WAOA 2016 Program and Abstracts

Thursday, Aug 25

0900-1015 Session 16B **Invited talk**

Ronald de Wolf:
On Linear and Semidefinite Programs for Polytopes in Combinatorial Optimization

1015-1035 Break

1035-1125 Session 17B

Khaled Elbassioni, Kazuhisa Makino and Waleed Najy:
A Multiplicative Weights Update Algorithm for Packing and Covering

George Rabanca and Amotz Bar-Noy:
Tight Approximation Bounds for the Seminar Assignment Problem

1130-1230 EATCS-IPEC

1230-1400 Lunch

1400-1515 Session 18B

Martijn van Ee, Leo van Iersel, Teun Janssen and Rene Sitters:
A Priori TSP in the Scenario Model

Yossi Azar and Adi Vardi:
Dynamic Traveling Repair Problem with an Arbitrary Time Window

Esther Arkin, Jie Gao, Adam Hesterberg, Joseph Mitchell and Jiemin Zeng:
The Shortest Separating Cycle Problem

1515-1530 Break

1530-1645 Session 19B

Joan Boyar, Leah Epstein, Lene Favrholdt, Kim S. Larsen and Asaf Levin: Batch Coloring of Graphs

Roy B. Ofer and Tami Tamir: Resource Allocation Games with Multiple Resource Classes

Jean-Claude Bermond, Nathann Cohen, David Coudert, Dimitrios Letsios, Ioannis Milis, Stéphane Pérennes and Vassilis Zissimopoulos:
Bin Packing with Colocations

1645-1700 Break

1700-1815 Session 20B

Gramoz Goranci and Harald Räcke:
Vertex Sparsification in Trees

Felix J. L. Willamowski and Andreas Bley:
Local Search Based Approximation Algorithms for Two-Stage Stochastic Location Problems

Akira Matsubayashi:
Non-Greedy Online Steiner Trees on Outerplanar Graphs

Friday, Aug 26

0900-1015 Session 21B

Annette M.C. Ficker, Frits C.R. Spieksma and Gerhard J. Woeginger:
Balanced Optimization with Vector Costs

Nathaniel Grammel, Lisa Hellerstein, Devorah Kletenik and Patrick Lin:
Scenario Submodular Cover

Parinya Chalermsook and Daniel Vaz:
New Integrality Gap Results for the Firefighters Problem on Trees

1015-1035 Break

1035-1125 Session 22B

André Berger, Alexander Grigoriev and Andrej Winokurow:
A PTAS for the Cluster Editing Problem on Planar Graphs

N.S. Narayanaswamy and Astha Chauhan:
A Refined Analysis of Online Path Coloring in Trees

1130-1230 **Invited Talk**

Marek Cygan:
Approximation Algorithms for the k-Set Packing Problem.

1230-1400 Lunch

WAOA 2016 Invited Talks

RONALD DE WOLF

Bio
Ronald de Wolf is a senior researcher at CWI and full professor at the University of Amsterdam. He obtained his PhD in 2001, advised by Harry Buhrman and Paul Vitanyi, and subsequently spent a year at Berkeley. He works on quantum computing, focusing on algorithms, complexity theory, and the applications of quantum information to other areas. His main results include lower bounds on quantum algorithms, new separations between quantum and classical communication protocols, and lower bounds on linear programs for polytopes in combinatorial optimization.

Title

On linear and semidefinite programs for polytopes in combinatorial optimization

Abstract

Combinatorial problems like TSP optimize a linear function over some polytope P. If we can obtain P as a projection from a larger-dimensional polytope with a small number of facets, then we get a small linear program for the optimization problem; if we obtain P as a projection from a small spectrahedron, then we get a small semidefinite program. The area of extension complexity studies the minimum sizes of such LPs and SDPs. In the 1980s Yannakakis was the first to do this, proving exponential lower bounds on the size of symmetric LPs for the TSP and matching polytopes. In 2012, Fiorini et al. proved exponential lower bounds on the size of all (possibly non-symmetric) LPs for TSP. This was followed by many new results for LPs and SDPs, for exact optimization as well as for approximation. We will survey this recent line of work.

MAREK CYGAN

Bio
Marek Cygan has obtained his PhD degree in Computer Science at the Institute of Informatics, University of Warsaw, Poland in 2012. After being a researcher at the University of Maryland and a post-doc in IDSIA, Lugano, he returned to the University of Warsaw, where he currently is an assistant professor. Marek Cygan works in various branches of algorithmics, with main focus on parameterized complexity and approximation algorithms.

Title

Approximation algorithms for the k-Set Packing problem

Abstract

In the k-Set Packing problem we are given a universe and a family of its subsets, where each of the subsets has size at most k. The goal is to select a maximum number of sets from the family which are pairwise disjoint. It is a well known NP-hard problem, that has been studied from the approximation perspective since the 80's. During the talk I will describe the history of progress on both the weighted and unweighted variants of the problem, with an exposition of methods used to obtain the best known approximation algorithms mostly involving local search based routines.

WAOA 2016 ABSTRACTS

A Multiplicative Weights Update Algorithm for Packing and Covering

Khaled Elbassioni, Kazuhisa Makino and Waleed Najy

We consider the following semi-infinite linear programming problems: max (resp., min $c^T x$ s.t. $y^T A_i x+(d^i)^T x \leq b_i$ (resp., $y^T A_i x+(d^i)^T x \geq b_i$), for all $y \in Y_i$, for $i=1,...,N$, where $Y_i \subseteq \mathbb{R}_+^{m_i}$ are given compact convex sets and $A_i \in \mathbb{R}_+^{m_i \times n}$, $b=(b_1,...,b_N) \in \mathbb{R}_+^N$, $d_i \in \mathbb{R}_+^n$, and $c \in \mathbb{R}_+^n$ are given non-negative matrices and vectors. This general framework is useful in modeling many interesting problems. For example, it can be used to represent a sub-class of Robust Optimization in which the coefficients of the constraints are drawn from convex uncertainty sets Y_i, and the goal is to optimize the objective function for the worst-case choice in each Y_i. When the uncertainty sets Y_i are ellipsoids, we obtain a sub-class of Second-Order Cone Programming. We show how to extend the multiplicative weights update method to derive approximation schemes for the above packing and covering problems. When the sets Y_i are simple, such as ellipsoids or boxes, this yields substantial improvements in the running time over general convex programming solvers.

Tight Approximation Bounds for the Seminar Assignment Problem

George Rabanca and Amotz Bar-Noy

The seminar assignment problem is a variant of the generalized assignment problem in which items have unit size and the space used in each bin is restricted to be either zero, or within a certain interval. The problem has been shown to be NP-complete and to not admit a PTAS. Moreover, the only constant factor approximation algorithm known to date is randomized and it's not guaranteed to produce a feasible solution.
In this paper we show that unless P = NP, the problem cannot be approximated in polynomial time within $1 - 1/e + \varepsilon$ for any $\varepsilon > 0$ even in very restricted settings. Moreover, we show that this bound is tight by proving that a natural greedy algorithm outputs a solution that is guaranteed to be within a factor of $1 - 1/e$ of the optimal solution.

A Priori TSP in the Scenario Model

Martijn van Ee, Leo van Iersel, Teun Janssen and Rene Sitters

In this paper, we consider the a priori traveling salesman problem (TSP) in the scenario model. In this problem, we are given a list of subsets of the vertices, called scenarios, along with a probability for each scenario. Given a tour on all vertices, the resulting tour for a given scenario is obtained by restricting the solution to the vertices of the scenario. The goal is to find a tour on all vertices that minimizes the

expected length of the resulting restricted tour. We show that this problem is already NP-hard and APX-hard when all scenarios have size four. On the positive side, we show that there exists a constant-factor approximation algorithm in three restricted cases: if the number of scenarios is fixed, if the number of missing vertices per scenario is bounded by a constant, and if the scenarios are nested. Finally, we discuss an elegant relation with an a priori minimum spanning tree problem.

Dynamic Traveling Repair Problem with an Arbitrary Time Window

Yossi Azar and Adi Vardi

We consider the online Dynamic Traveling Repair Problem (DTRP) with an arbitrary size time window. In this problem we receive a sequence of requests for service at nodes in a metric space and a time window for each request.
The goal is to maximize the number of requests served during their time window. The time to traverse between two points is equal to the distance. Serving a request requires unit time. Irani et al., SODA 2002 considered the special case of a fixed size time window. In contrast, we consider the general case of an arbitrary size time window. We characterize the competitive ratio for each metric space separately. The competitive ratio depends on the relation between the minimum laxity (the minimum length of a time window) and the diameter of the metric space. Specifically, there exists a constant competitive algorithm only when the laxity is larger than the diameter. In addition, we characterize the rate of convergence of the competitive ratio, which approaches 1, as the laxity increases. Specifically, we provide matching lower and upper bounds. These bounds depend on the ratio between the laxity and the optimal TSP solution of the metric space (the minimum distance to traverse all nodes). An application of our result improves the previously known lower bound for colored packets with transition costs and matches the known upper bound. In proving our lower bounds we use an embedding with some special properties.

The Shortest Separating Cycle Problem

Esther Arkin, Jie Gao, Adam Hesterberg, Joseph Mitchell and Jiemin Zeng

Given a set of pairs of points in the plane, the goal of the shortest separating cycle problem is to find a simple tour of minimum length that separates the two points of each pair to different sides. In this article we prove hardness of the problem and provide approximation algorithms under various settings. Assuming the Unique Games Conjecture, the problem cannot be approximated within a factor of 2. We provide a polynomial algorithm when all pairs are unit length apart with horizontal orientation inside a square board of size $2-\varepsilon$. We provide constant approximation algorithms for unit length horizontal or vertical pairs or constant length pairs on points laying on a grid. For pairs with no restriction we have an O(sqrt(n))-approximation algorithm and an O(log n)-approximation algorithm for the shortest separating planar graph.

Batch Coloring of Graphs

Joan Boyar, Leah Epstein, Lene Favrholdt, Kim S. Larsen and Asaf Levin

In graph coloring problems, the goal is to assign a positive integer color to each vertex of an input graph such that adjacent vertices do not receive the same color assignment. For classic graph coloring, the goal is to minimize the maximum color used, and for the sum coloring problem, the goal is to minimize the sum of colors assigned to all input vertices. In the offline variant, the entire graph is presented at once, and in online problems, one vertex is presented for coloring at each time, and the only information is the identity of its neighbors among previously known vertices. In batched graph coloring, vertices are presented in k batches, for a fixed integer $k \geq 2$, such that the vertices of a batch are presented as a set, and must be colored before the vertices of the next batch are presented. This last model is an intermediate model, which bridges between the two extreme scenarios of the online and offline models. We provide several results, including a general result for sum coloring and results for the classic graph coloring problem on restricted graph classes: We show tight bounds for any graph class containing trees as a subclass (e.g., forests, bipartite graphs, planar graphs, and perfect graphs), and a surprising result for interval graphs and $k = 2$, where the value of the (strict and asymptotic) competitive ratio depends on whether the graph is presented with its interval representation or not.

Resource Allocation Games with Multiple Resource Classes

Roy B. Ofer and Tami Tamir

We define and study a resource-allocation game, arising in Media on Demand (MoD) systems where users correspond to self-interested players who choose a MoD server. A server provides both storage and broadcasting needs. Accordingly, the user's cost function encompasses both positive and negative congestion effects. A system in our model consists of m identical servers and n users. Each user is associated with a type (class) and should be serviced by a single server. Each user generates one unit of load on the server it is assigned to. The load on the server constitutes one component of the user's cost. In addition, the service requires an access to an additional resource whose activation-cost is equally shared by all the users *of the same class* that are assigned to the same server. In MoD systems, the bandwidth required for transmitting a certain media-file corresponds to one unit of load. The storage cost of a media-file on a server is shared by the users requiring its transmission that are serviced by the server. We provide results with respect to equilibrium existence, computation, convergence and quality. We show that a pure Nash Equilibrium (NE) always exists and best-response dynamics converge in polynomial time. The equilibrium inefficiency is analyzed with respect to the objective of minimizing the maximal cost. We prove that the Price of Anarchy is bounded by m and by the size of the smallest class and that these bounds are tight and almost tight, respectively. For the Price of Stability we show an upper bound of 2, and a lower bound of $2-1/m$. The upper bound is proved by introducing an efficient 2-approximation algorithm for calculating a NE. For two servers we show a tight bound of 3/2.

Bin Packing with Colocations

Jean-Claude Bermond, Nathann Cohen, David Coudert, Dimitrios Letsios, Ioannis Milis, Stéphane Pérennes and Vassilis Zissimopoulos

Motivated by the work of [Afrati, Dolev, Korach, Sharma and Ullman 2015] on an assignment problem in MapReduce computations, we investigate a generalization of the Bin Packing problem which we call the *Bin Packing with Colocations Problem* (BPCP). Given a set of n items with positive integer weights, an underlying graph G = (V,E), and a capacity q, the goal is to pack the vertices into a minimum number of bins so that (i) the total weight of the items packed in every bin is at most q, and (ii) for each edge (i,j) ∈E there is at least one bin containing both items i and j.

In this paper, we first show that when all the vertices have equal weights, the problem is equivalent to the q-clique problem, and when furthermore the underlying graph is a clique, optimal solutions are obtained from covering designs. After proving that the problem is strongly NP-hard even for weighted paths and unweighted trees, we propose approximation algorithms for particular families of graphs, including: a (3+sqrt(5))-approximate algorithm for weighted complete graphs (improving a previous 8-approximation), a 2-approximate algorithm for weighted paths, a 5-approximate algorithm for weighted trees, and a (1+ε)-approximate algorithm for unweighted trees. For general weighted graphs, we propose a 3+⌈mad(G)/2⌉-approximate algorithm, where mad(G) is the maximum average degree of G. Finally, we show how to convert any ρ-approximation for the k-dense subgraph problem or for bin packing into approximations for BPCP.

Vertex Sparsification in Trees

Gramoz Goranci and Harald Räcke

Given a tree T=(V,E) with terminals K ⊂ V, we show how to obtain a 2-quality vertex flow and cut sparsifier H with V_H = K. We prove that our result is essentially tight by providing a 2-o(1) lower-bound on the quality of any cut sparsifier for stars. In addition we give improved results for quasi-bipartite graphs. First, we show how to obtain a 2-quality flow sparsifier with V_H = K for such graphs. We then consider the other extreme and construct exact sparsifiers of size $O(2^k)$.

Local Search Based Approximation Algorithms for Two-Stage Stochastic Location Problems

Felix J. L. Willamowski and Andreas Bley

We present a nested local search approximation algorithm for variants of the metric two-stage stochastic uncapacitated facility location (tsUFL) problem. The problems are generalizations of the well-studied metric UFL problem, taking uncertainties in demand values and costs into account. The proposed nested local search procedure uses three facility operations: adding, dropping, and swapping. To the best of our knowledge,

this is the first constant-factor local search approximation algorithm for two-stage stochastic facility location problems.
Beside the traditional assignments directly from clients to facilities, we investigate connections via capacitated trees and tours. We obtain the first constant-factor approximation algorithms for both connection types in the setting of two-stage stochastic optimization. Our algorithms also admit order-preserving metrics, which significantly generalize and improve the allowed mutability of the metric in contrast to previous algorithms, only allowing scenario-dependent inflation factors.

Non-Greedy Online Steiner Trees on Outerplanar Graphs

Akira Matsubayashi

This paper addresses the classical online Steiner tree problem on edge-weighted graphs. It is known that a greedy (nearest neighbor) online algorithm has a tight competitive ratio for wide classes of graphs, such as trees, rings, any class including series-parallel graphs, and unweighted graphs with bounded diameter. However, we did not know any greedy or non-greedy tight deterministic algorithm for other classes of graphs. In this paper, we observe that a greedy algorithm is $\Omega(\log n)$-competitive on outerplanar graphs, where n is the number of vertices, and propose a 5.828-competitive deterministic algorithm on outerplanar graphs. Our algorithm is non-greedy and connects a requested vertex and the tree constructed thus far using a path that is constant times longer than the distance between them. The algorithm can be applied to a 21.752-competitive file allocation algorithm against adaptive online adversaries on outerplanar graphs. We also present a lower bound of 4 for arbitrary deterministic online Steiner tree algorithms on outerplanar graphs.

Balanced Optimization with Vector Costs

Annette M.C. Ficker, Frits C.R. Spieksma and Gerhard J. Woeginger

An instance of a balanced optimization problem with vector costs consists of a ground set X, a vector cost for every element of X, and a system of feasible subsets over X. The goal is to find a feasible subset that minimizes the spread (or imbalance) of values in every coordinate of the underlying vector costs.
We investigate the complexity and approximability of balanced optimization problems in a fairly general setting. We identify a large family of problems that admit a 2-approximation in polynomial time, and we show that for many problems in this family this approximation factor 2 is best-possible (unless P = NP).
Special attention is paid to the balanced assignment problem with vector costs, which is shown to be NP-hard even in the highly restricted case of sum costs.

Scenario Submodular Cover

Nathaniel Grammel, Lisa Hellerstein, Devorah Kletenik and Patrick Lin

Many problems in Machine Learning can be modeled as submodular optimization problems. We introduce the Scenario Submodular Cover problem. In this problem, the goal is to produce a cover with minimum expected cost, with respect to an empirical joint distribution, given as input by a weighted sample of realizations. The problem is a counterpart to the Stochastic Submodular Cover problem studied by Golovin and Krause [8], which assumes independent variables. We give two approximation algorithms for Scenario Submodular Cover. Assuming an integer-valued utility function and integer weights, the first achieves an approximation factor of O(log Qm), where m is the sample size and Q is the goal utility. The second, simpler algorithm achieves an approximation factor of O(log QW), where W is the sum of the weights. We our bounds by building on approaches from previous related work (in [6,8,16]) and by exploiting a simple but useful technique we call the Scenario- OR modification. We apply these algorithms to a new problem, Scenario Boolean Function Evaluation. Our results yield approximation bounds for other problems involving non-independent distributions that are explicitly specified by their support.

New Integrality Gap Results for the Firefighters Problem on Trees

Parinya Chalermsook and Daniel Vaz

In the firefighter problem on trees, we are given a tree G = (V,E) together with a vertex s in V where the fire starts spreading. At each time step, the firefighters can pick one vertex while the fire spreads from burning vertices to all their neighbors that have not been picked. The process stops when the fire can no longer spread. The objective is to find a strategy that maximizes the total number of vertices that do not burn. This is a simple mathematical model, introduced in 1995, that abstracts the spreading nature of, for instance, fire, viruses, and ideas. The firefighter problem is NP-hard and admits a (1-1/e)-approximation based on rounding the canonical LP. Recently, a PTAS was announced [Adjiashvili et al].

The goal of this paper is to develop better understanding on the power of LP relaxations for the firefighter problem. We first show a matching lower bound of $(1 - 1/e + \varepsilon)$ on the integrality gap of the canonical LP. This result relies on a powerful combinatorial gadget that can be used to derive integrality gap results in other related settings. Next, we consider the canonical LP augmented with simple additional constraints (as suggested by Hartke). We provide several evidences that these constraints improve the integrality gap of the canonical LP: (i) Extreme points of the new LP are integral for some known tractable instances and (ii) A natural family of instances that are bad for the canonical LP admits an improved approximation algorithm via the new LP. We conclude by presenting a 5/6 integrality gap instance for the new LP.

A PTAS for the Cluster Editing Problem on Planar Graphs

André Berger, Alexander Grigoriev and Andrej Winokurow

The goal of the cluster editing problem is to add or delete a minimum number of edges from a given graph, so that the resulting graph becomes a union of disjoint cliques. The cluster editing problem is closely related to correlation clustering and has applications, e.g. in image segmentation. For general graphs this problem is APX-hard. In this paper we present a polynomial time approximation scheme for the cluster editing problem on graphs with few edge crossings, e.g. for planar graphs. The running time of this algorithm is $O(2^{1/\varepsilon \cdot \log (1/\varepsilon)} n)$ for planar graphs and $O(2^{k^6 \cdot (1/\varepsilon)^3} n)$ for k-planar graphs.

A Refined Analysis of Online Path Coloring in Trees

N.S. Narayanaswamy and Astha Chauhan

Our results are on the online version of path coloring in trees where, each request is a path to be colored online, and two paths that share an edge must get different colors. For each T, we come up with a hierarchical partitioning of its edges with a minimum number of parts, denoted by h(T), and design an O(h(T))-competitive online algorithm. We then use the lower bound technique of Bartal and Leonardi [1] along with a structural property of the hierarchical partitioning, to show a lower bound of $\Omega(h(T)/\log(4h(T)))$ for each tree T on the competitive ratio of any deterministic online algorithm for the problem. This gives us an insight into online coloring of paths on each tree T, whereas the current lower bound results are known only for special trees like paths and complete binary trees.