



Birla Institute of Technology & Science, Pilani
Hyderabad Campus

FIRST SEMESTER 2022-2023
Course Handout Part II

Date: 29-08-2022

In addition to part-I (General Handout for all courses appended to the time table) this portion gives further specific details regarding the course.

Course No. : CS F431
Course Title : **Combinatorial Optimization**
Instructor-in-Charge : Manjanna B.

1. **Scope and Objectives of the Course:** The main paradigm in the course will be the design and analysis of algorithms for combinatorial optimization. This course focuses on linear programming and related topics, studying algorithms based on linear programming approaches. The course encompasses mostly the study of problems that can be solved optimally in polynomial time (matchings, flows, min-cost flows). The topics are basic graph algorithms review, linear algebra basics, geometry basics, convex combination and convexity, Linear programming(LP), simplex algorithm, duality in LP, dual simplex algorithm, applications of duality and primal-dual algorithm to solve graph problems: flows in networks, min-cut, maximum bipartite matching, weighted bipartite matching, stable matching, spanning trees and matroids. Polynomial-time algorithms for LP: ellipsoid algorithm, Karmakar's algorithm, interior point methods. Algorithms for integer programming problems; total unimodularity and its applications.

The objectives of the course are to:

- Give deeper insight into the theory of linear and integer programming, a general framework capable of modeling and efficiently solving many problems arising in real-life applications.
- Understand graph-theoretic results on bipartite matchings and network flows and various generalizations.
- identify the range and the limits of applicability of linear and integer programming.
- Understand polynomiality of linear programming, and theoretical underpinnings behind how certain classes of integer programming problems can be solved in polynomial time.

Textbooks:

- T1. Papadimitriou, C., and Steglistz, K. Combinatorial Optimization: Algorithms and Complexity, Prentice-Hall, 1982.

Reference books



R1. Understanding and Using Linear Programming, Jiri Matousek, Bernd Gartner, Springer, 2007

R2. John Lee, A first course in combinatorial optimization, Cambridge University Press, 2004.

R3. W. Cook, W. Cunningham, W. Pulleyblank and A. Schrijver, *Combinatorial Optimization*, Wiley, 1997.

Course Plan:

Lecture No.	Learning objectives	Topics to be covered	Chapter in the Text Book
1-2	To review the basics.	basic graph algorithms review, linear algebra basics, geometry basics, convex combination and convexity	T1- Ch. 1, R1, R2 - Ch 1, Class Notes
3 – 4	To learn modeling using Linear and Integer Programming	The basic problem of linear programming, overview of Simplex method, The notion of integer programming.	T1 – Ch.2, 13 & R2 – Ch 4 & 5, Class Notes
5-7	To solve Matching as ILP problem	Matchings in bipartite graphs, the augmenting path algorithm.	T1 - Ch. 10, R2 - Ch 3
7-9	To study algorithms for Network flow	The maximum network flow problem, the Ford-Fulkerson algorithm.	T1 – Ch.6 & Ch.9
10 – 12	To understand the notion of Duality	The concept of Duality in linear programming. Complementary slackness. Farkas Lemma, Algorithmic complexity of the linear and integer programming problems.	T1 – Ch.3, R2 – Ch 6
12 – 20	To learn applications of LP, IP, and primal-dual techniques	the Ford-Fulkerson theorem for the maximum flow problem; the minimum cost flow, shortest path problems and the multi-commodity flow problems.	T1 – Ch.6, Ch. 7 & Ch.9, R2
21 – 25	To learn	Simplex is not polynomial time,	T1 – Ch. 8,



	algorithms for LP	Interior-point method, Ellipsoid and Karmakar's algorithm.	R2 – Ch 7
26 – 30	To learn algorithms for ILP problems	Overview of algorithms for ILP; Branch and bound using LP relaxation, cutting plane. Polynomial solvability of integer programming with a totally unimodular coefficient matrix (TUM).	T1- Ch. 13, 14, 18, R1
30 – 42	To learn applications of TUM	Applications: vertex cover in bipartite graphs, minimum-cost bipartite matching, clique of interval graphs.	T1- Ch. 13 R2- Ch. 8

Evaluation Scheme:

Component	Duration	Weightage (%)	Date & Time	Nature of Component
Quiz-1	30 mins	10%	To be announced	Open Book
Quiz-2	30 mins	10%	To be announced	Open Book
Project	Throughout the semester	15%		
Midsem	1.5 hrs	25%	03/11 1.30 - 3.00PM	Open Book
Comprehensive Examination	3 hrs	40%	26/12 AN	Open Book

Note: minimum 40% of the evaluation to be completed by midsem grading.

Project details: Project topic and relevant papers will be discussed in the class. Each project group will consist of at most three students. Projects should be carried out using commercial, but free optimization solvers like Cplex, Gurobi, etc. There will be two presentations, premidsem (5% weightage) and final (10%) seminars.

Chamber Consultation Hour: Will be announced by the instructor.

Notices: All notices about the course will be put on CMS.

Make-up Policy: Make-up will be granted only to genuine cases with prior permission only.

Academic Honesty and Integrity Policy: Academic honesty and integrity are to be maintained by all the students throughout the semester and no type of academic dishonesty is acceptable.

INSTRUCTOR-IN-CHARGE
Manjanna B.

