DEPARTMENT OF MATHEMATICS,
UNIVERSITYOFKARACHI,

M.S (Computational Mathematics)
Two Years Degree Program

Program Overview:

Two years M.S / M.Phil. degree program in Computational Mathematics offers a deep dive into the intersection of mathematical theory, algorithms, and computational techniques. Students explore advanced topics in numerical analysis, optimization, mathematical modeling, and simulation methods. The program emphasizes problem-solving skills, mathematical reasoning, and computational proficiency, preparing graduates for roles in research, academia, and industries such as finance, engineering, and technology. Through coursework, projects, and research thesis, students develop expertise in areas like high-performance computing, data analysis, machine learning, and mathematical software development, making them well-equipped to tackle complex real-world problems with mathematical rigor and computational precision.

Total Credit Hours: 30
Courses: 08 Courses (24 Credit Hours)
Thesis: 06 Credit Hours

UNIVERSITY OF KARACHI

Course Structure of M.S in Computational Mathematics

M.S (First Year) *Computational Mathematics*

SEMESTER I			SEMESTER II		
Course Code	**Course Title**	**Credit Hours**	**Course Code**	**Course Title**	**Credit Hours**
CM-700.1	Fundamentals of Python Programming	Non-Credit			
CM-701	Research Skills for Computational Mathematics	3+0	CM-702	High Performance Data Analytics	2+1
CM-703	Applied Numerical Methods	2+1	CM-704	Machine Learning with Python	2+1
CM-705	Computational Complexity and Approximation	3+0		Elective-I	
CM-707	Bayesian Theory	3+0		Elective-II	

M.S (Second Year) *Computational Mathematics*

Semester III & IV		
Course code	**Course Title**	**Credit hours**
CM-	M.S Thesis	06

Electives/ Optional Courses

Course code	Course Title	Credit hours
CM-711	Advanced Stochastic Processes	3+0
CM-712	Dynamical Systems and Chaos	3+0
CM-713	Soft Computing	3+0
CM-714	Statistical Methods and Data Analysis	3+0
CM-715	Nature Inspired Optimization Algorithms	3+0
CM-716	Cryptography & Network Security	3+0
CM-717	Image Processing & Computer Vision	3+0
CM-718	Data processing for Big data	3+0
CM-719	Modeling, Simulation, and Monte Carlo	3+0

CM-700.1 Fundamentals of Python Programming (Non-Credit)

Introduction to Python, History and features of Python, Installation and setup of Python environment, Python interactive shell and basic syntax, Variables and Data Types, Variables and their types (integer, float, string, etc.), Variable assignment, naming conventions, and scope, Type conversion and built-in functions for data type manipulation, Operators and Expressions, Arithmetic, comparison, logical, and bitwise operators, Operator precedence and associativity, Expressions, statements, and operator chaining, Control Structures, Conditional statements (if,elif, else), Loops (for, while) for iteration and looping control, Loop control statements (break, continue) and nested loops, Function definition, parameters, and return values, List comprehensions and dictionary comprehensions, Input / Output Operations, Reading and writing files in Python (file handling).

Recommended books:

1. Charles R. Severance. (2016). Python for Everybody, 1st edition, University of Michigan.
2. Dawson. M. (2010). Python Programming for the Absolute Beginner, 3rd edition, Course Technology.
3. John V. Guttag. (2016). Introduction to Computation and Programming Using Python, 2nd edition, The MIT Press.
4. Lott, S. F., & Phillips, D. (2021). Python Object-Oriented Programming: Build robust and maintainable object-oriented Python applications and libraries, 4th edition: Packt. Publishing.
5. Paul Jones. (2016).Python: The Fundamentals of Python Programming, Create Space Publishing.

CM-701 Research Skills for Computational Mathematics (3+0)

Understanding the research process, problem formulation, and research questions, Introduction to academic writing, Research ethics, Citation practices, Conducting literature searches using digital libraries and academic databases, Critical reading and evaluation of research papers, books, and scholarly articles, Summarizing and synthesizing information, Understanding ethical guidelines and standards in research, Addressing ethical issues related to data privacy, intellectual property, and research integrity, Selecting appropriate data collection methods such as simulations, numerical experiments, or data analysis, Problem Solving and Algorithm Design, Analyzing mathematical problems, Formulating computational solutions, Designing algorithms, pseudocode, and flowcharts for problem-solving, Exploring data analysis techniques for computational mathematics research, Using statistical methods, data preprocessing, Data cleaning, Visualizing data using graphs, plots, and interactive visualization tools, Introduction to computational tools and software commonly used in research, Basics of mathematical modeling and simulation techniques, Formulating mathematical models for real-world problems, Simulating and analyzing model behavior using computational tools.

Recommended books:

1. Aguinis. H. (2024). Research Methodology: Best Practices for Rigorous, Credible, and Impactful Research, 1st edition, SAGE Publications.
2. Kelly. A.D& Richard A. Lesh. (2000).Handbook of Research Design in Mathematics and Science Education,1st edition, Rutledge.
3. Mukherjee. S.P. (2019). A Guide to Research Methodology: An Overview of Research Problems, Tasks and Methods, 1st edition, CRC Press.
4. Singh. R.N. (2012). Research Methodology and Techniques in Mathematics, Centrum Press.
5. Uwe Flick. (2015). Introducing Research Methodology: A Beginner′s Guide to Doing a Research Project, 2nd edition, SAGE Publications.

CM-702 High Performance Data Analytics (2+1)

Overview of data analytics concepts and techniques, Introduction to high-performance computing and parallel processing, Motivation for combining data analytics with HPC, Data preprocessing techniques (e.g., cleaning, transformation, integration), Exploratory data analysis (EDA) methods, Statistical analysis and hypothesis testing, Introduction to parallel computing architectures, Techniques for managing and storing large-scale datasets, Distributed file systems for distributed data storage, Parallel algorithms for machine learning (e.g., parallel gradient descent, distributed training), Large-scale data mining techniques (e.g., frequent pattern mining, clustering), Deep learning with distributed training frameworks (e.g., Tensor Flow, Py Torch),Data visualization techniques for large-scale datasets, Interactive visualization tools and libraries (e.g., D3.js, Plotly), Interpretation and communication of data analysis results, Applications of data analytics with HPC in various domains (e.g., finance, healthcare, scientific research), Case studies demonstrating the use of HPC for solving real-world data analytics problems.

Labs / Practicals:

- Overview of data analytics tools and libraries (e.g., Python with Num Py, pandas, scikit-learn).
- Accessing and setting up HPC environments for data analytics tasks.
- Handling missing data and outliers.
- Data transformation and normalization techniques.
- Implementing data preprocessing pipelines using Python and HPC resources.
- Statistical analysis and visualization of large-scale datasets.
- Exploring data distributions, correlations, and patterns.
- Conducting EDA tasks using Python and parallel computing techniques.
- Training and evaluating machine learning models at scale.
- Applying parallel computing techniques to various machine learning tasks (e.g., classification, regression, clustering).
- Introduction to real-time data analytics frameworks (e.g., Apache Kafka, Apache Flink).
- Processing streaming data with low latency using HPC resources.
- Hands-on experience with real-time data analytics tools.

Recommended books:

1. Grandinetti.L, Mirtaheri.S.L, & Shahbazian.R. (2019). High-Performance Computing and Big Data Analysis, 1st edition, Springer.
2. Khosrow Hassibi. (2014). High Performance Data Mining and Big Data Analytics, Create Space Publishing.
3. Raj.P, Raman.A, Nagaraj.D, & Duggirala.S. (2015). High-Performance Big-Data Analytics: Computing Systems and Approaches, 1st edition, Springer.
4. Severance. C, Dowd. K ,&McKinley. K. (1998). High Performance Computing, 2nd edition, O'Reilly Media.
5. Thomas. J, Karagoz. P, & Ahamed. B. B. (2019). Deep Learning Techniques and Optimization Strategies in Big Data Analytics, Wiley.

CM-703 Applied Numerical Methods (2+1)

Advanced methods for non-linear Equations; Convergence criterion for nonlinear Equations, Newton-Raphson method and its variants, , Order of convergence of advance methods. Splines, Cubic Splines. Romberg integration, Richardson extrapolation. Error estimation of integration formulas, Gaussian quadrature. Radau integration, Pade approximation, Chebyshev approximation, Chebyshev polynomial, Numerical Solution of ODE'S; Runge-Kutta Methods upto order 4, Predictor–Corrector Methods, Haar wavelets, Haar wavelets methods for Integration and differential Equations.

Labs/Practicals:

- To find the roots of non-linear equations through different methods.
- Curve fitting by least square approximations.
- To solve the system of linear equations.
- To find numerical solution of ordinary differential equations.
- Numerical differentiation formulae based on interpolation polynomials.
- Error estimation of integration formulas.
- Evaluating Gaussian Formulae

Recommended books:

1. Curtis F. Gerald (Author), Patrick O. Wheatley. (1989). Applied Numerical Analysis, 4th edition, Addison Wesley Publishing Company.
2. Gerald. (2003). Applied Numerical Analysis, 7th edition, Pearson.
3. Richard W. Hamming. (2012). Introduction to Applied Numerical Analysis, Dover Publications.
4. Steven Chapra. (2006). Applied Numerical Methods with MATLAB for Engineers and Scientists, 2nd edition, McGraw-Hill.
5. Sudhir Kumar Pundir. (2023). Applied Numerical Analysis, CBS Publishers.

CM-704 Machine Learning with Python (2+1)

Definition of machine learning and its applications, Types of machine learning: supervised learning, unsupervised learning, reinforcement learning, Historical overview and key milestones in machine learning, Supervised learning, Unsupervised learning, Python libraries suitable for Machine Learning, Linear regression, Ordinary least squares, Gradient descent, Logistic regression and classification algorithms, Support vector machines (SVM), Decision trees, Random forests, Evaluation metrics, Accuracy, Precision, Recall, F1-score,Unsupervised Learning, Clustering algorithms, K-means, Hierarchical clustering, Dimensionality reduction techniques, Principal component analysis (PCA), t-distributed stochastic neighbor embedding, Basics of artificial neural networks (ANNs), Perceptron, Activation functions, Feed forward networks, Training neural networks, Back propagation, Stochastic gradient descent, Regularization techniques, Convolutional neural networks, Recurrent neural networks, Cross-validation techniques, k-fold cross-validation, Leave-one-out cross-validation, Model selection and hyper parameter tuning.

Labs/Practicals:

- Implement supervised, unsupervised, and reinforcement learning algorithms using Python libraries like Scikit-learn and Tensor Flow.
- Implement linear regression models using Python's Num Py and Scikit-learn libraries.
- Use gradient descent algorithms in Python to optimize model parameters.
- Evaluate model performance using Python's evaluation metrics such as mean squared error (MSE) and R-squared.
- Develop logistic regression models for binary classification tasks using Python.
- Utilize Python libraries like Scikit-learn to implement support vector machines (SVM) and decision trees for classification.
- Perform dimensionality reduction with Principal Component Analysis (PCA) and t-distributed Stochastic Neighbor Embedding (t-SNE) in Python.
- Build artificial neural networks (ANNs) using Python frameworks like Tensor Flow or Keras.
- Implement activation functions, feed forward networks, and back propagation in Python for training ANNs.
- Fine-tune model hyper parameters in Python using techniques like grid search or random search for improved performance.

Recommended books:

1. Artasanchez. A, &Joshi. P. (2020).Artificial Intelligence with Python, 2nd edition, Packt Publishing.
2. Ethem Alpaydin. (2020). Introduction to Machine Learning,4th edition, The MIT Press.
3. Müller. A, & Guido. S. (2016).Introduction to Machine Learning with Python, 1st edition, O'Reilly Media.
4. Raschka. S, &Mirjalili. V. (2019).Python Machine Learning: Machine Learning and Deep Learning with Python, 3rd edition, Packt Publishing.
5. Wes McKinney. (2022).Python for Data Analysis, 3rd edition, O'Reilly Media.

CM-705 Computational Complexity and Approximation (3+0)

Overview of optimization problems in data science (e.g., machine learning, deep learning, statistical modeling), Challenges and considerations when dealing with large-scale datasets, Introduction of computational approximation properties, Evaluate approximation algorithms, Basics of convex sets and convex functions, Convex optimization problems and formulations, Gradient descent and its variants (e.g., stochastic gradient descent, mini-batch gradient descent), Proximal gradient methods, Mini-batch and online optimization techniques, Convergence analysis and convergence rates, Distributed computing frameworks for optimization (e.g., Map Reduce, Apache Spark), Parallel and distributed optimization algorithms, Consensus optimization methods, Asynchronous and decentralized optimization, Scalability considerations and communication overhead, Challenges and opportunities in non-convex optimization for data science, Local vs. global optimization methods, Robust optimization techniques, Adversarial machine learning and optimization, Bias and discrimination mitigation, Ethical considerations in optimization for data science.

Recommended books:

1. Ausiello. G, Crescenzi. P, Kann. V, Marchetti. S, Gambosi. G, & Spaccamela. A. M. (1999). Complexity and Approximation, Springer.
2. Ding-Zhu Du, & Kerlo. K. (2014).Theory of Computational Complexity, 2nd edition, Wiley.
3. Kreinovich.V, Lakeyev. A. V, Rohn.J, Kahl. P.T, Kahl. P, Rohn. J, & Lakeyev. A. (1997). Computational Complexity and Feasibility of Data Processing and Interval Computations, Springer.
4. Papadimitriou. C.H, & Steiglitz. K. (1998).Combinatorial Optimization: Algorithms and Complexity, Dover Publications.
5. Vijay V. Vazirani. (2001). Approximation Algorithms, 1st edition, Springer.

CM-707 Bayesian Theory (3+0)

Overview of Bayesian reasoning and inference, Motivation for Bayesian approaches in data analysis and decision-making, Introduction to Bayesian modeling, Prior, likelihood, and posterior distributions, Bayesian interpretation of probability, Maximum a posteriori (MAP) estimation, Bayesian estimation using conjugate priors, Bayesian estimation of parameters in common distributions, Markov chain Monte Carlo (MCMC) methods, Gibbs sampling, Metropolis-Hastings algorithm, Practical considerations in implementing MCMC algorithms, Introduction to hierarchical modeling, Estimation of hyper parameters in hierarchical models, Applications of hierarchical models in various domains, Bayes factors and model comparison, Information criteria (e.g., AIC, BIC) for model selection, Cross-validation and other model validation techniques, Introduction to Bayesian time series models, Bayesian dynamic linear models (DLMs), Applications of Bayesian time series analysis in forecasting and anomaly detection, Bayesian linear regression, Bayesian generalized linear models (GLMs), Applications of Bayesian regression in predictive modeling and inference, Nonparametric Bayesian methods (e.g., Dirichlet process, Gaussian process priors), Bayesian spatial statistics, Bayesian methods for big data and streaming data analysis, Introduction to Bayesian decision theory, Utility theory and decision-making under uncertainty, Applications of Bayesian decision theory in real-world decision problems.

Recommended books:

1. Bernardo.J,& Smith.A. (2000).Bayesian Theory, 1st edition, Wiley.
2. Dellaportas.P, Polson.N.G, David A., &Stephens.S.P. (2015).Bayesian Theory and Applications,Oxford University Press.
3. James O. Berger. (1985).Statistical Decision Theory and Bayesian Analysis, 2nd edition, Springer.
4. Sumio Watanabe. (2018). Mathematical Theory of Bayesian Statistics, 1st edition, Chapman and Hall/CRC.
5. Wolfgang von der Linden. (2014).Bayesian Probability Theory: Applications in the Physical Sciences, 1st edition, Cambridge University Press.

Electives/ Optional Courses

CM-711 Advanced Stochastic Processes (3+0)

Definition and properties of martingales, Optional stopping theorem and applications, Martingale convergence theorems, Applications in finance, Gambling, and modeling, Renewal processes, Renewal functions, Key renewal theorems (Wald's identity, Key Renewal Theorem), Applications in reliability theory, Queuing theory, Introduction to stochastic calculus, Stochastic integration, Ito's lemma, Diffusion processe, Stochastic differential equations (SDEs), Introduction to Brownian motion, Poisson process, Relationship between Poisson processes and renewal processes, Applications in queuing theory, Telecommunications, and finance, Introduction to continuous-time Markov chains, Chapman-Kolmogorov equations, Stationary distributions and limiting behavior.

Recommended books:

1. David Applebaum. (2009). Lévy Processes and Stochastic Calculus, 2nd edition, Cambridge University Press.
2. Emanuel Parzen. (2015).Stochastic Processes, 2nd edition, Dover Publications.
3. Kroese.D.P, & Botev.Z. (2023).An Advanced Course in Probability and Stochastic Processes, 1st edition, Chapman and Hall/CRC.
4. Robert G. Gallager . (2014). Stochastic Processes: Theory for Applications, 1st edition, Cambridge University Press.
5. Speyer.J.L, & Chung.W.H. (2008).Stochastic Processes, Estimation, and Control, Wiley.

CM-712 Dynamical Systems and Chaos (3+0)

Overview of dynamical systems theory, Classification of dynamical systems (e.g., linear vs. nonlinear, discrete vs. continuous), Concepts of stability, Attractors, and bifurcations, Analysis of one-dimensional maps and flows, Fixed points and their stability, Periodic orbits and bifurcations (e.g., period-doubling bifurcation, saddle-node bifurcation), Stability analysis of linear systems, Lyapunov stability theory, Phase space analysis and eigenvalue analysis, Definition and characteristics of chaos, Chaotic attractors (e.g., Lorenz attractor, Rossler attractor), Routes to chaos (e.g., period doubling, intermittency), Chaotic behavior in discrete maps (e.g., logistic map, Henon map), Chaotic behavior in continuous flows, Introduction to chaos control methods (e.g., OGY method, delayed feedback control), Synchronization and its application, Introduction to fractals and self-similarity, Fractal dimension and box-counting dimension, Applications of fractals in dynamical systems and chaos.

Recommended books:

1. Alligood.K.T, Yorke.J.A, & Sauer.T.D. (1996). Chaos: An Introduction to Dynamical Systems, Springer.
2. Broer.H, & Takens.F. (2010). Dynamical Systems and Chaos, 2nd edition, Springer.
3. David Feldman. (2019). Chaos and Dynamical Systems, Princeton University Press.
4. Hirsch.M.W, Smale.S, & Devaney.R.L. (2012). Differential Equations, Dynamical Systems, and an Introduction to Chaos, 3rd edition, Academic Press.
5. Stephen Wiggins. (2003). Introduction to Applied Nonlinear Dynamical Systems and Chaos, 2nd edition, Springer.

CM-713 Soft Computing (3+0)

Overview of soft computing paradigms, Comparison with traditional computing approaches, Applications in engineering, Data analysis, Optimization, Introduction to fuzzy sets and fuzzy logic, Fuzzy inference systems (Mamdani and Sugeno models), Fuzzy control systems and their applications, Basics of artificial neural networks (ANNs), Multilayer perceptrons (MLPs), activation functions, and training algorithms, Radial basis function networks, self-organizing maps (SOMs), Adaptive neuro-fuzzy inference systems (ANFIS) and learning algorithms, Basics of swarm intelligence algorithms, Combining soft computing techniques with traditional algorithms, Ensemble learning methods (e.g., neural network ensembles, genetic programming ensembles), Applications and advantages of hybrid and ensemble approaches, Soft computing techniques for classification and clustering, Feature selection and dimensionality reduction using soft computing approaches, Applications in image processing, text mining, and bioinformatics, Case studies and real-world applications across different domains.

Recommended books:

1. Barua.K, & Chakrabarti.P. (2019).Fundamental of Soft Computing, BPB Publications.
2. Matthew.N, Adebo.P, & Chukwu.U.C. (2023).Soft Computing And Its Applications, Springer.
3. Sivanandam.S, & Deepa.S.N. (2018).Principles of Soft Computing, 3rd edition, Wiley.
4. Sushil Kumar Singh. (2012). Soft Computing: Neural Networks, Fuzzy Logic and Genetic Algorithms, 1st edition, Galgotia Publishers.
5. Vojislav Kecman. (2001). Learning and Soft Computing: Support Vector Machines, Neural Networks, and Fuzzy Logic Models, 1st edition, Bradford Publishing.

CM-714 Statistical Methods and Data Analysis (3+0)

Definition of statistics and its importance in data analysis, Types of data (categorical, numerical), Descriptive vs inferential statistics, Data visualization techniques (histograms, box plots, scatter plots), Discrete probability distributions, Continuous probability distributions, Properties of probability distributions, Estimation techniques (point estimation, interval estimation), Hypothesis testing principles, Parametric vs non-parametric tests, Correlation and Regression Analysis, Pearson correlation coefficient, Simple linear regression analysis,
Multiple linear regression analysis, Assumptions of regression analysis and model diagnostics, Analysis of Variance (ANOVA), Mann-Whitney U test, Wilcoxon signed-rank test, Kruskal-Wallis test, Spearman's rank correlation coefficient, Time Series Analysis, Components of time series data (trend, seasonality, cyclicality, irregularity), Time series decomposition, Forecasting techniques (moving average, exponential smoothing, ARIMA, SARIMA models), Challenges and opportunities in big data analysis, Tools and techniques for handling large datasets (Hadoop, Spark), Data preprocessing and feature engineering for big data analytics, Data privacy and security concerns, Ethical considerations in data collection and analysis.

Recommended books:

1. Lyman.R.O,& Longnecker.M.T. (2015).An Introduction to Statistical Methods and Data Analysis, 7th edition, Cengage Learning.
2. Siegmund Brandt. (2014). Data Analysis: Statistical and Computational Methods for Scientists and Engineers, 4th edition, Springer.
3. R. Gnanadesikan. (1997).Methods for Statistical Data Analysis of Multivariate Observations, 2nd edition, Wiley.
4. Jim Frost. (2020).Introduction to Statistics: An Intuitive Guide for Analyzing Data and Unlocking Discoveries, Jim Publishing.
5. John Mandel. (1999).The Statistical Analysis of Experimental Data, Dover Publications.

CM-715 Nature-Inspired Optimization Algorithms (3 + 0)

Overview of optimization problems, Classification of optimization problems, objective function, search space, solution representation, Introduction to evolutionary computation, Genetic algorithms (GAs), including representation, selection, crossover, and mutation, Genetic programming and evolutionary strategies, Basics of swarm intelligence algorithms, Particle swarm optimization (PSO), ant colony optimization (ACO), Bee colony optimization and other swarm-based algorithms, Introduction to firefly algorithm (FA), Attraction-repulsion mechanisms in firefly behavior, Application of FA to optimization problems, Principles of cuckoo behavior and brood parasitism, Cuckoo search algorithm (CS) and its variants, Applications of CS in optimization and parameter estimation, Case studies and real-world applications in various domains (e.g., engineering design, data mining, image processing), Comparative studies and benchmarking of nature-inspired algorithms, Challenges and future directions in nature-inspired optimization research.

Recommended books:

1. Bottou.L, Curtis.F, &Nocedal.J. (2016). Optimization Methods for Large-Scale Machine Learning, SIAM publications.
2. Jeyakumar.V& Rubinov.A.M. (2005). Continuous Optimization: Current Trends and Modern Applications, Springer.
3. Roberto Cominetti, Francisco Facchinei &Jean B. Lasserre. (2012). Modern Optimization Modelling Techniques, Springer.
4. Ross Baldick. (2009). Applied Optimization: Formulation and Algorithms for Engineering Systems, 1st edition, Cambridge University Press.
5. Xin-She Yang. (2020).Nature-Inspired Optimization Algorithms, 2nd edition, Academic Press.

CM-716 Cryptography & Network Security (3+0)

Overview of cryptography and its importance in network security, Historical development of cryptographic techniques, Cryptographic goals, Confidentiality, Integrity, Authentication, Non-repudiation, Substitution ciphers, Symmetric encryption algorithms: DES, AES, 3DES, Block cipher modes of operation: ECB, CBC, CTR, Stream ciphers and their application, Public-key cryptography, RSA algorithm for public-key encryption and digital signatures, Diffie-Hellman key exchange protocol and its variants, Cryptographic hash functions like SHA-1, SHA-256, SHA-3, HMAC construction for generating MACs, Secure communication protocols, Secure email protocols, Wireless network security protocols, Threats and vulnerabilities in wireless networks, Mobile device security, encryption, authentication, remote wipe, Mobile network protocols and security mechanisms.

Recommended books:

1. Behrouz A. Forouzan. (2007).Cryptography & Network Security, 1st edition, McGraw-Hill Education.
2. Katz, J., &Lindell, Y. (2014). Introduction to Modern Cryptography, 2nd edition, Taylor & Francis.
3. Maria.G, Baldoni.M.W, &Ciliberto.C. (2008). Number Theory, Elementary cryptography and codes, 2nd edition, Springer.
4. Weish D. (1998). Codes and Cryptography, Clarenelon press.
5. William Stallings. (2022). Cryptography and Network Security: Principles and Practice, 2nd edition, Pearson Education.

CM-717 Image Processing & Computer Vision (3+0)

Basics of digital image representation, Pixels, Color spaces, Image formats, Image acquisition techniques, Overview of image processing tasks and applications, Point processing techniques, Histogram equalization, Contrast stretching, Spatial domain filtering, Convolution, Smoothing, Sharpening, Frequency domain filtering, Fourier transform, Low-pass and high-pass filtering, Degradation model and restoration process, Image degradation and noise models, Restoration techniques: inverse filtering, Wiener filtering, total variation regularization, Thres holding techniques, Global thres holding, Adaptive thres holding, Edge detection algorithms, Corner detection algorithms, Harris corner detector, Shi-Tomasi corner detector, Scale-invariant feature transform (SIFT) and Speeded-up robust features (SURF), Optical flow estimation methods, Lucas-Kanade, Horn-Schunck, Object tracking techniques, Kalman filter, Particle filter, Multi-object tracking and data association, Image registration techniques, Affine transformation, Elastic registration.

Recommended Textbooks:

1. Arcangelo.D, & Distante.C. (2020).Handbook of Image Processing and Computer Vision, 1st edition, Springer.
2. Burger.W, & Burge.M.J. (2009).Principles of Digital Image Processing, Springer.
3. J. R. Parker. (2010).Algorithms for Image Processing and Computer Vision, 2nd edition, Wiley.
4. Nixon.M, & Aguado.A. (2019).Feature Extraction and Image Processing for Computer Vision, 4th edition, Academic Press.
5. Richard Szeliski. (2022).Computer Vision: Algorithms and Applications, 2nd edition, Springer.

CM-718 Data Processing for Big data (3+0)

Definition and characteristics of big data, Challenges in big data processing, Overview of big data analytics and its applications, Data sources and collection methods, Sensors, Social media, Web scraping, Data preprocessing techniques, Cleaning, Integration, Transformation, Introduction to distributed computing paradigms, Overview of big data platforms, Hadoop, Spark, Flink, Distributed file system, NoSQL databases: Key-value stores, Document stores, Column-family stores, Graph databases, Data modeling and schema design for NoSQL databases, CAP theorem and consistency models, Stream processing frameworks, Visualization techniques for big data, Heatmaps, Scatter plots, Treemaps, Exploratory data analysis (EDA) on large datasets, Interactive visualization tools and dashboards, Scalability challenges in big data processing, Performance optimization techniques: data partitioning, caching, parallelism, Monitoring and tuning big data systems, Challenges and threats in big data security, Access control and encryption techniques, Privacy-preserving data mining and anonymization methods.

Recommended books:

1. Brian Paul. (2023). Big Data Processing for Beginners, Wiley.
2. Dawn E. Holmes. (2018). Big Data: A Very Short Introduction, Oxford University Press.
3. Janev.V, Graux.D, Jabeen.H, & Sallinger.E. (2020). Knowledge Graphs and Big Data Processing, 1st edition, Springer.
4. Kumar.V.N, & Shindgikar.P. (2018). Modern Big Data Processing with Hadoop, 1st edition, Packt Publishing.
5. Mohammed Guller. (2015).Big Data Analytics with Spark, 1st edition, APress

CM-719 Modeling, Simulation, and Monte Carlo (3+0)

Definition and importance of modeling and simulation, Types of models (physical, mathematical, conceptual),
Simulation vs analytical methods, Probability theory and random variables, Statistical distributions (uniform, normal, exponential, etc.), Stochastic processes (Markov chains, Poisson processes), Monte Carlo integration and sampling techniques, Simulation Modeling Process, Problem formulation and model conceptualization, Model development and validation, Input data collection and analysis, Output analysis and interpretation, Discrete Event Simulation, Event scheduling and time advance mechanisms, Simulation clock and event-driven simulation, Introduction to Monte Carlo simulation, Monte Carlo integration for numerical integration, Random number generation and pseudo-random number generators, Variance reduction techniques, Techniques for model validation (comparison with real-world data, sensitivity analysis), Model verification and correctness testing, Model calibration and optimization.

Recommended books:

1. George S. Fishman A. (2005). First Course in Monte Carlo, 1st edition, Duxbury Press.
2. Kroese. D.P, Taimre.T, &Botev.I. (2011). Hand Textbooks of Monte Carlo Methods, 1st edition, Wiley.
3. Liu.J.S, & Owen. A.B. (2008). Monte Carlo Strategies in Scientific Computing, Springer.
4. Paul Glasserman. (2003). Monte Carlo Methods in Financial Engineering, 3rd edition, Springer.
5. Thomas C. M. Lee. (2013). Monte Carlo Simulation and Resampling Methods for Social Science, 1st edition, SAGE Publications.