São Paulo School of Advanced Science on Algorithms, Combinatorics and Optimization

July 18 to 29, 2016

Relatório Científico

São Paulo School of Advanced Science on Algorithms, Combinatorics and Optimization

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Responsável: Yoshiko Wakabayashi

Unidade: IME-USP

RELATÓRIO CIENTÍFICO

SÃO PAULO SCHOOL OF ADVANCED SCIENCE ON ALGORITHMS, COMBINATORICS AND OPTIMIZATION

Sumário

1. Introdução

O **São Paulo School of Advanced Science on Algorithms, Combinatorics and Optimization (SPAS-ACO)** foi realizada no período de 18 a 29 de julho de 2016 na USP. Foi organizada por membros do Grupo de Teoria da Computação, Combinatória e Otimização do Departamento de Ciência da Computação do IME-USP.

Nessa Escola, foram oferecidos 11 cursos, todos de nível avançado, e proferidas 6 palestras em tópicos relevantes e de ponta nas áreas de algoritmos, combinatória e otimização. Mais informações sobre a Escola podem ser encontradas em: `http://sp-school2016.ime.usp.br`

Na proposta original que apresentamos à FAPESP, previmos a aceitação de cerca de 90 participantes. Tendo porém recebido inscrições de 238 candidatos de 31 países, a maioria de excelente formação, solicitamos à FAPESP um aditivo para viabilizar a aceitação de mais candidatos do que o previsto. A FAPESP concedeu-nos um aditivo que nos permitiu aceitar 150 candidatos.

Dos candidatos inscritos, perto de 130 eram provenientes do exterior. Uma tabela contendo os dados a respeito dos candidatos é apresentada na Seção 7. Para se inscreverem (para serem aceitos e/ou obterem auxílio financeiro), os candidatos tiveram que enviar um CV, histórico escolar, breve resumo da pesquisa em andamento, carta de recomendação e justificativa sobre a importância da Escola para sua formação. Uma comissão composta de 3 professores da Comissão Organizadora selecionou os candidatos.

2. Membros da comissão organizadora

Yoshiko Wakabayashi, USP (coordenadora)
Carlos Eduardo Ferreira, USP (vice-coordenador)
Marcel Kenji de Carli Silva, USP (vice-coordenador)
Arnaldo Mandel, USP
Cristina Gomes Fernandes, USP
José Coelho de Pina Jr, USP
Sinai Robins, USP
Yoshiharu Kohayakawa, USP
Guilherme Oliveira Mota, pós-doutorando USP
Gabriel Coutinho, pós-doutorando USP
Roberto Freitas Parente, doutorando USP

Além da equipe acima, os seguintes alunos de doutorado ou mestrado do IME-USP ajudaram na organização da Escola: Fábio Happ Botler, Rafael Santos Coelho, Renzo Gómez, Fabrício Caluza Machado, Giulia Satiko Maesaka e Henrique Stagni.

3. Atividades realizadas

Detalhamos a seguir os 11 cursos oferecidos e as 6 palestras que foram proferidas na Escola. Indicamos também os ministrantes, todos pesquisadores de renome do exterior ou do Brasil.

Para acompanhar os cursos, os participantes receberam material de aula preparados pelos ministrantes, que foram disponibilizados a todos tanto na forma impressa quanto digital (na página da Escola).

Além dos cursos e das palestras foram realizadas oito *Sessões de pôsteres*, conforme as tabelas a seguir. Essas sessões foram extremamente produtivas: contaram com um expressivo número de participantes que mostraram grande interesse. Foram apresentados 55 pôsteres (uma média de 7 pôsteres por dia). No final de cada um desses dias cada participante indicou sua preferência, votando em no máximo dois dos pôsteres apresentados. A lista dos pôsteres com a indicação dos que receberam menção honrosa (com (*)) é apresentada na subseção 3.2. Além dessas atividades, foram oferecidas diariamente *aulas de exercícios*, durante as quais monitores deram assistência aos alunos.

Apresentamos a seguir o programa completo das duas semanas da Escola. Observamos que, além das atividades científicas, foram também previstas algumas atividades sociais. Os participantes avaliaram muito positivamente as atividades sociais (jantar do grupo; "Talent Show"– um show organizado pelos próprios alunos; aulas opcionais de forró e de capoeira), dizendo que estas contribuíram para integrar melhor os participantes. Os programas dos cursos e os resumos das palestras são dadas na Seção 6. Essas informações podem ser melhor visualizadas na página do evento: `http://sp-school2016.ime.usp.br`

3.1. **Cursos e palestras.**

SPSAS-ACO

São Paulo School of Advanced Science on Algorithms, Combinatorics and Optimization

First Week – July 18–22, 2016

Time	Monday 18	Tuesday 19	Wednesday 20	Thursday 21	Friday 22
8:00 – 9:15	R & O	—	—	—	—
9:00 – 10:00	Course 1	Course 4	Course 6	Course 5	Course 2
10:00 – 10:15	coffee	coffee	coffee	coffee	coffee
10:15 – 11:15	Course 2	Course 1	Course 5	Course 2	Talk 3
11:15 – 12:15	Course 4	Course 3	Talk 1	Course 6	Talk 3
12:15 – 13:30	lunch	lunch	lunch	lunch	lunch
13:30 – 14:30	Course 3	Course 2	Course 1	Course 1	Course 4
14:30 – 15:30	Course 5	Course 6	Course 4	Talk 2	Course 5
15:30 – 16:30	coffee & opening (16:00)	coffee & posters	coffee & posters	coffee & posters	coffee posters
16:30 – 17:30	opening	classwork	classwork	classwork	Course 6
17:30 – 18:30	music	classwork	classwork	classwork	classwork
19:30	–	(forró)	Dinner	–	–

R & O Registration and opening ceremony

Course 1 Eli Upfal, Brown University, USA
Sample complexity and uniform convergence

Course 2 Yoshiharu Kohayakawa, Universidade de São Paulo, Brazil
The regularity method and blow-up lemmas for sparse graphs

Course 3 Robert Kleinberg, Cornell University, USA
Combinatorial stochastic search and selection

Course 4 Cláudio L. Lucchesi, Universidade Federal do Mato Grosso do Sul, Brazil
The perfect matching polytope, solid bricks and the perfect matching lattice

Course 5 David Williamson, Cornell University, USA
Recent progress in approximation algorithms for the traveling salesman problem

Course 6 Sinai Robins, Universidade de São Paulo, Brazil
Harmonic analysis on polytopes and cones

Talks by: Jayme Szwarcfiter (UFRJ, Brazil) - Talk 1
Marcos Kiwi (Universidad de Chile) - Talk 2
Robert Kleinberg (Cornell University, USA) - Talk 3

SPSAS-ACO

São Paulo School of Advanced Science on Algorithms, Combinatorics and Optimization

Second Week – July 25–29, 2016

Time	Monday 25	Tuesday 26	Wednesday 27	Thursday 28	Friday 29
9:00 – 10:00	Course 7	Course 11	Course 9	Course 11	Course 9
10:00 – 10:15	coffee	coffee	coffee	coffee	coffee
10:15 – 11:15	Course 11	Course 9	Course 8	Course 9	Course 7
11:15– 12:15	Talk 4	Course 10	Course 10	Course 7	Talk 6
12:15 – 13:30	lunch	lunch	lunch	lunch	lunch
13:30 – 14:30	Course 9	Course 7	Course 11	–	
14:30 – 15:30	Course 8	Course 8	Talk 5	Course 8	
15:30 – 16:30	coffee+posters	coffee+posters	coffee+posters	coffee+posters	
16:30 – 17:30	classwork	classwork	classwork	classwork	
17:30 – 18:30	Talent Show	classwork	classwork	classwork	
19:30	–	(capoeira)	Dinner	–	

Course 7 Alexandr Kostochka, University of Illinois at Urbana-Champaign, USA
Coloring sparse graphs with few colors

Course 8 Rob Morris, IMPA, Brazil
The method of hypergraph containers

Course 9 Daniel Král, University of Warwick, UK
Graph limits and their applications in extremal combinatorics

Course 10 Flávio Keidi Miyazawa, Universidade Estadual de Campinas, Brazil
Geometric Packing

Course 11 Levent Tunçel, University of Waterloo, Canada
Semidefinite programming techniques in combinatorial optimization

Talks by: Bruce Reed (McGill University, Canada) - Talk 4 and Talk 5
Cid Carvalho de Souza (UNICAMP, Brazil) - Talk 6

3.2. **Pôsteres apresentados.**

- July 19
  - (*) Adam Wagner, University of Illinois at Urbana-Champaign, US; *Tutorial on the Container Method: A simple guide to solve (not so simple) problems*
  - Alberto Miranda, IFNMG, BR; *Pfaffian graphs*
  - Alexandre Abreu, UFRJ, BR; *Staggered Quantum Algorithm for Element Distinctness*

- Alvaro Franco, UFSC, BR; *A new kinship machine: characteristics, use and perspectives*
  - Ioannis Lamprou, University of Liverpool, UK; *Fast Two-Robot Disk Evacuation*
  - Raul Lopes, UFC, BR; *A Proof for a Conjecture of Gorgol*
  - (*) Yingjie Qian, McGill University, CA; *Teaching dimension, VC dimension and critical sets for Latin squares*
- July 20
  - (*) Frederik Garbe, University of Birmingham, UK; *Hamilton cycles in hypergraphs below the Dirac threshold*
  - Johanna Strömberg, Vanderbilt University, CA; *Multicoloured Containers and Graphon Entropy*
  - Lizeth Riascos-Alvarez, Universidad Autónoma de Nuevo León, MX; *The Kidney Exchange Problem*
  - (*) Richard Lang, Universidad de Chile, CL; *Chromatic index, treewidth and maximum degree*
  - Robert Aduviri Choque, PUC Peru, PE; *An Evolutionary Optimization Approach for Disaster Relief Supplies Distribution*
  - Veronica Moyano, Universidad de Buenos Aires, AR; *Solvable cases for the perfect edge domination problem*
- July 21
  - (*) Anton Bernshteyn, University of Illinois at Urbana-Champaign, US; *The asymptotic behavior of the correspondence chromatic number*
  - Dafne García de Armas, University of Havana, CU; *Route Selection Strategy applied to Heterogeneous and Multi-Compartment Vehicle Routing Problem*
  - David Narváez, Rochester Institute of Technology, US; *C5-Free k-Colorings of Complete Graphs*
  - (*) Liana Yepremyan, McGill University, CA; *The Local Stability Method and its applications: New Turán Numbers*
  - Julian Romero, University of Waterloo, CA; *Applied Hilbert s Nullstellensatz for Combinatorial Problems*
  - (*) Malgorzata Sulkowska, Wroc aw University of Technology, PL; *Best choice problem for powers of paths*
  - Omar Latorre Vilca, UFAM, BR; *An efficient algorithm for the Closest String Problem*
- July 22
  - (*) Andrea Visentin, University College Cork, IE; *Robust Principal Component Analysis by Reverse Iterative Linear Programming*
  - Daniel Rorabaugh, Queens University, CA'; *Densities of Unavoidable Words*
  - Gleb Nenashev, Stockholm University, SE; *"K-theoretic"analog of Postnikov-Shapiro algebra distinguishes graphs*
  - He Guo, Georgia Institute of Technology, US; *Maximum number of triangles in wheel-free graphs and its relation with Turán number of expansion of wheels in 3-graphs*
  - (*) Lucas de Oliveira Contiero, UFRGS, BR; *Advances in a Hypergraph Coloring Conjecture*

  - Pablo Terlisky, Universidad de Buenos Aires, AR; *Integrality of Minimal Circular Arc Models*
  - Yaqiao Li, McGill University, CA; *A characterization of functions with vanishing averages over products of disjoint sets*
- July 25
  - César Hernández Vélez, Universidad Autónoma de San Luis Potosí, MX; *Hamiltonian Cycles in the Matroid Basis Graph*
  - (*) Diego Delle Donne, Universidad Nacional de General Sarmiento, AR; *Polyhedral studies of vertex coloring problems*
  - Gabriel Sobral, UFPR, BR: *Study of k-biclique edge-choosability in some graph classes*
  - László Papp, Budapest University of Technology and Economics, HU; *Optimal pebbling number*
  - (*) Nicolás Sanhueza Matamala, University of Birmingham, UK; *Minimum codegree threshold for covering with tight cycles in k-uniform hypergraphs*
  - Sebastián Bustamante, Universidad de Chile, CL; *Monochromatic tree covers and Ramsey numbers for set-coloured graphs*
  - Victor Verdugo, École normale supérieure and University of Chile, CL; *SDP and LP integrality gaps for scheduling identical machines*
- July 26
  - Edin Husić, University of Primorska, SI; *Minimum conflict-free row split problem: a model for reconstructing perfect phylogeny*
  - Igor Carboni Oliveira, Charles University in Prague, CZ; *Circuit lower bounds from nontrivial learning algorithms*
  - Luís Doin, USP, BR; *Legitimate Coloring of Finite Projective Planes via Entropy Compression*
  - (*) Marko Savić, University of Novi Sad, SR; *Faster bottleneck non-crossing matchings of points in convex position*
  - (*) Natália Pedroza, UFRJ, BR; *Variable-length error correcting codes*
  - Santiago Viertel, UFPR, BR; *Compact routing schemes in complex networks*
  - (*) Yanina Lucarini, Universidad Nacional de Rosario, AR; *Polyhedra associated with identifying codes in graphs*
- July 27
  - Daniel Severin, Universidad Nacional de Rosario, AR; *The additive coloring problem on graphs*
  - Katherine Edwards, Princeton University, US; *Fast approximations for p-centres in δ-hyperbolic graphs*
  - Lilian Cavalet, UFRGS, BR; *Applying Spectral Graph Theory to classical extremal problems*
  - Murilo de Lima, UNICAMP, BR; *Online Network Leasing Problems*
  - Nikolai Karpov, Saint Petersburg Academic University, RU; *Parameterized Complexity of Secluded Connectivity Problems*
  - (*) Renan Pinto, UFRJ, BR; *The problem of covering solids by spheres of different radii*

  - (*) Ruth Luo, University of Illinois at Urbana Champaign, US; *A stability version for a theorem of Erdős on nonhamiltonian graphs*
- July 28
  - (*) Christopher Kusch, FU Berlin, DE; *Strong Ramsey Games: Drawing on an infinite board*
  - Diogo Braga, UFF, BR; *Combinatorial Optimization Models for Global Value Chains*
  - (*) Fiona Skerman, University of Oxford, UK; *Modularity of Random Graphs*
  - Guilherme Porto da Silva, UFRGS, BR; *The Sum of Signless Laplacian Eigenvalues of a Graph*
  - Jefferson Elbert Simões, UFRJ, BR; *Local symmetry in random graphs*
  - Josimar Chire Saire, San Pablo Catholic University, PE; *An approach using probability density function and rewarding criteria for numerical optimization*
  - Rodrigo Martins, UTFPR, BR; *On the cycle structure of mappings with restriction on the indegrees*

4. Contrapartida da USP, patrocínio de empresas, e recursos da Fapesp

Na tabela abaixo indicamos os valores recebidos pela Escola, tanto da Fapesp quanto de outras fontes.

Unidade/Empresa/Agência	valor em reais	valor em dólares
IME-USP	4.000,00	–
Google	6.000,00	–
B2W	12.000,00	–
IBM	6.000,00	–
PRP-USP	20.000,00	–
FAPESP	512.281,00	5.750,00
	560.281,00	5.750,00

Com relação à verba concedida pela Fapesp, utilizamos um total de R$ 526 mil, contabilizando a parte em dólares, que foi convertida em reais. As despesas em dólares foram para o pagamento de anúncios em revistas de circulação internacional (um total de 3.825 dólares). Devolvemos da ordem de R$ 9.800,00 para a Fapesp.

5. Ministrantes de cursos e palestrantes

Acreditamos que a Escola tenha atraído um grande interesse da comunidade internacional, pela diversidade de cursos que foram oferecidos, ministrados por pesquisadores de grande renome, muitos dos quais premiados em suas áreas de atuação.

Para dar uma visão global dos pesquisadores convidados, destacamos a seguir alguns deles e alguns pontos de seus currículos. Os textos estão em inglês, pois foram obtidos de seus currículos.

Eli Upfal is a Professor of Computer Science at Brown University. Prior to joining Brown in 1998, he was a researcher and project manager at the IBM Almaden Research Center in California, and a professor of Applied Mathematics and Computer Science at the Weizmann Institute of Science in Israel.

Upfal's research focuses on the design and analysis of algorithms. In particular he is interested in randomized algorithms, probabilistic analysis of algorithms, and computational statistics, with applications ranging from combinatorial and stochastic optimization to routing and communication networks, computational biology, and computational finance.

Upfal published over 150 research papers in scientific journals and conferences. He is co-author of a popular textbook *Probability and Computing: Randomized Algorithms and Probabilistic Analysis* (with M. Mitzenmacher, Cambridge University Press 2005). Upfal is the inventor of 13 US patents. His patents related to sequencing by hybridizations (with F. Preparata) were licensed to GeneSpectrum Inc., a bio-tech startup (acquired by NABsys Inc. in 2006).

Upfal is a fellow of the IEEE and the Association for Computing Machinery (ACM). He received the IBM Outstanding Innovation Award, and the IBM Research Division Award. His work at Brown has been funded in part by the National Science Foundation (NSF), The Defense Advanced Research Projects Agency (DARPA), The office of Naval Research (ONR), and the National Institute of Health (NIH).

Robert Kleinberg is an Associate Professor of Computer Science at Cornell University. His broad area of research is the design and analysis of algorithms. He is best known for his work on group theoretic algorithms for matrix multiplication, online learning, greedy embedding, and economic aspects of algorithms (game theory) and their applications to electronic commerce, networking, information retrieval, and other areas. Prior to receiving his doctorate from MIT in 2005, Kleinberg spent three years at Akamai Technologies, where he assisted in designing the world's largest Internet Content Delivery Network. He is the recipient of a Microsoft Research New Faculty Fellowship, an Alfred P. Sloan Foundation Fellowship, and an NSF CAREER Award.

David P. Williamson is a Professor at Cornell University in the School of Operations Research and Information Engineering. He received his Ph.D. in Computer Science from MIT under Professor Michel X. Goemans in 1993. After a postdoc at Cornell under Professor Éva Tardos, he was a Research Staff Member for IBM Research at the T.J. Watson Research Center in Yorktown Heights, New York. From 2000 to 2003, he was the Senior Manager of the Computer Science Principles and Methodologies group at IBM's Almaden Research Center in San Jose, California. He moved to Cornell University in 2004.

Williamson's research focuses on finding efficient algorithms for hard discrete optimization problems, with a focus on approximation algorithms for problems in network design, facility location, and scheduling. Other interests include algorithms for information networks.

Williamson is an *ACM Fellow* (2013) and is a recipient of the *Lanchester Prize* for best contribution to operations research and the management sciences published in English (INFORMS 2013). He received an *Alexander Humboldt Research Award* (Alexander von Humboldt Foundation) in 2010 and the *Fulkerson Prize* (Mathematical Programming Society) in 2000. In 1999, he was awarded the *Group on Optimization Prize* (SIAM, Society of Industrial and Applied Mathematics).

Alexandr V. Kostochka is a Professor of Mathematics at the University of Illinois at Urbana-Champaign (UIUC). Before joining UIUC in 2000, he was a Leading Researcher at the Institute of Mathematics of the Siberian Branch of the Russian Academy of Sciences in Novosibirsk. He obtained his PhD in 1978 and his Doctor of Science in 1991 from the Academy of Sciences of the USSR. His research interests are mainly in the areas of graph coloring, the Hadwiger number, acyclic coloring, oriented coloring, planar graphs, extremal problems on the n-cube, random subgraphs of sparse graphs, Δ-systems, cycles and paths in graphs, dimensions of partially ordered sets. He is a member of the editorial board of several journals, including the *Journal of Combinatorial Theory, Series B*, often considered to be one of the top two journals in combinatorics.

Levent Tunçel is a Professor of Mathematics at the University of Waterloo. He obtained his PhD at Cornell (1992). Tunçel has very broad research interests, including convex optimization, interior point methods, quantum protocols, combinatorial optimization, mixed integer programming, and computational complexity. His deepest contributions are in interior point methods and semidefinite optimization, two cornerstones of modern convex optimization. In 1999, he received the *Premier's Research Excellence Award* (Province of Ontario, Canada). He is currently an associate editor of the leading journals in the area of optimization, including *Mathematical Programming A*, *Mathematics of Operations Research*, and *SIAM Journal on Optimization.*

Daniel Král' became a Professor of Mathematics at the University of Warwick in 2012. He obtained his PhD in 2004 (Charles University, Prague) and his Doctor of Science in 2012 (Academy of Sciences of the Czech Republic). Král' works in graph theory and related fields in mathematics and computer science. Most of his research is now focused on topics related to his ERC Starting grant CCOSA and to his recently awarded ERC Consolidator grant LaDIST. Král' received the *The European Prize in Combinatorics* in 2011. In 2014, Král' was awarded the *Philip Leverhulme Prize in Mathematics and Statistics.* The Philip Leverhulme Prizes recognise the achievement of outstanding researchers whose work has already attracted international recognition and whose future career is exceptionally promising. The prize scheme makes up to thirty awards of £100,000 a year, across a range of academic disciplines. Král' is on the editorial board of the *Journal of Graph Theory* and of the *European Journal of Combinatorics*, besides being an associate editor of *Discrete Mathematics*, *Discrete Optimization* and *SIAM Journal on Discrete Mathematics.*

Robert Morris is an Associate Professor at IMPA, Instituto Nacional de Matemática Pura e Aplicada. He obtained his PhD at the University of Memphis in 2006, under the supervision of Béla Bollobás. His main research field is extremal and probabilistic combinatorics. Morris has made deep contributions in the areas of percolation, Ramsey theory, random graphs, extremal graph theory and additive combinatorics. An underlying theme in his research is the application of 'randomness' in deterministic settings. Morris is a managing editor of *Combinatorics, Probability and Computing* (Cambridge University Press). Morris was awarded the *European Prize in Combinatorics* in 2015.

Bruce Reed obtained his PhD in 1986 from McGill University, under the supervision of Vašek Chvátal. Reed works in the areas of combinatorics, graph theory, algorithms, and probability. Among his numerous contributions, of special importance is his work in the area of graph colouring, which he approached with the use of novel and sophisticated probabilistic methods.

Reed is also an expert on random graphs, with particular emphasis on how they can be applied to the World Wide Web. Before returning to McGill as a Canada Research Chair (2001 to 2008 and 2008 to 2015), Reed held positions at the University of Waterloo, Carnegie Mellon University, and the CNRS. Reed was inducted as a *Fellow* of the *Royal Society of Canada* in 2009 and he was awarded a *Humboldt Research Prize* in 2014. Reed was the recipient of the *CRM/Fields/PIMS Prize* in 2013, with the citation "for his profound contributions to difficult and important problems in the areas of graph minors, graph colouring, algorithmic graph theory, random graphs and the probabilistic analysis of algorithms." This prize recognizes exceptional achievement in the area of mathematical sciences and is considered to be one of Canada's top honours in mathematics.

6. Detalhamento dos cursos e das palestras

Apresentamos nesta seção os programas dos cursos e os resumos das palestras.

Cursos da primeira semana

Sample complexity and uniform convergence

Eli Upfal, Brown University, USA

Sampling is a powerful technique, which is at the core of statistical data analysis and machine learning. Using a finite, often small, set of observations, we attempt to estimate properties of an entire sample space. How good are estimates obtained from a sample? Any rigorous application of sampling requires an understanding of the *sample complexity* of the problem - the minimum size sample needed to obtain the required results. In this course we will cover some of the rich mathematical theory that has been develop in recent years to address this question, in particular in the context of statistical machine learning and rigorous data mining.

Main topics:

1. Review of large deviation bounds: Chernoff, Hoeffding, Azuma, McDiarmid bounds (adapted to the students background).
2. Uniform convergence - Glivenko-Cantelli theorem
3. VC-dimension
4. The ε-net and ε-sample theorems
5. Applications to sample complexity in machine learning and data mining
6. Rademacher complexity
7. Sample complexity through Rademacher complexity.
8. Applications

The regularity method and blow-up lemmas for sparse graphs

Yoshiharu Kohayakawa, Universidade de São Paulo, Brazil

A fundamental result in extremal graph theory is the regularity lemma of Szemerédi (1976). The combined use of the regularity lemma and an embedding or a subgraph counting lemma is now usually called the *regularity method*.

The power of the regularity method can be appreciated when one observes that the removal lemma (1978) and the asymptotic formula for the Turán number of general graphs, due to Erdős, Stone and Simonovits (1946, 1966), have straightforward proofs based on the regularity method.

In its simplest form, the regularity method allows one to investigate the existence of a given fixed graph as a subgraph of a large graph. Komlós, Sárközy and Szemerédi (1997) strengthened the regularity method by developing the *blow-up lemma*, which, combined with the regularity lemma, allows one to address problems in which the subgraphs being sought are large, for instance, when they are spanning subgraphs (e.g., the kth power of a Hamilton cycle (1998)).

Owing to the work of several researchers, including Balogh, Conlon, Fox, Gowers, Morris, Rödl, Samotij, Saxton, Schacht, Thomason, and Zhao, the regularity method has also been successfully strengthened to handle graphs with a subquadratic number of edges, that is, one now knows quite well how to apply this method in the sparse setting, at least when one investigates the existence of *small subgraphs*. What can one do if one is after large subgraphs? Are there blow-up lemmas in the sparse setting?

This course will start with a recap on the basics of the regularity method. We shall discuss in more detail the blow-up lemma and its classical applications. We shall then move on to the discussion of the regularity method in the sparse setting. Novel results on the blow-up lemma in the sparse setting, currently under development in collaboration with P. Allen, J. Böttcher, H. Hàn and Y. Person, will form the last and original part of the course.

Combinatorial stochastic search and selection

Robert Kleinberg, Cornell University, USA

This course will focus on problems that involve designing algorithms for sequential decision problems in the face of uncertainty about future inputs, and combinatorial constraints on the feasible sets of decisions the algorithm may make. One examplar is the Matroid Secretary Problem, in which the elements of a matroid have (initially unknown) non-negative weights, they are presented to the algorithm in random order, and it must decide upon seeing each element whether or not to select it, with the constraint that the selected elements must form an independent set in the matroid, and with the goal of maximizing the sum of the weights. (The classical secretary problem corresponds to the special case of a rank-one matroid.) Other topics in the same circle of ideas are prophet inequalities, online matching algorithms, and combinatorial generalizations of Weitzman's "Pandora's Box" model of optimal search.

The perfect matching polytope, solid bricks and the perfect matching lattice

Cláudio L. Lucchesi, Universidade Federal do Mato Grosso do Sul, Brazil

Fifty years ago, Jack Edmonds gave a characterization of the perfect matching polytope. It consists of three kinds of restrictions: (i) nonnegativity, (ii) regularity and (iii) restrictions on odd cuts.

The number of odd cuts is exponentially large. Yet there are certain graphs that do not require any restrictions of the third kind at all. It is well known that this is the case of bipartite graphs. We present a characterization of graphs whose perfect matching polytopes are described solely by the first two kinds of restrictions, they are called solid graphs.

Clearly, the linear space spanned by perfect matchings has a basis consisting solely of perfect matchings. However, we also explore the observations and techniques used for the first result and give a proof for the existence of a basis for the perfect matching lattice consisting solely of perfect matchings. We also pose the open problem of polynomial recognition of solid graphs. All this material is joint work with Marcelo H. de Carvalho and U. S. R. Murty. We shall distribute notes containing most of the results discussed in the course.

Recent progress in approximation algorithms for the traveling salesman problem

David Williamson, Cornell University, USA

After several decades of little to no progress, the past few years have brought significant progress in designing approximation algorithms for special cases and variants of the traveling salesman problem (TSP)—and yet big questions remain open. In these lectures, I will go through some of the recent results for the graph TSP, the s-t path TSP, and the asymmetric TSP, and discuss possible approaches to the remaining open questions.

Harmonic analysis on polytopes and cones

Sinai Robins, University of São Paulo, Brazil

The course develops results in the discrete geometry of polytopes and polyhedral cones, mostly from the perspective of Harmonic analysis, and we introduce all necessary techniques from first principles, assuming some knowledge of Linear Algebra and Complex Analysis. One of the motivating themes is the question of how to discretize the volume of a polytope or a cone. It is straightforward to see that there are infinitely many ways to do so, and we will focus on at least two discretizations, the first of which relies on a higher dimensional generalization of the concept of an angle. The other most popular discretization of volume is the counting of lattice points in a polytope, and has combinatorial underpinnings. One of the recurring themes for us is the analytic tool called the Poisson summation formula, and there are many interesting number-theoretic corollaries of some of these developments.

We begin with examples in 2 and 3 dimensions, and by computing the Laplace transform of cones, and find that they are rational functions. We then give a new proof of a classical (1988) theorem of Brion, which essentially tells us that the Laplace transform of a polytope is equal to the sum of the Laplace transforms of its tangent cones.

While finding formulas for volumes of d-dimensional polytopes, we introduce a higher-dimensional analogue of an angle, which is called a "solid angle", namely the intersection of a d-dimensional sphere with a cone. Finally, introduce and study cone theta functions, from first principles, a natural discrete analogue of the d-dimensional solid angle. We will also study some Euler-Maclaurin summation formulae over polyhedral cones and polytopes, which are natural extensions of the classical 1-dimensional Euler-Maclaurin summation formula on an interval.

Coloring sparse graphs with few colors

Alexandr Kostochka, University of Illinois at Urbana-Champaign, USA

It is natural that graphs with fewer edges are easier to color. The structure of the lectures is as follows.

1. We will describe the history of lower bounds on the minimum number of edges in k-color-critical graphs with a given number of vertices and prove some of these bounds. In particular, we prove the case $k = 4$ of Gallai's Conjecture from 1963 on the topic.
2. We describe some applications of these bounds. In particular, we give short proofs of Grötzsch's Theorem and of Axenov-Grünbaum Theorem on 3-coloring of planar graphs.
3. We describe some constructions of sparse color-critical graphs and hypergraphs.
4. Some unsolved problems will be discussed.

The method of hypergraph containers

Robert Morris, IMPA, Brazil

Given a (fixed) graph H, consider (for each $n \in \mathbb{N}$) the family $\mathcal{F}_n(H)$ graphs on n vertices that do not contain a copy of H as a subgraph. This family has been a central object of study in extremal combinatorics for over 70 years, since the groundbreaking work of Turán, Erdős and Stone, and others, on the maximum number of edges in a member of $\mathcal{F}_n(H)$. Over the intervening decades, a huge amount of work has been put into understanding this problem in various special cases (see [?]), but nevertheless many basic questions remain unanswered, most notably when H is bipartite (see [?]). Another famous question asks for the minimum independence number of a member of $\mathcal{F}_n(H)$; indeed, this is equivalent to determining the Ramsey numbers $r(H, K_t)$.

More recently, beginning in the 1970s but most notably since the 1990s, a new direction of research has attracted a great deal of attention (see [?]). The basic questions are as follows: How many H-free graphs are there with n vertices? What is the typical structure of such a graph (perhaps with a given number of edges)? And what can one say about the H-free subgraphs of the Erdős-Rényi random graph $G(n,p)$? (Similar questions can of course be asked in related combinatorial settings, e.g., for sets of integers containing no k-term arithmetic progression, or graphs containing no induced copy of H.)

In this course we will discuss a recently-developed technique (see [?] and [?]) that has proved to be extremely useful in the study of such problems. In order to illustrate the method, we will consider the number of C_4-free graphs, the typical structure of a K_r-free graph, and the extremal problem in $G(n,p)$ for general H. We will also briefly discuss how the method can be applied to a diverse variety of discrete objects, such as sum-free sets of integers, colourings of graphs, and metric spaces.

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Graph limits and their applications in extremal combinatorics

Daniel Král, University of Warwick, UK

Combinatorial limits give an analytic way to represent large discrete objects. The theory of combinatorial limits led to development new techniques in discrete mathematics and provided new vies on existing notions and concepts. It has also opened new links between analysis, combinatorics, computer science, group theory and probability theory. Combinatorial limits are also closely related to the flag algebra method which led to solving several long-standing open problems in extremal combinatorics.

The tutorial will be focused on limits of dense graphs, which form the best understood case in the theory of combinatorial limits, and the flag algebra method. The lectures will be complemented by exercise problems of various difficulty to give the participants an opportunity to practice the presented material.

The tentative syllabus of the tutorial is the following:

1. Introduction - dense graph convergence, graph limits
2. Existence and uniqueness of graph limit representations
3. Flag algebras and their relation to graph limits
4. Graph quasirandomness via graph limits
5. Use of flag algebras via SDP in extremal graph theory

Depending on the interest of the participants, some of the following topics will also be discussed at the end of the tutorial: finite forcibility of graph limits, limits of sparse graphs, limits of other discrete objects (hypergraphs, partial orders, permutations).

Geometric Packing - algorithms for packing circles

Flávio Keidi Miyazawa, Unicamp, Brazil

We show some techniques to obtain approximation algorithms for the circle bin packing problem. For the offline case, we present an approach to obtain asymptotic approximation schemes that is valid for packing circles, spheres and more generally, d-dimensional spheres under the L_p-norm. The idea is to iteratively separate small and large items, and may be extended to a wide range of packing problems that satisfy certain conditions. These extensions comprise problems with different kinds of items, such as regular polygons, or with bins of different shapes, such as circles and spheres. As an example, we obtain APTAS's for the problems of packing d-dimensional spheres into hypercubes under the L_p-norm and an APTAS for the strip packing version of these problems.

For the online case, we present an approach to obtain competitive algorithms for the online bounded space circle bin packing problem. The techniques used are borrowed from the rectangle packing version and we show how to obtain competitive algorithms and lower bounds for any constant competitive algorithm.

Semidefinite Programming Techniques in Combinatorial Optimization

Levent Tunçel, University of Waterloo, Canada

We will start with the discussion of various forms of Semidefinite Programming (SDP) problems and some necessary background (no previous background on SDPs is required). Then, we will formulate various problems in combinatorial optimization, graph theory, and discrete mathematics in general either as SDP problems or as nonconvex optimization problems with natural and useful SDP relaxations. We will continue with some geometric representations of graphs as they relate to SDP, more recent work on Lovász theta body and its extensions, lift-and-project methods, and conclude with some of the more recent work in these research areas and the research area of lifted SDP-representations (or extended formulations) and some open research problems.

Palestras

Determining the rank of some graph convexities

Jayme L. Szwarcfiter, UFRJ

A *graph convexity* is a pair $(V(G), \mathcal{C})$, where $V(G)$ is the vertex set of a finite graph G, and $\mathcal{C}$ a family of subsets of $V(G)$, each called *convex*, where $\emptyset, V(G) \in \mathcal{C}$, and $\mathcal{C}$ is closed under intersections. The most studied graph convexities are based on paths. The *geodetic, monophonic* and P_3 convexities are those in which $\mathcal{C}$ is closed under shortest paths, induced paths and common neighbors, respectively. For a set $S \subseteq V(G)$ the *convex hull* of S, denoted $H(S)$ is the minimum convex set containing S. Say that S is *convexly independent* when $v \notin H(S \setminus \{v\})$, for any $v \in S$. The *rank* of $(V(G), \mathcal{C})$ is the size of the largest convexly independent set. We study the determination of the rank in the above path convexities.

Adaptive rumor spreading

Marcos Kiwi, Universidad de Chile

Rumor spreading is a basic model for information dissemination in a social network. In this setting a central concern for an entity, say the service provider, is to find ways to speed up the dissemination process and to maximize the overall information spread. However, a central issue absent in this setting is that of adaptivity. How can the service provider use information about the current state of the network to cost effectively speed up the process?

Motivated by the recent emergence of the so-called opportunistic communication networks, we take a novel approach by considering the issue of adaptivity in the most basic continuous time (asynchronous) rumor spreading process. In our setting a rumor has to be spread to a population and the service provider can push it at any time to any node in the network and has unit cost for doing this. On the other hand, as usual in rumor spreading, upon meeting, nodes share the rumor and this imposes no cost on the service provider. We consider the cost version of the problem with a fixed deadline and ask for a minimum cost strategy that spreads the rumor to every node. A non-adaptive strategy can only intervene at the beginning and at the end, while an adaptive strategy has full knowledge and intervention capabilities. Our main result is that in the homogeneous case (where every pair of nodes randomly meet at the same rate) the benefit of adaptivity is bounded by a constant. This requires a subtle analysis of the underlying random process that is of interest in its own right. Joint work with J.R. Correa (U. Chile), N. Olver (VU University Amsterdam; and CWI, Amsterdam), and A. Vera (U. Chile).

Progression-free sets, the polynomial method, and arithmetic removal lemmas

Robert Kleinberg, Cornell University, USA

Letting C_m denote the cyclic group Z/mZ, what is the largest subset of $(C_m)^n$ having no three distinct elements in arithmetic progression? Up until a couple of weeks ago, the best known upper bounds were barely better than the trivial upper bound of m^n , even for the case of $m = 3$, when the question is known as the "cap set" problem. In a breakthrough just this month, Croot, Lev, and Pach found a way to prove a non-trivial upper bound for $m = 4$ using the polynomial method. This was soon extended by Ellenberg and (independently) Gijswijt to derive an upper bound of $(0.95m)^n$ for all $m > 2$. The proof is simple, beautiful, and unbelievably short.

The Croot-Lev-Pach lemma has subsequently found other applications: for example, Fox and Lovasz have used it to give an optimal bound for Green s "arithmetic triangle removal lemma" in vector spaces over F_p. Blasiak, Church, Cohn, Grochow, and Umans have shown that it refutes many (but not all) of the conjectured approaches for applying the group-theoretic fast matrix multiplication paradigm of Cohn-Umans to prove that the exponent of matrix multiplication equals 2. In this talk, I will give some historical background on these problems, present the proofs of the new upper bounds for progression-free sets, present a nearly-matching lower bound for a "tripartite" version of the progression-free set problem, and discuss the application to arithmetic removal lemmas.

On the structure of almost every H-free graph, when H is a tree or a cycle

Bruce Reed, McGill University, Canada

Solving NP-hard geometric optimization problems to optimality

Cid Carvalho de Souza, UNICAMP

There are several NP-hard problems investigated by researchers in Computational Geometry for which no exact algorithms have been developed and/or tested. The common approach in the field is to look for approximation algorithms. In practice, these algorithms often produce a solution whose cost is far from the optimum. In this talk we show that large-sized instances of some geometric problems can be solved to proven optimality when integer programming techniques are combined in a clever way with geometrical properties. Among the successful examples, we discuss the well-known Art Gallery Problem.

Random models of 21st century networks and their connectivity structure

Bruce Reed, McGill University, Canada

The traditional Erdős–Rényi model of a random network is of little use in modeling the type of complex networks which modern researchers study. It postulates that each node has the same likelihood of being attached to every other node. However, in, e.g. the web, certain authoritative pages will have many more links entering them. A 1995 paper of Molloy and Reed, cited over 1500 times, sets out some conditions guaranteeing the existence of a giant component in a graph with a specified degree sequence. This work has attracted such a great deal of attention because it can be applied to random models of a wide range of complicated 21st century networks such as the web or biological networks operating at a sub-molecular level. A heuristic argument suggests that a giant component will exist provided the sum of the squares of the degrees of the vertices of the network is at least twice the sum of the degrees. Molloy and Reed proved that this is indeed true subject to certain technical conditions. Many authors, have obtained related results by specifying different technical conditions, or by tying down the size of the giant component. Since the interest in this result is its wide applicability, it is natural to try and prove it under as few assumptions as possible. Recently, Joos, Perarnau-Llobet, Rautenbach, and Reed proved the result under essentially no conditions. I will present, in an accessible way, a variety of complex networks and their random models to which the Molloy Reed result has been applied. I will then sketch briefly the proof of our result and how it differs from the proof of the Molloy-Reed result.

7. Sobre os candidatos inscritos e aceitos

Recebemos 238 inscrições, de candidatos provenientes de 31 países, com excelente formação, de instituições reconhecidas, e muitos com forte recomendação de pesquisadores de renome. Desses, a Escola aceitou 150, sendo 80 do exterior e 70 do Brasil.

Por categoria em termos de formação, a distribuição foi a seguinte: 106 alunos de doutorado (DR), 48 de mestrado (MS), 27 alunos da graduação (GR), 18 pós-doutorandos (PD) e 38 outros. Na categoria "outros" estão jovens pesquisadores (candidatos com doutorado que obtiveram o título nos últimos 5 anos e candidatos que trabalham em empresas).

Os alunos de graduação que foram aceitos são de excepcional qualidade, altamente recomendados (muitos dos quais estão em programas de iniciação científica e têm resultados de pesquisa). Todos os alunos de mestrado que aceitamos já se encontram pelo menos no segundo ano (com exceção de um aluno do IME-USP, que chegou de Santa Catarina neste semestre). Os alunos de doutorado aceitos estão em diferentes estágios, havendo uma boa mescla dos diferentes estágios. Consideramos assim que os candidatos que selecionados formou um grupo com status acadêmico e distribuição geográfica bem balanceada.

Os candidatos que selecionamos são provenientes de excelentes universidades, dentre as quais citamos: Princeton University, Cornell, Georgia Tech, Brown, Emory, Illinois at UC, Vanderbilt, Waterloo, McGill, Oxford, Birmingham, Warwick, Liverpool, ENS Lyon, ETH Zürick, Hamburg, FU Berlin, Cologne, Charles University (Praga), Warsaw, Wroclaw, Havana, Universidad de Chile, Buenos Aires, USP, UNICAMP, UFRJ, UFC, UFRGS, etc.

A tabela abaixo mostra a distribuição de candidatos e participantes da escola divididos em sua origem e formação.

Origem	GRAD		MS		DR		PD		Outros		Total	
	Insc	Ac.	Insc.	Ac.	Insc.	Ac.	Insc.	Ac.	Insc.	Ac.	Insc.	Ac.
BR (Cidade SP)	5	5	6	6	10	10	3	3	6	6	30	30
BR (Estado SP)	2	0	4	0	12	7	0	0	3	3	21	10
BR (outros estados)	7	1	14	7	22	7	4	3	15	12	62	30
África	0	0	0	0	1	0	1	0	0	0	2	0
Am. Latina	6	1	13	7	11	8	0	0	5	4	35	20
Am. do Norte	3	2	3	3	17	15	2	2	2	0	27	22
Ásia	1	0	4	2	4	0	2	0	4	0	15	2
Europa	4	2	4	3	29	22	6	6	3	3	46	36
Total	28	11	48	28	106	69	18	14	38	28	238	150

8. Avaliação da Escola feita pelos participantes

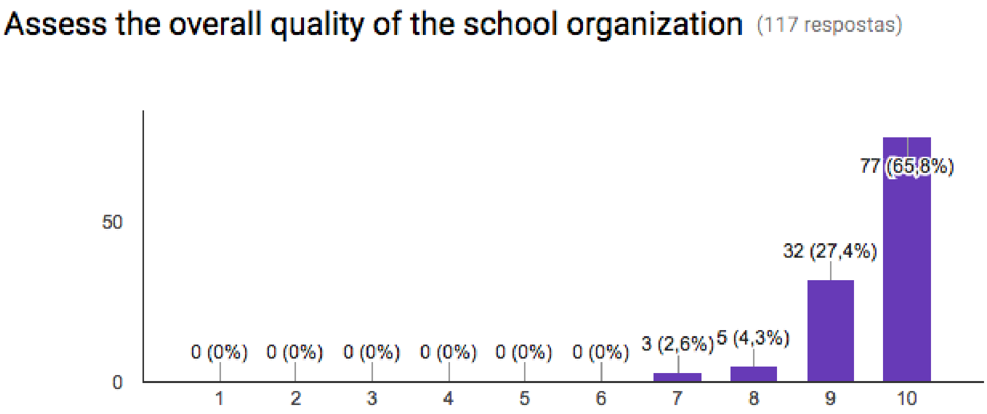
O questionário sobre a avaliação da Escola consistiu em 13 questões de mútipla escolha e uma questão dissertativa, onde o participante podia expressar livremente a sua impressão geral da escola.

Obtivemos 117 respostas ao questionário. A seguir apresentamos um extrato das respostas obtidas às questões de múltipla escolha, e depois mostramos algumas respostas dissertativas que dão uma ideia da impressão geral sobre a Escola.

Pergunta	**Porcentagens por resposta**			
	excellent	good	ok	poor
Overall quality of courses and talks	76,9%	23,1%	—	—
	strongly agree	agree	neutral	disagree
Chosen topics were interesting and recent	74,4%	25,6%	—	—
The contents of the courses were compatible with what was advertised	78,6%	20,5%	0,9%	—
The exercises helped to get a deeper understanding of the course material	46,2%	40,2%	13,7%	—
The teaching assistants and the classwork were helpful	38,5%	41,9%	19,7%	—
	very good	good	ok	poor
What did you think of the venue and overall infrastructure for the school	84,6%	14,5%	0,9%	—
		< 1 hour	1 – 3 hours	> 3 hours
How much off-class time did you put into each of the courses?		24,8%	63,2%	12%
		for sure	likely	unlikely
The courses will be useful for your research?		50,4%	46,2%	3,4%
Have you met probable collaborators?		31,6%	57,3%	11,1%

Pergunta	Porcentagens por resposta									
	1	2	3	4	5	6	7	8	9	10
How many talks did you attend?	6,8%	12,0%	14,5%	24,8%	25,6%	16,2%				
How many courses did you attend?	0,9%	1,7%	6,8%	11,1%	45,3%	17,9%	12%	1,7%	0,9%	1,7%
Assess your overall learning throughout the courses (10 is best)			0,9%	1,7%	3,4%	18,8%	28,2%	29,7%	6,8%	11,1%

A última pergunta de múltipla escolha dá uma ideia geral do que os participantes acharam da Escola. Exibimos no gráfico abaixo as respostas obtidas a essa pergunta.



Além das respostas às perguntas de múltipla escolha, 47 participantes preencheram um quadro (opcional) para comentários. Selecionamos uma amostra desses comentários, e os apresentamos a seguir.

- *"The school was an amazing experience. I learned a lot and met many people, whom I expect to collaborate in the future. I think the organizers did an amazing job. Thanks for everything!"*

- *"The school was absolutely pertinent. Amazing organization and very meaningful topics. Thank you for the financial aid and for the courses that gave me a clear sight about current research directions".*

- *"I wish opportunities like this happened more often in SP".*

- *"It was really excellent. The courses were all a little too advanced for me (which is perfect!) so I don't think I learnt anything near everything that was taught. However, I got a feel of which tools might be useful for what, which probably matters more. I also met a lot of people and made friends".*

- *"The school is great! And I can see the organizers payed great effort on it. I sincerely appreciate the financial support as well as the organizers' effort to make this fantastic school!"*

- *"Very friendly atmosphere, perfect organisation".*
- *"There could be more schools like this".*
- *"I want to praise the excellent idea of scheduling the courses so there were no overlaps between them".*
- *"The organizers have put so much time into it, and have thought about a single little detail; which made the school incredible and unforgetful experience for us. Thank you organizers for your hard work, bringing top researchers to school for us to learn from, willingness to help whenever we had questions, for delicious snacks in the afternoons, for your smiles and enthusiasm despite being tired, I really appreciate it all".*
- *"Thank you to sponsors of this program for your generosity; it wouldn't have been possible for us to fly from this far to participate without your generous financial support."*
- *"It was an excellent school, plenty of interesting talks and interesting people. Hopefully there will be new versions of the school in the future, I think it's a very good opportunity for the people working in the region to meet and get to know each other".*

9. Conclusões finais

Considerando o relato que fizemos nas seções anteriores, concluímos que a Escola foi um grande sucesso. Ela cumpriu o papel que se propunha: oferecer cursos e palestras de alto nível, atrair muito bons participantes do Brasil e do exterior, oferecer oportunidade de interação aos participantes, divulgar a pesquisa que se faz no país, e em particular no Estado de São Paulo.

Antes de concluir este relatório, gostaríamos de comentar o fato de a Escola ter tido 150 participantes. As escolas avançadas apoiadas pela Fapesp prevêem aceitação de cerca de 100 participantes. Nossa proposta original contemplava aceitação de 90 participantes, tendo em vista o fato de que no IME-USP os dois maiores auditórios não comportam mais do que 90 pessoas. No entanto, após receber cerca de 240 inscrições, de candidatos muito bons, fizemos um pedido de aditivo para a Fapesp. Fomos contemplados com uma verba adicional da ordem de R$ 150 mil da Fapesp, e auxílios da Pró-Reitoria da USP e de três empresas. O montante adicional recebido possibilitou-nos aceitar um total de 150 participantes.

Nem todos os participantes selecionados receberam auxílio financeiro completo em termos de diárias e passagens. Optamos por dar ajuda parcial de passagem aérea, a menos dos casos dos participantes que atuaram como monitores dos cursos. Com isso, pudemos aceitar mais participantes. Muitos deles vieram mesmo sem ter obtido auxílio da Escola (alguns receberam auxílios de suas instituições).

Após receber uma avaliação muito positiva por parte dos participantes, concluímos que valeu a pena aceitar mais participantes.

10. Cartaz da Escola

Anexamos o cartaz da Escola em formato A4. Na página da Escola, encontra-se o mesmo cartaz em formato A3: `http://sp-school2016.ime.usp.br`

São Paulo School of Advanced Science on Algorithms, Combinatorics and Optimization

July 18 to 29, 2016

**The school will be held at the Institute of Mathematics and Statistics of the University of São Paulo, Brazil.
It is aimed at Master's students, PhD students, and young researchers.
Undergraduate students may also qualify.**

COURSES

R. Kleinberg (Cornell), Combinatorial stochastic search and selection

Y. Kohayakawa (USP), The regularity method and blow-up lemmas for sparse graphs

A. Kostochka (UIUC), Coloring sparse graphs with few colors

Daniel Král' (Warwick), Graph limits and their applications in extremal combinatorics

C.L. Lucchesi (UFMS), The perfect matching polytope, solid bricks and the perfect matching lattice

F.K. Miyazawa (UNICAMP) and **F.M. Oliveira Filho (USP),** Geometric packing

R. Morris (IMPA), The method of hypergraph containers

S. Robins (USP), Harmonic analysis on polytopes and cones

L. Tunçel (Waterloo), Semidefinite programming techniques in combinatorial optimization

E. Upfal (Brown), Sample complexity and uniform convergence

D. Williamson (Cornell), Recent progress in approximation algorithms for the TSP

TALKS

C.C. de Souza (UNICAMP), M. Kiwi (U. Chile), B. Reed (McGill) and J.L. Szwarcfiter (UFRJ)

FELLOWSHIPS and REGISTRATION

Funding will be provided for local expenses and travel. Funding applications sent by March 28 will receive full consideration. Early registration (by May 1): 50 US dollars (students) and 80 US dollars (others).

http://sp-school2016.ime.usp.br

Foto: Reprodução/ USP Imagens

Organization — IME-USP

Funding — FAPESP; SÃO PAULO SCHOOL OF ADVANCED SCIENCE

Sponsors — Google; IBM

11. Material de divulgação da Escola

Para divulgar a Escola enviamos mensagens eletrônicas em redes (listas) internacionais de grande alcance: DMANET (Discrete Mathematics Net), THEORYNET e LATINTCS.

Também fizemos anúncios em duas revistas internacionais, de grande alcance na comunidade: *Communications of ACM* and *Notices of the American Mathematical Society*. Cópias dos anúncios que foram publicados nessas revistas encontram-se anexas a este relatório.

12. Algumas fotos da Escola

Apresentamos a seguir algumas fotos tiradas antes ou durante a Escola. A primeira delas mostra o CDI (Centro de Difusão Internacional), local onde foi realizada a Escola. No documento anexo a este relatório, apresentamos mais fotos. Estas não foram incluídas aqui por causa da limitação de tamanho do relatório.

São Paulo School of Advanced Science on Algorithms, Combinatorics and Optimization

Funded by FAPESP SPSAS Program


July 18-29, 2016 USP, Brazil
São Paulo School of Advanced Science on
Algorithms, Combinatorics and Optimization
First Week


São Paulo School of Advanced Science on
Algorithms, Combinatorics & Optimization
July 18-29, 2016 USP, Brazil
Second Week