SARDAR PATEL UNIVERSITY, BALAGHAT

School of Engineering and Technology

Syllabus

Course: B.Tech **Semester: VI**

Branch: Computer Science and Engineering (AI & ML) **w.e.f. Academic Session: 2024-25**

AIML601 Parallel and Distributed Computing

Course Objectives:

1. To introduce the Basics of Parallel and Distributed Computing Concepts and Architectures.
2. To study distributed computing using MPI/OpenMPI.
3. To learn shared memory programming with PThreads, OpenMP, and TBB.
4. To understand GPU Programming with CUDA/OpenCL.

Unit I: Introduction to PDC:

Latency vs. Bandwidth, Applications and Challenges, Types of Architecture, Flynn's Taxonomy, Basic Concepts: Cores, Nodes, Threads, Processes, Speedup, Efficiency, Overhead, Strong and Weak Scaling (Amdahl's law, Gustafson's law), Cache, Principle of Locality, Programming Models.

Unit II: Distributed Computing:

Distributed Memory, Message Passing Interface, Asynchronous/Synchronous Computation/Communication, Concurrency Control, Fault Tolerance, Distributed Programming with OpenMPI.

Unit III: Parallel Computing:

Shared Memory, Data and Task Parallelism, Synchronization, Concurrent Data Structures, Shared Memory Programming with available APIs: PThreads, OpenMP, TBB.

Unit IV: GPU Programming:

GPU Architecture, Programming Models: CUDA/OpenCL, Basic Concepts: Threads, Blocks, Grids, GPU Memory Hierarchy, Thread Scheduling, Warps and Control Divergence, Memory Coalescing, Programming with CUDA, Using CUDA Libraries: CuBLAS, CuFFT.

Reference Books:

1. The Art of Multiprocessor Programming by Maurice Herlihy and NirShavit, Morgan Kaufmann Publishers.
2. Principles of Parallel Programming, by Calvin Lin, Larry Snyder, Addison-Wesley.
3. Introduction to Parallel Computing, by Ananth Grama, Anshul Gupta, George Karypis, Vipin Kumar, Second Edition.
4. Wen-Mei W Hwu, David B Kirk, Programming Massively Parallel Processors A Hands-on Approach, Morgann Kaufmann, 3e.

Course Outcome:

At the end of the course, students should be able to:

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1. Understand parallel and distributed computing concepts and architectures.
2. Implement distributed systems using MPI/OpenMPI.
3. Develop parallel programs with shared memory (PThreads, OpenMP, TBB).
4. Write GPU programs *u*sing CUDA/OpenCL.

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AIML602 Cloud Computing

Course Objectives:

1. To introduce the fundamentals and characteristics of cloud computing.
2. To understand cloud architecture, service models, and deployment models.
3. To explore benefits, limitations, and security issues in cloud environments.
4. To learn cloud simulation tools such as CloudSim and GreenCloud.
5. To understand Virtualization Concepts using VMware.

Unit I: Introduction to Cloud Computing:
Origins of Cloud Computing, Cloud Components, Essential Characteristics, On-demand self-service, Broad Network Access, Location independent resource pooling ,Rapid Elasticity , Measured Service, Comparing Cloud Providers with Traditional IT Service Providers, Roots of Cloud Computing.

Unit II: Cloud Insights:
Architectural Influences – High Performance Computing, Utility and Enterprise Grid Computing, Cloud Scenarios – Benefits: Scalability, Simplicity, Vendors, Security, Limitations-Sensitive information - Application Development- Security level of third party – Security Benefits, Regularity issues: Government policies.

Unit III: Cloud Architecture:
Layers and Models, Layers in Cloud Architecture, Software as a Service (SaaS), Features of SaaS and Benefits, Platform as a Service (PaaS), Features of PaaS and Benefits, Infrastructure as a Service (IaaS), Features of IaaS and Benefits, Service Providers, Challenges and Risks in Cloud Adoption. Cloud Deployment Model: Public Clouds – Private Clouds, Community Clouds - Hybrid Clouds - Advantages of Cloud computing.

Unit IV: Cloud Simulators - CloudSim and GreenCloud:
Introduction to Simulator, understanding CloudSim Simulator, CloudSim Architecture (User code, CloudSim, GridSim, SimJava), Understanding Working platform for CloudSim, Introduction to GreenCloud.

Unit V: Introduction to VMware Simulator:
Basics of VMware, Advantages of VMware Virtualization, using VMware Workstation, Creating Virtual Machines-Understanding Virtual Machines, Create a New Virtual Machine on Local Host, Cloning Virtual Machines, Virtualize a Physical Machine, Starting and Stopping a Virtual Machine.

Text Book/ Reference Books:

1. Cloud Computing a Practical Approach - Anthony T.Velte, Toby J. Velte Robert Elsenpeter,

TATA McGraw - Hill, New Delhi - 2010.
2. Cloud Computing: Web-Based Applications That Change the Way You Work and Collaborate Online - Michael Miller - Que 2008.
3. Cloud computing for dummies- Judith Hurwitz , Robin Bloor , Marcia Kaufman, Fern Halper, Wiley Publishing, Inc, 2010.
4. Cloud Computing (Principles and Paradigms), Edited by Rajkumar Buyya, James Broberg, Andrzej Goscinski, John Wiley Sons, Inc. 2011.

Course Outcome:

At the end of the course, students should be able to:

1. Explain cloud computing concepts, components, and service models (SaaS, PaaS, IaaS).
2. Analyze cloud architecture, deployment models, and related security challenges.
3. Use cloud simulation tools like CloudSim and GreenCloud.
4. Implement and manage virtual machines using VMware.
5. Evaluate the advantages and challenges of adopting cloud solutions.

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AIML603 Data and Visual Analytics

Course Objectives:

1. To introduce fundamental statistical concepts and data analysis techniques.
2. To understand advanced statistical modeling and hypothesis testing methods.
3. To learn data wrangling and data visualization techniques.
4. To explore the data ecosystem including big data tools and platforms.
5. To develop practical skills using data visualization tools and analytics software.

Unit I: Data Definitions and Analysis Techniques:

Elements, Variables, and Data categorization, Levels of Measurement Data management and indexing Introduction to Statistical Concepts: Sampling Distributions, Resampling, Statistical Inference and Descriptive Statistics, Measures of central tendency, Measures of location of dispersions.

Unit II: Advance Data Analysis Techniques:

Statistical hypothesis generation and testing, Chi-Square test, t-Test, Analysis of variance, Correlation analysis, Maximum likelihood test, Regression Modelling, Multivariate Analysis, Bayesian Modelling, Inference and Bayesian Network, Regression Analysis.

Unit III: Data Wrangling:

Introduction to Data Wrangling, Gathering Data, Assessing Data, Cleaning Data. Data Visualization in Data Analysis: Design of Visualizations, Univariate Exploration of Data, Bivariate Exploration of Data, Multivariate Exploration of Data, Explanatory Visualizations.

Unit IV: Data Ecosystem:

Overview of the Data Analyst Ecosystem, Types of Data, Understanding Different Types of File Formats, Sources of Data, Overview of Data Repositories, NoSQL, Data Marts, Data Lakes, ETL, and Data Pipelines, Foundations of Big Data, Big Data processing tools such as Hadoop, Hadoop Distributed File System (HDFS), Hive, and Spark.

Unit V: Data Visualization Tools:

Python visualization libraries (matplotlib, pandas, seaborn, ggplot, plotly), Introduction to PowerBI tools, Examples of inspiring (industry) projects, Exercise: create your own visualization of a complex dataset.

Reference Books / Text Books:

1. Joel Grus, Data Science from Scratch, Shroff Publisher Publisher /O'Reilly Publisher Media.
2. Annalyn Ng, Kenneth Soo, Numsense! Data Science for the Layman, Shroff Publisher Publisher.

3. Cathy O'Neil and Rachel Schutt. Doing Data Science, Straight Talk from The Frontline. O'Reilly Publisher Media.
4. Jure Leskovek, Anand Rajaraman and Jeffrey Ullman. Mining of Massive Datasets. v2.1, Cambridge University Press.
5. Jake VanderPlas, Python Data Science Handbook, Shroff Publisher Publisher /O'Reilly Publisher Media.
6. Philipp Janert, Data Analysis with Open Source Tools, Shroff Publisher Publisher /O'Reilly Publisher Media.

Course Outcome:

At the end of the course, students should be able to:

1. Apply statistical measures and inference techniques to analyze data.
2. Perform hypothesis testing, regression, and multivariate analysis.
3. Clean, transform, and visualize data for meaningful insights.
4. Understand big data concepts and tools such as Hadoop, HDFS, Hive, and Spark.
5. Create effective visualizations using Python libraries and Power BI.

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AIML604 Algorithms for Intelligent Systems

Course Objectives:

1. To understand the fundamentals of intelligent agents and environments.
2. To apply uninformed and informed search algorithms for problem solving.
3. To study adversarial search and game-playing strategies.
4. To learn planning techniques for deterministic and uncertain domains.
5. To understand probabilistic reasoning and decision-making models.

Unit I: Introduction:

Intelligent Agents: Introduction. Agents and Environments, Good Behavior: The Concept of Rationality, The Nature of Environments, The Structure of Agents.

Problem Formulation: Problem-Solving Agents, Example Problems, Searching for Solutions, Uninformed Search Strategies, Avoiding Repeated States, Searching with Partial Information.

Unit II: Search Methods:

Uninformed Search Techniques: DFS, BFS, Uniform cost search, Depth Limited Search, Iterative Deepening, Bidirectional search, Comparing Different Techniques.

Informed Search Methods: Heuristic functions, Hill Climbing, Simulated Annealing, Best First Search, A*, IDA*, SMA*, Crypto- Arithmetic Problem, Backtracking for CSP, Performance Evaluation. Adversarial Search: Game Playing, Min-Max Search, Alpha Beta Pruning.

Unit III: Planning:

Introduction to Planning, Planning with State Space Search, Partial Ordered planning, Hierarchical Planning, Conditional Planning, Planning with Operators.

Planning and Acting in the Real World: Time, Schedules and Resources, Hierarchical Task Network Planning, Planning and Acting in Nondeterministic Domains, Conditional Planning, Execution Monitoring and Re-planning, Continuous Planning, Multi- Agent Planning.

Unit IV: Uncertain Knowledge and Reasoning:

Uncertainly, Representing Knowledge in an Uncertain Domain, Conditional Probability, Joint Probability, Baye's theorem, Belief Networks, Simple Inference in Belief Networks.

Unit V: Making Simple and Complex Decisions:

Combining Beliefs and Desires under Uncertainty, The Basis of Utility Theory, Utility Functions, Multi-attribute Utility Functions, Decision Networks, The Value of Information, Decision-Theoretic Expert Systems, Sequential Decision Problems, Value Iteration, Policy Iteration.

Reference Books / Text Books:

1. S. Russell and P. Norvig, "Artificial Intelligence: A Modern Approach", Prentice Hall, Third Edition, 2009.
2. Elaine Rich, Kevin Knight, Shivshankar B Nair, "Artificial Intelligence", McGraw Hill, 3rd Edition, 2017.
3. Elaine Rich, Kevin Knight, "Artificial Intelligence", Tata McGraw Hill, 2nd Edition, 1991.
4. Patrick Henry Winston, "Artificial Intelligence", 3rd Edition, Pearson Publication, 1993.
5. Patrick Henry Winston., "Lisp programming language", 3rd Edition, Pearson Publication.

Course Outcome:

At the end of the course, students should be able to:

1. Explain intelligent agents, rationality, and problem formulation.
2. Implement and compare search algorithms such as BFS, DFS, A*, and Alpha-Beta pruning.
3. Apply planning methods including state-space and hierarchical planning.
4. Use probability concepts, Bayes' theorem, and belief networks for reasoning under uncertainty.
5. Solve decision-making problems using utility theory, value iteration, and policy iteration.

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Elective-II AIML6051 Optimization Techniques in ML

Course Objectives:

1. To understand formulation and classification of optimization problems in engineering and ML.
2. To apply classical optimization methods and Kuhn–Tucker optimality conditions.
3. To solve linear and non-linear constrained and unconstrained optimization problems.
4. To study modern optimization techniques such as evolutionary and swarm-based methods.
5. To implement optimization algorithms using MATLAB/R/Python for real-world applications.

Unit I: Introduction:

Engineering applications – Statement of an optimization problem – Classifications of Optimization problems – Optimal problem formulation: Problems involving design and manufacturing – Optimality criteria – Classical optimization techniques – Kuhn-Tucker (KT) optimality conditions.

Unit II: Non-Linear Programming:

One Dimensional Minimization Methods – Unconstrained Optimization Techniques – Constrained Optimization Techniques – Transformation Methods – Interior and Exterior Penalty Function Method – Convergence and Divergence of Optimization Algorithms – Complexity of algorithms.

Unit III: Modern Methods in Optimization:

Genetic Algorithm – Simulated Annealing – Particle Swarm Optimization – Neural Network based optimization – Optimization of Fuzzy systems – Multi-Objective optimization – Data Analytics and optimization using Machine learning approach.

Unit IV: Implementation of Optimization Algorithms:

Implementing optimization algorithms in MATLAB / R / Python environment and solving linear, non-linear, multi- objective un-constrained and constrained optimization problems.

Text Books / Reference Books:

1. S.S. Rao, Engineering optimization: Theory and Practice, New age international, 3rd edition, 2013.
2. K. Deb., Optimization for Engineering Design: Algorithms and Examples, PHI, 2nd Edition, 2012.
3. J. S. Arora, Introduction to Optimum Design, Academic press, 4th Edition, 2017.

Course Outcome:

At the end of the course, students should be able to:

1. Formulate optimization problems with appropriate objective functions and constraints.
2. Apply classical and non-linear programming techniques for engineering and ML problems.
3. Analyze convergence, complexity, and optimality conditions of algorithms.

4. Use modern optimization methods such as Genetic Algorithms, Particle Swarm Optimization, and Simulated Annealing.
5. Implement and solve single and multi-objective optimization problems using computational tools.

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Elective-II AIML6052 Computational Intelligence

Course Objectives:

1. To understand the fundamentals of Computational Intelligence.
2. To learn neural network models and training methods.
3. To study evolutionary algorithms for optimization.
4. To understand fuzzy sets and fuzzy inference systems.
5. To apply CI techniques to real-world problems.

Unit I: Introduction to Computational Intelligence:
Computational Intelligence: Definition and Paradigms. Brief historical sketch.

Unit II: Foundations of Neural Computation:
Introduction to neural computation: biological inspiration, neural network models, architectures and training algorithms, focusing on Multi-layer Perceptrons and Convolutional Neural Networks. Learning and Generalization. Experimental Issues.

Unit III: Foundations of Evolutionary Computation:
Introduction to evolutionary computation: evolutionary processes in nature, genetic operators, evolutionary optimization algorithms. Genetic algorithms. Evolution Strategies and CMA-ES.

Unit IV: Foundations of Fuzzy Computation:
Introduction to Fuzzy Computation: Fuzzy Sets and Systems, Fuzzy Inference Systems and Hybrid. Applications and Case Studies on Real problems in Regression, Classification, Identification and System Optimization.

Text Books / Reference Books:

1. Neural networks and learning machines - Haykin, S, Prentice Hall, 2009. ISBN: 9780131471399.
2. Evolutionary algorithms in theory and practice: evolution strategies, evolutionary programming, genetic algorithms - Bäck, T, Oxford University Press, 1996. ISBN: 0195099710.
3. Fuzzy sets and fuzzy logic: theory and aplications - Klir, G.J.; Yuan, B, Prentice Hall, 1995. ISBN: 0131011715.
4. Computational intelligence: an introduction - Engelbrecht, A.P, John Wiley & Sons, 2008. ISBN: 9780470035610.
5. A course in fuzzy systems and control - Wang, L.-X, Prentice-Hall PTR , 1997. ISBN: 0135408822.

Course Outcome:

At the end of the course, students should be able to:

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1. Explain key paradigms of Computational Intelligence.
2. Design basic neural network models (MLP, CNN).
3. Apply Genetic Algorithms and Evolution Strategies.
4. Develop fuzzy inference systems.
5. Solve regression, classification, and optimization problems using CI methods.

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Elective-II AIML6053 Reinforcement Learning

Course Objectives:

1. To understand the fundamentals and history of Reinforcement Learning (RL).
2. To learn RL concepts including Markov Decision Processes and Bellman equations.
3. To apply dynamic programming methods like policy iteration and value iteration.
4. To explore Monte Carlo and model-free RL methods with function approximation.
5. To study policy gradient and actor-critic methods for advanced RL.

Unit I: Overview of Reinforcement Learning:

Origin and History of Reinforcement Learning Research. Its Connections with Other Related Fields and with Different Branches of Machine Learning. Brush up of Probability Concepts - Axioms of Probability, Concepts of Random Variables, PMF, PDFs, CDFs, Expectation. Concepts of Joint and Multiple Random Variables, Joint, Conditional and Marginal Distributions. Correlation and Independence.

Unit II: Introduction to RL Terminology:

Markov Property, Markov Chains, Markov Reward Process (MRP). Introduction and Proof of Bellman Equations for MRPs along with Proof of Existence of Solution to Bellman Equations in MRP. Introduction to Markov Decision Process (MDP), State and Action Value Functions, Bellman Expectation Equations, Optimality of Value Functions and Policies, Bellman Optimality Equations.

Unit III: Overview of Dynamic Programming for MDP:

Definition and formulation of planning in MDPs, principle of optimality, iterative policy evaluation, policy iteration, value iteration, Banach fixed point theorem, proof of contraction mapping property of Bellman expectation and optimality operators, proof of convergence of policy evaluation and value iteration algorithms, DP extensions.

Unit IV: Monte Carlo Methods:

Overview of Monte Carlo methods for model free RL, First visit and every visit Monte Carlo, Monte Carlo control, On policy and off policy learning, Importance sampling. Getting started with the function approximation methods, Revisiting risk minimization, gradient descent from Machine Learning, Gradient MC and Semi-gradient TD(0) algorithms, Eligibility trace for function approximation, Afterstates, Control with function approximation, Least squares, Experience replay in deep Q-Networks.

Unit V: Policy Gradient Methods:

Getting started with Policy Gradient Methods, Log-Derivative Trick, Naive REINFORCE Algorithm,

Bias and Variance in Reinforcement Learning, Reducing Variance in Policy Gradient Estimates, Baselines, Advantage Function, Actor-Critic Methods.

Text Books / Reference Books:

1. Reinforcement Learning: An Introduction, Sutton and Barto, 2nd Edition
2. Algorithms for Reinforcement Learning. C. Szepesvari. Morgan and Claypool Publishers, 2010
3. Reinforcement Learning: State-of-the-Art, Marco Wiering and Martijn van Otterlo, Eds.
4. Deep Learning, Ian Goodfellow, Yoshua Bengio, and Aaron Courville.

Course Outcome:

At the end of the course, students should be able to:

1. Explain RL concepts, MDPs, and Bellman equations.
2. Apply dynamic programming techniques to solve planning problems.
3. Implement Monte Carlo and temporal-difference methods for model-free RL.
4. Use function approximation, eligibility traces, and experience replay in RL.
5. Apply policy gradient and actor-critic algorithms to real-world problems.