effectively regularize a simple deep network, Train a competitive deep network via model exploration and hyperparameter tuning.

Convolutional Neural Networks: Train a convolutional neural net, Explore the design space for convolutional nets

Deep Models for Text and Sequences: Train a text embedding model, Train a LSTM model.

Text Books: Jeff Heaton, Deep Learning and Neural Networks, Heaton Research Inc, 2015

Mindy L Hall, Deep Learning, VDM Verlag, 2011

Li Deng (Author), Dong Yu, Deep Learning: Methods and Applications (Foundations and Trends in Signal Processing), Now Publishers Inc, 2009

Probabilistic Graphical Models

Introduction: The Bayesian network and Markov network representation, including extensions for reasoning over domains that change over time and over domains with a variable number of entities

Inference: Reasoning and inference methods, including exact inference (variable elimination, clique trees) and approximate inference (belief propagation message passing, Markov chain Monte Carlo methods)

Learning parameters and structure in PGMs: Learning parameters and structure in PGMs, Using a PGM for decision making under uncertainty., Case studies and applications (3-4) of PGMs to real-world problems

Text Book: Daphne Koller. Nir Friedman, Probabilistic Graphical Models: Principles and Techniques (Adaptive Computation and Machine Learning series), MIT Press, 2010,

Machine Learning

Introduction: Basic Spark architecture, Common operations, avoiding coding mistakes, debugging Spark program

Spark for Data Analysis: Using Apache Spark to perform data analysis, parallel programming to explore data sets, applying log mining, textual entity recognition and collaborative filtering techniques to real-world data questions

Scalability Issues: The underlying statistical and algorithmic principles required to develop scalable real-world machine learning pipelines, exploratory data analysis, feature extraction, supervised learning, and model evaluation, Application of these principles using Spark, implementing distributed algorithms for fundamental statistical models

Text Books: Joseph Moore, Learning Analytics with Spark Framework, Amazon Digital South Asia Services, Inc., 2015

Sandy Ryza, Uri Laserson, Advanced Analytics with Spark, O'Reilly, 2015

CUDA Programming

Introduction: Introduction to Heterogeneous Computing, Overview of CUDA C, and Kernel-Based Parallel Programming, with lab tour and programming assignment of vector addition in CUDA C.

Performance Issues: Memory Model for Locality, Tiling for Conserving Memory Bandwidth, Handling Boundary Conditions, and Performance Considerations, simple matrix-matrix multiplication in CUDA C.

Applications: Parallel Convolution Pattern, Parallel Scan Pattern, Parallel Histogram Pattern and Atomic Operations, Data Transfer and Task Parallelism, Introduction to OpenCL, Introduction to C++AMP, Introduction to OpenACC, with programming assignment of vector addition using streams in CUDA C.

Text Book: Shane Cook, CUDA Programming: A Developer's Guide to Parallel Computing with GPUs, Elsevier; 2014

Norman Matloff, Parallel Computing for Data Science: With Examples in R, C++ and CUDA, Chapman & Hall/CRC, 2015.

Course work to be carried out by Ph.D. students:

Paper 1: Research Methodology

Paper 2: One paper out of the followings:

1. Neural Networks
2. Swarm Intelligence
3. Algorithmic Graph Theory
4. Approximation Algorithms
5. Theory of NP Completeness
6. Software Quality Assurance
7. Ad-hoc Networks
8. Human Computer Interaction (HCI)
9. Combinatorial Optimization
10. Digital Image Processing
11. Software Testing
12. Computer Security
13. Information Hiding Techniques
14. Machine Learning
15. Biometrics
16. Modern Approach to Artificial Intelligence
17. Linear and Integer Programming
18. Deep Learning