

SEMESTER S5

ADVANCED GRAPH ALGORITHMS

Course Code	PECST595	CIE Marks	40
Teaching Hours/Week (L: T:P: R)	3:0:0:0	ESE Marks	60
Credits	5/3	Exam Hours	2 Hrs. 30 Min.
Prerequisites (if any)	GAMAT401 PCCST303 PCCST502	Course Type	Theory

Course Objectives:

1. To gain proficiency in designing and implementing sophisticated graph algorithms for analyzing large-scale networks, and apply these techniques to real-world problems such as social network analysis and transportation optimization.
2. To develop the ability to critically evaluate and enhance advanced graph algorithms for dynamic and evolving graphs, using real-world case studies to illustrate their application and performance in complex scenarios.

SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	<p>Maximum Flow Algorithms - Dinic's Algorithm, Push-Relabel Algorithm. Applications - network bandwidth allocation, data center resource management.</p> <p>Minimum Cost Flow - Cycle-Canceling Algorithm, Capacity Scaling Algorithm. Applications - transportation logistics, network routing with cost constraints.</p> <p>Assignments:</p> <ol style="list-style-type: none">1. Network Bandwidth Allocation - Optimize bandwidth allocation in a communication network using Dinic's Algorithm. <p>Implement Dinic's Algorithm to solve a network flow problem where you are given a communication network represented as a directed graph with capacities on edges. Your goal is to maximize</p>	9

	<p>the flow from a source node to a sink node. Use a real-world network dataset (e.g., a telecommunications network with nodes and link capacities).</p> <p>2. Logistics Optimization - Optimize the transportation of goods in a supply chain network using the Capacity Scaling Algorithm.</p> <p>Use the Capacity Scaling Algorithm to address a logistics problem where you need to minimize transportation costs in a supply chain network. The network is represented as a graph where nodes represent locations (warehouses, distribution centers, etc.), and edges represent transportation routes with associated costs. Use a dataset representing a supply chain network with nodes, edges, and costs.</p>	
2	<p>Strongly Connected Components (SCC) - Tarjan's Algorithm, Kosaraju's Algorithm. Applications - analyzing web page link structures, understanding connected components in social networks.</p> <p>Dynamic Graph Connectivity - Dynamic connectivity algorithms, Eulerian and Hamiltonian paths. Applications - real-time network monitoring, dynamic route planning.</p> <p>Assignments:</p> <p>1. Web Page Link Analysis - Objective: Analyze strongly connected components (SCC) in a web graph using Tarjan's Algorithm.</p> <p>Implement Tarjan's Algorithm to find SCCs in a web graph where nodes represent web pages and edges represent hyperlinks. SCCs help in understanding the structure of the web and identifying clusters of interconnected pages. Use a real-world web graph dataset with nodes and edges.</p> <p>2. Dynamic Route Planning - Manage and analyze routes in a transportation network that evolves over time using dynamic connectivity algorithms.</p> <p>Implement dynamic connectivity algorithms to handle a transportation network where edges and nodes may be added or removed over time. The goal is to maintain and update the connectivity information efficiently. Use a dataset representing a transportation network with dynamic updates.</p>	9
3	<p>Graph Matching - Edmonds' Algorithm for finding maximum matchings. Applications - job assignment, network design.</p> <p>Graph Coloring - Colorings for special classes of graphs (e.g., planar graphs, interval graphs). Applications - frequency assignment in wireless networks,</p>	9

	<p>scheduling problems</p> <p>Assignments:</p> <ol style="list-style-type: none"> 1. Job Assignment Optimization - Solve job assignment problems using Edmonds' Algorithm. Implement Edmonds' Blossom Algorithm to address job assignment problems where you need to match workers to jobs in a way that maximizes the overall efficiency or minimizes the cost. Use a dataset with job assignments and associated costs or efficiencies. 2. Frequency Assignment - Allocate frequencies in wireless communication systems using graph coloring techniques. Apply graph coloring techniques to allocate frequencies to transmitters in a wireless communication network to avoid interference. The goal is to minimize the number of frequencies used while ensuring that adjacent transmitters do not use the same frequency. Use a dataset representing a network of transmitters with potential interference. 	
4	<p>Graph Partitioning and Community Detection - Kernighan-Lin Algorithm, Spectral Partitioning. Applications - social network community detection, large-scale data clustering.</p> <p>Parameterized Algorithms for Graph Problems - Fixed-parameter tractability for vertex cover, feedback vertex set. Applications - network security, bioinformatics.</p> <p>Assignments:</p> <ol style="list-style-type: none"> 1. Social Network Community Detection - Detect communities in a social network using the Kernighan-Lin Algorithm. Apply the Kernighan-Lin Algorithm to detect communities in a social network where nodes represent individuals and edges represent relationships. The goal is to find clusters of highly interconnected individuals. Use a social network dataset with nodes and edges representing social connections. 2. Network Security Analysis - Identify critical nodes in a network using parameterized algorithms to assess network security. Use parameterized algorithms to identify critical nodes and vulnerabilities in a network. These nodes are crucial for the network's connectivity, and their removal would impact the network's security and robustness. Use a dataset representing a network with nodes and edges, along with possible vulnerabilities. 	9

Course Assessment Method
(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

<i>Attendance</i>	<i>Internal Ex</i>	<i>Evaluate</i>	<i>Analyse</i>	<i>Total</i>
5	15	10	10	40

Criteria for Evaluation(Evaluate and Analyse): 20 marks

Assignment evaluation pattern:

- Correctness and Accuracy (30%) - Correct Solution and Implementation.
- Effectiveness and Efficiency (25%) - Algorithm Efficiency and Performance Metrics.
- Analytical Depth (25%) - Problem Understanding and Solution Analysis.
- Justification and Comparisons (20%) - Choice Justification and Comparative Analysis.

End Semester Examination Marks (ESE):

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
<ul style="list-style-type: none"> ● 2 Questions from each module. ● Total of 8 Questions, each carrying 3 marks (8x3 =24 marks) 	<p>2 questions will be given from each module, out of which 1 question should be answered. Each question can have a maximum of 3 subdivisions. Each question carries 9 marks. (4x9 = 36 marks)</p>	60

Course Outcomes (COs)

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

Course Outcome		Bloom's Knowledge Level (KL)
CO1	Develop and implement advanced algorithms for network flow, graph connectivity, and matching, and evaluate their performance on real-world datasets.	K3
CO2	Analyze and compare the efficiency and effectiveness of various graph algorithms, including those for network optimization and community detection.	K4
CO3	Apply advanced graph algorithms to solve practical problems such as network optimization, job assignment, and frequency allocation, demonstrating their utility in real-world scenarios.	K3
CO4	Formulate and solve complex graph-related problems using appropriate algorithms, including those for graph traversal, minimum spanning trees, and network security analysis.	K5
CO5	Critically assess the strengths and limitations of different graph algorithms, and effectively communicate findings and recommendations through detailed reports and presentations.	K5

Note: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create

CO-PO Mapping Table (Mapping of Course Outcomes to Program Outcomes)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3								2
CO2	3	3	3	3								2
CO3	3	3	3	3								2
CO4	3	3	3	3								2
CO5	3	3	3	3	3							2

Note: 1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High), -: No Correlation

Text Books				
Sl. No	Title of the Book	Name of the Author/s	Name of the Publisher	Edition and Year
1	Introduction to Algorithms	Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest and Clifford Stein	The MIT Press Cambridge	4/e 2023
2	Algorithms	Robert Sedgewick and Kevin Wayne	Addison-Wesley	4/e, 2023
3	Graph Algorithms	Shimon Even	Cambridge University Press	2/e, 2011
4	Graph Theory	Reinhard Diestel	Springer	4/e, 2010

Reference Books				
Sl. No	Title of the Book	Name of the Author/s	Name of the Publisher	Edition and Year
1	A Guide to Graph Algorithms	Mingyu Xiao and Ton Kloks	Springer Verlag, Singapore;	1 st , 2022
2	Network Science	Albert-László Barabási and Márton Pósfai	Cambridge University Press	1 st , 2016
3	Modern Graph Theory	Bela Bollobas	Springer-Verlag New York Inc	1 st , 1998
4	Network Flows: Theory, Algorithms, and Applications	Ravindra Ahuja, Thomas Magnanti, and James Orlin	Pearson	1 st , 1993
5	Introduction to Graph Theory	Douglas B. West	Pearson	2 nd , 2020
6	Modern Graph Theory Algorithms with Python: Harness the power of graph algorithms and real-world network applications using Python	Colleen M Farrelly and Franck Kalala Mutombo	Packt Publishing	2024

Video Links (NPTEL, SWAYAM...)	
Module No.	Link ID
1	https://onlinecourses.nptel.ac.in/noc21_cs48/preview
2	https://onlinecourses.nptel.ac.in/noc21_cs48/preview
3	https://onlinecourses.nptel.ac.in/noc21_cs48/preview
4	https://onlinecourses.nptel.ac.in/noc21_cs48/preview