Annotated Bibliography of Selected Publications

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My research is in the area of combinatorial optimization, approximation algorithms, algorithmic game theory, and mathematical programming. In particular, it includes approximation algorithms for facility location problems, network design and routing, graph partitioning, and approximation schemes for linear and convex programming problems including computing market equilibria.

Graph Partitioning


While a lot of techniques have been developed for graph partitioning, the fastest of these algorithms are based on multi-commodity flow computations which are slow. In this work, we give a new approach that uses single commodity flows, which are easier to compute both in theory and perhaps even more so in practice. We obtain an $O(\log^2 n)$ approximation for sparsest cuts and separators by doing $O(\log^2 n)$ single commodity max-flow computations. While the approximation is worse than previous results, we continue to get a polylogarithmic approximation and break the quadratic-time multicommodity flow barrier as well as, get by the typically slow convergence rates of spectral methods.

Lagrangian Relaxation based Algorithms for Convex Programming Problems


This dissertation deals with a class of combinatorial algorithms for linear and convex programming developed in the computer science community in last couple of decades. We present a unified framework for designing such algorithms for a large family of convex programming problems. A distinguishing feature of our algorithms is that their running times depend logarithmically on the number of constraints. The ellipsoid algorithm, on the other hand, has a polynomial dependence. Our algorithms, however, can compute only approximate solutions since their dependence on the error parameters is polynomial, as opposed to the ellipsoid algorithm’s logarithmic dependence. Another useful feature of our algorithms is their “combinatorial” nature that is often insightful for solving programs arising from combinatorial optimization problems. Using this framework, we derive new algorithms for various linear and convex programming problems.


The main contribution of this paper is that it extends the multiplicative update primal-dual approximation schemes known for packing and covering linear programs to a much larger class of linear problems. We illustrate this by giving such an algorithm for a fractional version of a Steiner network design problem.

Following [3], this paper also extends the known techniques for packing and covering linear programs to those with negative entries in the objective function or the constraint matrix. We apply this to a covering problem with upper bound constraints on the variables and compute strictly feasible near-optimum solutions, improving upon the work of Fleischer (2004). The previous such algorithms could only compute approximately feasible solutions.


Using the framework developed in the dissertation [2], we design combinatorial algorithms for computing approximate market equilibria in Leontief economies and its “dual” problem – fair resource allocation. Our algorithm is a natural variant of the tâtonnement process where the dual variables are interpreted as prices.


In this work, we design distributed combinatorial algorithms for solving a semi-definite programming formulation of the fastest mixing Markov chain in a graph. Our algorithm is more efficient than solving the semi-definite program by traditional methods. The number of iterations in our algorithm, however, is still large for it to be practical in large distributed networks.

**Local Search Algorithms for Facility Location Problems**


Local search techniques have been very popular as heuristics for hard combinatorial optimization problems. However, most of these heuristics have poor worst-case guarantees and very few approximation algorithms that rely on local search are known. For the k-median problem, we show that a simple swap-local-search yields a 5 approximation. The analysis is very simple and can be extended to the currently-best-known approximation guarantee of $3 + \epsilon$ by doing multiple swaps. We obtain similar results for uncapacitated and capacitated facility location problems as well.


The universal facility location problem, in which the cost of a facility is any increasing function of the number of clients it serves, is a generalization of several variants of facility location problems. We present a local search algorithm that yields a $6 + \epsilon$ approximation for this problem. Our algorithm builds on, and improves the results by Mahdian and Pál (2003) and also bridges the gap between the approximation factors known for this problem and its special case – the capacitated facility location.

In this paper, we define a network service provider game. We show that the price of anarchy of this game can be bounded by analyzing a local search heuristic for a related facility location problem called $k$-facility location. We show that the local-search-ratio of $k$-facility location, and hence the price of anarchy of the game, is at most 5. Our result gives evidence to the belief that the price of anarchy of certain games are related to analyses of local search heuristics.

**Network Design and Routing**


We study a natural network design problem that reflects the economies of scale in the cost of routing flows in the network. We provide an integer programming formulation of the problem, and show that it has a logarithmic integrality gap. This also leads to an approximation algorithm by rounding the LP relaxation.


We consider the problem of computing a multicast overlay tree so as to maximize the throughput achievable for transmitting streaming data to several terminals. We prove several algorithmic and hardness results for this problem. We, however, ignore the latency incurred in sending the data in this model.

**Disk Scheduling**


We consider a disk scheduling problem to minimize the total seek time by reordering the input sequence of requests using a buffer of given size. For a disk, which is modeled as an array of tracks, we give a randomized online algorithm with a polylogarithmic competitive ratio. We also show that many natural strategies are not suitable for this problem. It would be interesting to extend our ideas to a more accurate model of disk that takes into account rotational latencies.

**Miscellaneous**


Autonomous exploration inside a virtual environment is an important problem in diverse applications like exploration of medical and other scientific data, medical surgery simulations, robotic path planning. We present an efficient and scalable algorithm for computing collision-free central paths in a closed virtual environment. The algorithm is based on the distance from the boundary field computed on a hierarchical subdivision of the free space inside the closed 3D object.