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	Maximum Flow Algorithms - Dinic's Algorithm, Push-Relabel Algorithm. Applications - network bandwidth allocation, data center resource management. Minimum Cost Flow - Cycle-Canceling Algorithm, Capacity Scaling Algorithm. Applications - transportation logistics, network routing with cost constraints. **Assignments:** 1. Network Bandwidth Allocation - Optimize bandwidth allocation in a communication network using Dinic's Algorithm. 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	9

	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). 2. Logistics Optimization - Optimize the transportation of goods in a supply chain network using the Capacity Scaling Algorithm. 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.	
2	Strongly Connected Components (SCC) - Tarjan's Algorithm, Kosaraju's Algorithm. Applications - analyzing web page link structures, understanding connected components in social networks. Dynamic Graph Connectivity - Dynamic connectivity algorithms, Eulerian and Hamiltonian paths. Applications - real-time network monitoring, dynamic route planning. **Assignments**: 1. Web Page Link Analysis - Objective: Analyze strongly connected components (SCC) in a web graph using Tarjan's Algorithm. 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. 2. Dynamic Route Planning - Manage and analyze routes in a transportation network that evolves over time using dynamic connectivity algorithms. 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.	**9**
3	Graph Matching - Edmonds' Algorithm for finding maximum matchings. Applications - job assignment, network design. Graph Coloring - Colorings for special classes of graphs (e.g., planar graphs, interval graphs). Applications - frequency assignment in wireless networks,	**9**

	scheduling problems **Assignments:** 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	Graph Partitioning and Community Detection - Kernighan-Lin Algorithm, Spectral Partitioning. Applications - social network community detection, large-scale data clustering. Parameterized Algorithms for Graph Problems - Fixed-parameter tractability for vertex cover, feedback vertex set. Applications - network security, bioinformatics. **Assignments:** 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):

Attendance	*Internal Ex*	*Evaluate*	*Analyse*	*Total*
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
• 2 Questions from each module. • Total of 8 Questions, each carrying 3 marks **(8x3 =24 marks)**	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)**	**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;	1st, 2022
2	Network Science	Albert-László Barabási and Márton Pósfai	Cambridge University Press	1st, 2016
3	Modern Graph Theory	Bela Bollobas	Springer-Verlag New York Inc	1st, 1998
4	Network Flows: Theory, Algorithms, and Applications	Ravindra Ahuja, Thomas Magnanti, and James Orlin	Pearson	1st, 1993
5	Introduction to Graph Theory	Douglas B. West	Pearson	2nd, 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