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Preface

We are very pleased to present this special issue which brings the papers presented to the XI Latin and American Algorithms, Graphs and Optimization Symposium (LAGOS 2021). We had planned and hoped to run the conference in May 2021, in São Paulo, Brazil. Unfortunately due to the ongoing situation of COVID-19 pandemic, we had to settle for an online event as many others since 2020.

LAGOS is the result of the union of two former conferences: the Brazilian Symposium on Graphs, Algorithms and Combinatorics (GRACO) and the Latin American Conference on Combinatorics, Graphs and Applications (LACGA). Previous editions of LAGOS took place in Fortaleza, Brazil (GRACO 2001), Santiago, Chile (LACGA 2004), Angra dos Reis, Brazil (GRACO 2005), Puerto Varas, Chile (LAGOS 2007), Gramado, Brazil (LAGOS 2009), Bariloche, Argentina (LAGOS 2011), Playa del Carmen, Mexico (LAGOS 2013), Fortaleza, Brazil (LAGOS 2015), Marseille, France (LAGOS 2017) and Belo Horizonte, Brazil (2019).

In this edition we received 116 submissions from around the world. Each submission was reviewed by three Program Committee members, often with the help of additional external referees. By the end of the reviewing process, the Program Committee selected 59 submissions.

We are delighted that the following distinguished speakers accepted our invitation to give a plenary lecture at LAGOS 2021: José Correa (University of Chile), Martin Grötschel (Berlin-Brandenburg Academy of Sciences and Humanities), Silvano Martello (University of Bologna), Joseph Mitchell (Stony Brook University), Kirk Pruhs (University of Pittsburgh), Laura Sanità (University of Waterloo), Jayme Szwarcfiter (Universidade Federal do Rio de Janeiro), Eduardo Uchoa (Universidade Federal Fluminense), Kristina Vušković (University of Leeds), and Xingxing Yu (Georgia Institute of Technology). Furthermore, Marcel Kenji de Carli Silva (University of São Paulo) kindly accepted to give a course on Semidefinite Programming at LAGOS 2021. We would like to thank all the speakers for accepting to support LAGOS 2021.

We are grateful to the Steering Committee, for their guidance and invaluable advice, to the Program Committee members, for the insightful discussions and evaluations to select the papers presented at the conference, and to the subreferees for their careful reports. We have an additional thanks to Celina de Figueiredo, who helped us with some papers that we could not take care.

LAGOS 2021 was also a great opportunity to honor Professor Yoshiko Wakabayashi. She has been an inspiring person who has influenced the research and career of many academics in Latin America in the path of algorithms, graph theory, and optimization, the main topics of this event.

For the first time LAGOS awarded prizes for the best papers of the conference. The Best Paper Award Committee was composed by Flavia Bonomo, Eduardo Moreno, and Alfredo Viola. The awardees are the following: The Best Paper Award was conferred to *Codegree conditions for cycle decompositions and Euler tours in 3-uniform hypergraphs*, by Simón Piga and Nicolás Sanhueza-Matamala. The 2nd place Best Paper Award was conferred to *An approximate blow-up lemma for sparse hypergraphs*, by Peter Allen, Julia Böttcher, Ewan Davies, Eng Keat Hng, and Jozef Skokan. The 3rd place Best Paper Award was conferred to *The chromatic index of split-interval graphs*, by Luis Gonzaga, Sheila Almeida, Cândida da Silva and Jadder Cruz.

We would like to thank FAPESP for their financial support.

Finally, this could not be done without the help of Carla N. Lintzmayer, Guilherme O. Mota and the organizing team. Our deepest thanks to all of them for their support. In the following, we list the plenary talks, the minicourse, and the composition of the scientific and organizing committees involved in the LAGOS 2021 conference.

May 2021

Carlos Ferreira
Orlando Lee
Flávio Miyazawa

Peer-review under responsibility of the scientific committee of the XI Latin and American Algorithms, Graphs and Optimization Symposium
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Plenary Talks

Prophet Inequalities from Sampled Data

Jose R. Correa
Universidad de Chile, Chile

Abstract. Prophet inequalities provide an idealized ground to study online decision making problems under stochastic input. The basic idea is to design good stopping rules for a given problem whose reward is, in expectation, close to what a prophet, that can foresee the whole instance of the problem in advance, can get. The area of prophet inequalities was very active in the probability theory community in the 70's and 80's. Then it took a two-decade nap, until about 10 years ago, when regained interest arouse because of its connections to posted price mechanisms and other problems. In this talk I will review some of these recent results and will discuss new variants of the problem in which the distributional information is replaced by the availability of samples taken from the input.

Digital Humanities: A New Application Area for Mathematics and Computer Science?

Martin Grötschel
Berlin-Brandenburg Academy of Sciences and Humanities

Abstract. The term Digital Humanities (briefly DH), coined just about a dozen years ago, is used to describe efforts aimed at supporting research (and teaching) in the humanities (and the social sciences) by employing tools and methods from information technology, computer science and mathematics. DH is developing in many directions, but despite some hype and significant media coverage, DH is still in its infancy. The current DH situation resembles the early days of Operations Research (OR), also a field in the interface of many other disciplines, where – even after 30 years of theory development since the 1950s – it was still unclear whether OR can ever be utilized successfully in industry and society.

Standard statistical analysis has a long tradition in various branches of the humanities, and the usual IT-tools are frequently employed as well. In my lecture I will address the issue how graph theory, optimization and other OR tools can support DH, i.e., which modeling approaches and solution techniques of Operations Research can be successfully employed in Digital Humanities. I will describe, in particular, some of the efforts (still rudimentary) made in this direction at the Berlin-Brandenburg Academy of Sciences and Humanities with a special focus linguistics, archeology, and on the edition of manuscripts (of famous scientists such as Leibniz, Alexander von Humboldt, Kant,...).

At the Roots of Combinatorial Optimization

Silvano Martello
Alma Mater Studiorum Università di Bologna, Italy

Abstract. The Fifties are the "official" birth years of Combinatorial Optimization. Our tour starts with the first modern polynomial-time algorithm for the assignment problem, invented by Kuhn in 1955. It was christened the "Hungarian method" to acknowledge its origin from older results obtained by two Hungarian mathematicians: Dénes Kőnig in 1916 and Jenő Egerváry in 1931. We next show that a number of other famous algorithms of the Fifties (for spanning trees, shortest paths, maximum flows,...) were independent re-discoveries of results obtained by central European mathematicians in the Thirties. We discuss the results and the complicated lives of Kőnig and Egerváry, as well as an old related result by Jacob Jacobi. We conclude our tour with a combinatorial optimization problem, independently defined in satellite communication and in scheduling theory, for which various modern authors discovered and rediscovered the same polynomial-time algorithm. We show that, again, such algorithm directly implements another result from the Thirties, which also implies the famous Birkhoff-von Neumann theorem.

Approximation Algorithms for Some Geometric Packing/Covering/Routing Problems

Joseph S. B. Mitchell
State University of New York at Stony Brook

Abstract. A fundamental class of combinatorial optimization problems involve packing and covering. Examples include maximum independent set, dominating set, set cover, hitting set, etc. Motivated by applications in sensor networks and robotics, natural instances of such problems arise in geometric situations, such as covering points with a small number of disks, viewing "art galleries" with a small number of guards or with a mobile guard on a short route, packing disks or other shapes within a bounded domain, etc. Almost all of these problems are NP-hard even in simple two-dimensional settings. The problems get even harder when we take into account uncertain data, time constraints for scheduled coverage, and routing/connectivity problems in combination with coverage constraints. We discuss several of these geometric optimization problems from the perspective of approximation algorithms and we describe some techniques that have led to new or improved bounds or running times for selected packing, covering, and routing/coverage problems.

Algorithms for Relational Machine Learning

Kirk Pruhs
University of Pittsburgh, USA

Abstract. The current standard practice for a data scientist, confronted with a machine learning task on relational data, is to issue a feature extraction query to extract the (carefully curated) data from a relational database by joining together multiple tables to materialize a design matrix, and then to import this design matrix into some machine learning tool to train the model. This standard practice is wasteful because computing relational joins is computationally expensive. In particular, The resulting design matrix will likely contain much redundant information and be significantly larger than the original tables (exponentially larger in the worst-case). Thus, conceptually this standard practice seems unnecessarily inefficient.

I will discuss our nascent efforts to develop "relational algorithms" for common machine learning problems. Informally a "relational algorithm" is one that works directly on the relational data, without forming the design matrix, and that is much faster than standard practice. Further I will discuss our current understanding of which algorithmic problems can be efficiently solved if the input is in relational form.

On the Hardness of Computing the Diameter of a Polytope

Laura Sanità
University of Waterloo, Canada/Eindhoven University of Technology, Netherlands

Abstract. The diameter of a polytope P is the maximum length of a shortest path between a pair of vertices on the 1-skeleton of P, which is the graph where the vertices correspond to the 0-dimensional faces of P, and the edges are given by the 1-dimensional faces of P. Despite decades of studies, it is still not known whether the diameter of a d-dimensional polytope with n facets can be bounded by a polynomial function of n and d. This is a fundamental open question in discrete mathematics, motivated by the (still unknown) existence of a polynomial pivot rule for the Simplex method for solving Linear Programs. In this talk, I will discuss algorithmic and complexity results related to the diameter of polytopes, highlighting some important open questions.

On Helly Numbers of Graphs and Hypergraphs

Jayme L. Szwarcfiter
Universidade Federal do Rio de Janeiro, Brazil

Abstract. Let $\mathcal{F}$ be a family of subsets of some universal set U, and h an integer ≥ 1. Say that $\mathcal{F}$ is *h-intersecting* when every h sets of $\mathcal{F}$ intersect. The core of $\mathcal{F}$ is the intersection of all sets of $\mathcal{F}$, denoted $core(\mathcal{F})$. The family $\mathcal{F}$ is *h-Helly* when every h-intersecting subfamily $\mathcal{F}'$ of it satisfies $core(\mathcal{F}') \neq \emptyset$. Finally, the *Helly number* of the family $\mathcal{F}$ is the least integer h such that $\mathcal{F}$ is h-Helly. The Helly number has been introduced about 100 years ago. It has been studied for some different families of subsets, with focus in some of its distinct aspects, algebraic, geometric, algorithmic. The Helly number has applications to problems originated from some different areas. In this talk, we will describe results related to the determination of this parameter. We concentrate on families of vertices or edges of a graph. Special emphasis will be given to families of paths on a grid.

Advances in Exact Algorithms for Vehicle Routing

Eduardo Uchoa
Universidade Federal Fluminense, Brazil

Abstract. The Vehicle Routing Problem (VRP) is among the most widely studied problems in the fields of operations research and combinatorial optimization. Its relevance stems from its direct application in the real world systems that distribute goods and provide services, vital to the modern economies. Reflecting the large variety of conditions present in those systems, the VRP literature is spread into dozens of variants. For example, there are variants that consider time windows, multiple depots, mixed vehicle fleet, split deliveries, pickups and deliveries, precedences, etc. The currently best exact VRP algorithms are based on the combination of column generation and cut separation, in the so called Branch-Cut-and-Price (BCP) algorithms. This talk surveys significant recent contributions by several authors. In particular, it presents the concept of cuts with limited-memory (Pecin *et al.* 2014), a technique that represented a breakthrough on some of the most classical VRP variants, allowing the optimal solution of instances with up to a few hundreds points. The talk also presents VRPSolver, a generic exact VRP framework that obtains state-of-the-art performance in dozens of variants.

Even-hole-free Graphs with Bounded Degree

Kristina Vušković
University of Leeds, United Kingdom

Abstract. The class of even-hole-free graphs (i.e. graphs that do not contain a chordless cycle of even length as an induced subgraph) has been studied since the 1990's, initially motivated by their structural similarity to perfect graphs. It is known for example that they can be decomposed by star cutsets and 2-joins into algorithmically well understood subclasses, which has led to, for example, their polynomial time recognition. Nevertheless, the complexity of a number of classical computational problems remain open for this class, such as the coloring and stable set problems.

In this talk we show that even-hole-free graphs with bounded degree have bounded treewidth (a result obtained in joint work with Abrishami and Chudnovsky), which implies that many algorithmic problems can be solved in polynomial time for this class.

Treewidth is a parameter that emerged out of the study of minor closed classes of graphs (i.e. classes closed under vertex and edge deletion, and edge contraction). It in some sense describes the global structure of a graph. Roughly, a graph has treewidth k if it can be decomposed by a sequence of noncrossing cutsets of size at most k into pieces of size at most $k + 1$. The study of hereditary graph classes (i.e. those closed under vertex deletion only) reveals a different picture, where cutsets that are not necessarily bounded in size (such as star cutsets, 2-joins and their generalization) are required to decompose the graph into simpler pieces that are structured but not necessarily bounded in size. A number of such decomposition theorems are known for complex hereditary graph classes, including for even-hole-free graphs, perfect graphs and others. They do not describe the global structure in the sense that a tree decomposition does, since the cutsets guaranteed by these decomposition theorems are far from being noncrossing. In the case of even-hole-free graphs of bounded degree we show how these cutsets can be partitioned into a bounded number of well-behaved collections, which allows us to bound the treewidth of such graphs.

Problems and Results Related to the Four Color Theorem

Xingxing Yu
Georgia Institute of Technology, USA

Abstract. The Four Color Theorem states that planar graphs are 4-colorable. Planar graphs are precisely the graphs that contain no subdivision of K_5 or $K_{3,3}$. Are graphs containing no subdivision of K_5 also 4-colorable? This was conjectured by Hajós in 1950s. We will discuss progress on this conjecture, as well as related problems about graph structures. We will also discuss problems about cycles in graphs that are partially motivated by the Four Color Theorem.

Minicourse

Some Discrete Aspects of Semidefinite Programming

Marcel K. de Carli Silva
Universidade de São Paulo, Brazil

Abstract. This minicourse is aimed at grad students in graph theory and/or combinatorial optimization, with little to no previous exposure to semidefinite programming. I intend to cover some basics of SDP formulations for discrete problems, e.g., the vector chromatic number.

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