FINAL PROGRAM & ABSTRACTS

ACM-SIAM Symposium on Discrete Algorithms

January 5-7, 2014
Hilton Portland & Executive Tower • Portland, Oregon, USA

ANALCO14
Meeting on Analytic Algorithmics and Combinatorics

January 6, 2014
Hilton Portland & Executive Tower
Portland, Oregon, USA

ALENEX14
Meeting on
Algorithm Engineering & Experiments

January 5, 2014
Hilton Portland & Executive Tower
Portland, Oregon, USA

SODA is jointly sponsored by the ACM Special Interest Group on Algorithms and Computation Theory and the SIAM Activity Group on Discrete Mathematics

The SIAG on Discrete Mathematics focuses on combinatorics, graph theory, cryptography, discrete optimization, mathematical programming, coding theory, information theory, game theory, and theoretical computer science, including algorithms, complexity, circuit design, robotics, and parallel processing. This activity group provides an opportunity to unify pure discrete mathematics and areas of applied research such as computer science, operations research, combinatorics, and the social sciences. It organizes a biennial conference on discrete mathematics; co-sponsors, with ACM SIGACT, the annual Symposium on Discrete Algorithms; and sponsors minisymposia at SIAM meetings and conferences. The activity group also runs DM-Net, an electronic forum; publishes an electronic newsletter; and maintains a website and a member directory.

Society for Industrial and Applied Mathematics
3600 Market Street, 6th Floor
Philadelphia, PA 19104-2688 USA
Telephone: +1-215-382-9800 Fax: +1-215-386-7999
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http://www.siam.org/meetings/da14/

http://www.siam.org/meetings/alenex14/

http://www.siam.org/meetings/analco14/

General Information

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Hotel Meeting Room Map.... Back Cover

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The SIAM registration desk is located in the Plaza Foyer on the Plaza Level. It is open during the following hours:

Saturday, January 4
5:00 PM - 8:00 PM

Sunday, January 5
8:00 AM - 5:00 PM

Monday, January 6
8:00 AM - 5:00 PM

Tuesday, January 7
8:00 AM - 5:00 PM

Hotel Information

Hilton Portland & Executive Tower
921 SW Sixth Avenue
Portland, Oregon, 97204, USA
Phone Number: +1-503-226-1611
Toll Free Reservations (USA and Canada): 1-800-445-8667
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Hotel web address: *http://www3.hilton.com/en/hotels/oregon/hilton-portland-and-executive-tower-PDXPHHH/index.html*

Hotel Telephone Number

To reach an attendee or to leave a message, call +1-503-226-1611. The hotel operator can either connect you with the SIAM registration desk or to the attendee's room. Messages taken at the SIAM registration desk will be posted to the message board located in the registration area.

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Check-in time is 3:00 PM.

Check-out time is 12:00 PM.

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The Hilton Portland & Executive Tower recommends Munchkin Care at *http://www.munchkincare.com/home.php* for local child care options.

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SIAM corporate members provide their employees with knowledge about, access to, and contacts in the applied mathematics and computational sciences community through their membership benefits. Corporate membership is more than just a bundle of tangible products and services; it is an expression of support for SIAM and its programs. SIAM is pleased to acknowledge its corporate members and sponsors. In recognition of their support, non-member attendees who are employed by the following organizations are entitled to the SIAM member registration rate.

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List current November 2013.

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All other concurrent/breakout rooms will have one (1) screen and one (1) data projector. Cables or adaptors for Apple computers are not supplied, as they vary for each model. Please bring your own cable/adaptor if using an Apple computer. Overhead projectors will be provided only if requested.

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Registration Fee Includes

- Admission to all technical sessions
- ANALCO/ALENEX Business Meeting
- Coffee breaks daily
- Continental Breakfasts daily
- Luncheon on Sunday, January 5, 2014
- Philippe Flajolet School on Analytic Combinatorics and the Analysis of Algorithms
- Proceedings (SODA USB distributed onsite; ALENEX, ANALCO and SODA posted online)
- Room set-ups and audio/visual equipment
- SODA Business Meeting (open to SIAG/DM members)
- Welcome Reception

Philippe Flajolet School on Analytic Combinatorics and the Analysis of Algorithms

Tuesday, January 7, 2014

Those interested in attending the Philippe Flajolet School on Analytic Combinatorics and the Analysis of Algorithms must register for the whole meeting or for Tuesday, January 7, 2014, as a one-day registrant.

The online program for the Flajolet school is available at *http://wwwagak.cs.uni-kl.de/analcoschool/program.html.*

Job Postings

Please check with the SIAM registration desk regarding the availability of job postings or visit *http://jobs.siam.org.*

SIAM Books and Journals

Display copies of books and complimentary copies of journals are available on site. SIAM books are available at a discounted price during the conference. If a SIAM books representative is not available, completed order forms and payment (credit cards are preferred) may be taken to the SIAM registration desk. The books table will close at 4:30 PM on Tuesday, January 7.

Table Top Display

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A space for emergency contact information is provided on the back of your name badge. Help us help you in the event of an emergency!

Comments?

Comments about SIAM meetings are encouraged! Please send to:

Sven Leyffer, SIAM Vice President for Programs (*vpp@siam.org*).

Get-togethers

Welcome Reception
Saturday, January 4
6:00 PM – 8:00 PM

ALENEX/ANALCO Business Meeting

Sunday, January 5

6:45 PM – 7:45 PM

SODA Business Meeting and Awards Presentation
(open to SIAG/DM members)

Monday, January 6

6:45 PM – 7:45 PM

Complimentary beer and wine will be served.

Please Note

SIAM is not responsible for the safety and security of attendees' computers. Do not leave your laptop computers unattended. Please remember to turn off your cell phones, pagers, etc., during sessions.

Recording of Presentations

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SODA Best Paper Awards

Best Papers

Polynomiality for Bin Packing with a Constant Number of Item Types

Michel X. Goemans and Thomas Rothvoss

This paper will be presented in Session CP6: Session 2C *(see page 16)*

An Almost-Linear-Time Algorithm for Approximate Max Flow in Undirected Graphs, and its Multicommodity Generalizations

Jonathan Kelner, Yin Tat Lee, Lorenzo Orecchia and Aaron Sidford

This paper will be presented in Session CP4: Session 2A *(see page 15)*

Best Student Paper

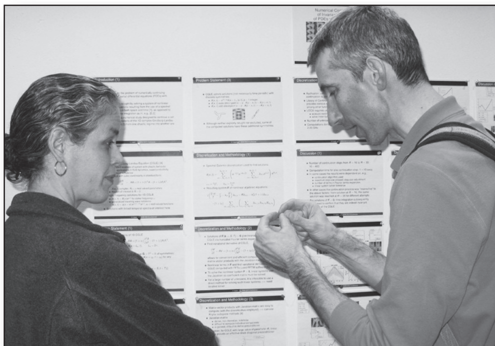
Improved Concentration Bounds for Count-Sketch

Gregory T. Minton and Eric Price

This paper will be presented in CP11: Session 4B *(see page 18)*

SIAM Activity Group on Discrete Mathematics (SIAG/DM)

www.siam.org/activity/dm



A GREAT WAY TO GET INVOLVED!

Collaborate and interact with mathematicians and applied scientists whose work involves discrete mathematics.

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ACTIVITIES INCLUDE:

- Special sessions at SIAM Annual Meetings
- Biennial conference on Discrete Mathematics
- Co-sponsors the annual ACM-SIAM Symposium on Discrete Algorithms
- Dénes König Prize
- DM-Net
- Website

BENEFITS OF SIAG/DM MEMBERSHIP:

- Listing in the SIAG's online membership directory
- Additional $10 discount on registration at SIAM Conference on Discrete Mathematics (excludes student)
- Electronic communications from your peers about recent developments in your specialty
- Eligibility for candidacy for SIAG/DM office
- Participation in the selection of SIAG/DM officers

ELIGIBILITY:

- Be a current SIAM member.

COST:

- $10 per year
- Student members can join two activity groups for free!

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- Vice-Chair: Ryan Martin, Iowa State University
- Program Director: Jacques Verstraete, University of California, San Diego
- Secretary: Debra Boutin, Hamilton College

TO JOIN:

SIAG/DM: my.siam.org/forms/join_siag.htm

SIAM: www.siam.org/joinsiam

* *Election in progress at time of printing*

Invited Plenary Speakers

** All Invited Plenary Presentations will take place in
Grand Ballroom I--Ballroom Level**

Sunday, January 5

11:30 AM - 12:30 PM

IP1 Shape, Homology, Persistence, and Stability

Herbert Edelsbrunner, *Institute of Science and Technology, Austria*

Monday, January 6

11:30 AM - 12:30 PM

IP2 Recent Developments in the Sparse Fourier Transform

Piotr Indyk, *Massachusetts Institute of Technology, USA*

Tuesday, January 7

11:30 AM - 12:30 PM

IP3 Interlacing Families: Mixed Characteristic Polynomials and the Kadison-Singer Problem

Daniel Spielman, *Yale University, USA*

SODA14, ALENEX14 and ANALCO14 At-a-Glance

Saturday, January 4

5:00 PM - 8:00 PM
Registration
Plaza Foyer - Plaza Level

6:00 PM - 8:00 PM
Welcome Reception
Plaza Foyer - Plaza Level

Sunday, January 5

8:00 AM - 5:00 PM
Registration
Plaza Foyer - Plaza Level

8:30 AM
Continental Breakfast
Plaza Foyer - Plaza Level

9:00 AM - 11:05 AM
Concurrent Sessions
ALENEX: Session 1
Broadway III/IV - Plaza Level
CP1 Session 1A
Grand Ballroom I - Ballroom Level
CP2 Session 1B
Galleria North - Ballroom Level
CP3 Session 1C
Galleria South - Ballroom Level

11:05 AM - 11:30 AM
Coffee Break
Plaza Foyer - Plaza Level

11:30 AM - 12:30 PM
IP1 Shape, Homology, Persistence, and Stability
Herbert Edelsbrunner, Institute of Science and Technology, Austria
Grand Ballroom I - Ballroom Level

12:30 PM - 2:00 PM
Luncheon
Ticketed Event
Grand Ballroom II - Ballroom Level

2:00 PM - 4:05 PM
Concurrent Sessions
ALENEX: Session 2
Broadway III/IV - Plaza Level
CP4 Session 2A
Grand Ballroom I - Ballroom Level
CP5 Session 2B
Galleria North - Ballroom Level
CP6 Session 2C
Galleria South - Ballroom Level

4:05 PM - 4:30 PM
Coffee Break
Plaza Foyer - Plaza Level

4:30 PM - 6:35 PM
Concurrent Sessions
ALENEX: Session 3
Broadway III/IV - Plaza Level
CP7 Session 3A
Grand Ballroom I - Ballroom Level
CP8 Session 3B
Galleria North - Ballroom Level
CP9 Session 3C
Galleria South - Ballroom Level

6:35 PM - 6:45 PM
Intermission

6:45 PM - 7:45 PM
ALENEX and ANALCO Business Meeting
Broadway III/IV - Plaza Level

Monday, January 6

8:00 AM - 5:00 PM
Registration
Plaza Foyer - Plaza Level

8:30 AM
Continental Breakfast
Plaza Foyer - Plaza Level

9:00 AM - 11:05 AM
Concurrent Sessions
ANALCO: Session 1
Broadway III/IV - Plaza Level
CP10 Session 4A
Grand Ballroom I - Ballroom Level
CP11 Session 4B
Galleria North - Ballroom Level
CP12 Session 4C
Galleria South - Ballroom Level

11:05 AM - 11:30 AM
Coffee Break
Plaza Foyer - Plaza Level

11:30 AM - 12:30 PM
IP2 Recent Developments in the Sparse Fourier Transform
Piotr Indyk, Massachusetts Institute of Technology, USA
Grand Ballroom I - Ballroom Level

12:30 PM - 2:00 PM
Lunch Break
Attendees on their own

2:00 PM - 4:05 PM
Concurrent Sessions
ANALCO: Session 2
Broadway III/IV - Plaza Level
CP13 Session 5A
Grand Ballroom I - Ballroom Level
CP14 Session 5B
Galleria North - Ballroom Level
CP15 Session 5C
Galleria South - Ballroom Level

4:05 PM - 4:30 PM
Coffee Break
Plaza Foyer - Plaza Level

4:30 PM - 6:35 PM
Concurrent Sessions
ANALCO: Session 3
Broadway III/IV - Plaza Level
CP16 Session 6A
Grand Ballroom I - Ballroom Level
CP17 Session 6B
Galleria North - Ballroom Level
CP18 Session 6C
Galleria South - Ballroom Level

6:35 PM - 6:45 PM
Intermission

6:45 PM - 7:45 PM
SODA Business Meeting and Awards Presentation
Grand Ballroom I - Ballroom Level
Complimentary beer and wine will be served.

Tuesday, January 7

8:00 AM - 5:00 PM
Registration
Plaza Foyer - Plaza Level

8:30 AM
Continental Breakfast
Plaza Foyer - Plaza Level

9:00 AM - 11:05 AM
Concurrent Sessions
CP19 Session 7A
Grand Ballroom I - Ballroom Level
CP20 Session 7B
Galleria North - Ballroom Level
CP21 Session 7C
Galleria South - Ballroom Level

11:05 AM - 11:30 AM
Coffee Break
Plaza Foyer - Plaza Level

11:30 AM - 12:30 PM
IP3 Interlacing Families: Mixed Characteristic Polynomials and the Kadison-Singer Problem
Daniel Spielman, Yale University, USA
Grand Ballroom I - Ballroom Level

12:30 PM - 2:00 PM
Lunch Break
Attendees on their own

2:00 PM - 4:05 PM
Concurrent Sessions
CP22 Session 8A
Grand Ballroom I - Ballroom Level
CP23 Session 8B
Galleria North - Ballroom Level
CP24 Session 8C
Galleria South - Ballroom Level

4:05 PM - 4:30 PM
Coffee Break
Plaza Foyer - Plaza Level

4:30 PM - 6:35 PM
Concurrent Sessions
CP25 Session 9A
Grand Ballroom I - Ballroom Level
CP26 Session 9B
Galleria North - Ballroom Level
CP27 Session 9C
Galleria South - Ballroom Level

Key to abbreviations and symbols

= Award Presentation
= Business Meeting
= Coffee Break
= Continental Breakfast and Luncheon
= Refreshments

SODA, ALENEX and ANALCO Program

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Algorithm Engineering & Experiments

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Notes

Final Program

Saturday, January 4

Registration
5:00 PM-8:00 PM

Room:Plaza Foyer - Plaza Level

Welcome Reception
6:00 PM-8:00 PM

Room:Plaza Foyer - Plaza Level

Sunday, January 5

Registration
8:00 AM-5:00 PM

Room:Plaza Foyer - Plaza Level

Continental Breakfast
8:30 AM

Room:Plaza Foyer - Plaza Level

Sunday, January 5

ALENEX: Session 1

9:00 AM-11:05 AM

Room:Broadway III/IV - Plaza Level

Chair: Ulrich Meyer, Goethe University Frankfurt am Main, Germany

9:00-9:20 Triangle Listing Algorithms: Back from the Diversion

Mark Ortmann and Ulrik Brandes, University of Konstanz, Germany

9:25-9:45 On the Scalability of Computing Triplet and Quartet Distances

Gerth S. Brodal, Jens Johansen, and Morten Holt, Aarhus University, Denmark

9:50-10:10 Simplifying Massive Planar Subdivisions

Jakob Truelsen, Lars Arge, and *Jungwoo Yang*, Aarhus University, Denmark

10:15-10:35 Distributed Computation of Persistent Homology

Ulrich Bauer, Michael Kerber, and Jan Reininghaus, Institute of Science and Technology, Austria

10:40-11:00 Top-K Substring Matching for Auto-Completion

Yuzuru Okajima, NEC Soft, Ltd., Japan

Sunday, January 5

CP1

Session 1A

9:00 AM-11:05 AM

Room:Grand Ballroom I - Ballroom Level

Chair: Artur Czumaj, University of Warwick, United Kingdom

9:00-9:20 A Constant Factor Approximation Algorithm for Fault-Tolerant k-Median

Mohammadtaghi Hajiaghayi, University of Maryland, College Park, USA; Wei Hu and *Jian Li*, Tsinghua University, P. R. China; Shi Li, Princeton University, USA; Barna Saha, AT&T Labs - Research, USA

9:25-9:45 Improved Approximation Algorithm for Two-Dimensional Bin Packing

Nikhil Bansal, Eindhoven University of Technology, Netherlands; *Arindam Khan*, Georgia Institute of Technology, USA

9:50-10:10 A Mazing $2+\varepsilon$ Approximation for Unsplittable Flow on a Path

Aris Anagnostopoulos, Sapienza – Università di Roma, Italy; Fabrizio Grandoni, University of Lugano, Switzerland; Stefano Leonardi, Sapienza – Università di Roma, Italy; *Andreas Wiese*, MPII Saarbrücken, Germany

10:15-10:35 Better Approximation Bounds for the Joint Replenishment Problem

Marcin Bienkowski and Jaroslaw Byrka, University of Wroclaw, Poland; *Marek Chrobak*, University of California, Riverside, USA; Lukasz Jez, Sapienza – Università di Roma, Italy; Dorian Nogneng, Ecole Polytechnique, France; Jiri Sgall, Charles University, Prague, Czech Republic

10:40-11:00 Better Algorithms and Hardness for Broadcast Scheduling Via a Discrepancy Approach

Nikhil Bansal, Eindhoven University of Technology, Netherlands; Moses Charikar, Princeton University, USA; Ravishankar Krishnaswamy, Carnegie Mellon University, USA; *Shi Li*, Princeton University, USA

Sunday, January 5

CP2

Session 1B

9:00 AM-11:05 AM

Room:Galleria North - Ballroom Level

Chair: Per Austrin, KTH Royal Institute of Technology, Sweden

9:00-9:20 An Excluded Grid Theorem for Digraphs with Forbidden Minors

Ken-ichi Kawarabayashi, National Institute of Informatics, Japan; Stephan Kreutzer, Technical University Berlin, Germany

9:25-9:45 Finding Small Patterns in Permutations in Linear Time

Sylvain Guillemot and Dániel Marx, Hungarian Academy of Sciences, Hungary

9:50-10:10 Minimum Common String Partition Parameterized by Partition Size Is Fixed-Parameter Tractable

Laurent Bulteau, Université de Nantes, France; Christian Komusiewicz, TU Berlin, Germany

10:15-10:35 Interval Deletion Is Fixed-Parameter Tractable

Yixin Cao and Dániel Marx, Hungarian Academy of Sciences, Hungary

10:40-11:00 Efficient Computation of Representative Sets with Applications in Parameterized and Exact Algorithms

Fedor Fomin and *Daniel Lokshtanov*, University of Bergen, Norway; Saket Saurabh, Institute of Mathematical Sciences, India

Sunday, January 5

CP3

Session 1C

9:00 AM-11:05 AM

Room:Galleria South - Ballroom Level

Chair: Tamal Dey, Ohio State University, USA

9:00-9:20 On the Computational Complexity of Betti Numbers: Reductions from Matrix Rank

Herbert Edelsbrunner, IST, Austria; *Salman Parsa*, Duke University, USA

9:25-9:45 Implicit Manifold Reconstruction

Siu-Wing Cheng and *Man-Kwun Chiu*, Hong Kong University of Science and Technology, Hong Kong

9:50-10:10 Approximating Local Homology from Samples

Primoz Skraba, Jozef Stefan Institute, Slovenia; Bei Wang, University of Utah, USA

10:15-10:35 Robust Satisfiability of Systems of Equations

Peter Franek, Academy of Sciences of the Czech Republic, Prague, Czech Republic; Marek Krcal, Charles University, Czech Republic

10:40-11:00 Solving 1-Laplacians of Convex Simplicial Complexes in Nearly Linear Time: Collapsing and Expanding a Topological Ball

Michael B. Cohen, Massachusetts Institute of Technology, USA; Brittany Terese Fasy, Tulane University, USA; Gary Miller and *Amir Nayyeri*, Carnegie Mellon University, USA; Richard Peng, Massachusetts Institute of Technology, USA; Noel J. Walkington, Carnegie Mellon University, USA

Coffee Break

11:05 AM-11:30 AM

Room:Plaza Foyer - Plaza Level

Sunday, January 5

IP1

Shape, Homology, Persistence, and Stability

11:30 AM-12:30 PM

Room:Grand Ballroom I - Ballroom Level

Chair: Tamal Dey, Ohio State University, USA

My personal journey to the fascinating world of geometric forms started 30 years ago with the invention of alpha shapes in the plane. It took about 10 years before we generalized the concept to higher dimensions, we produced working software with a graphics interface for the 3-dimensional case, and we added homology to the computations. Needless to say that this foreshadowed the inception of persistent homology, because it suggested the study of filtrations to capture the scale of a shape or data set. Importantly, this method has fast algorithms. The arguably most useful result on persistent homology is the stability of its diagrams under perturbations.

Herbert Edelsbrunner
Institute of Science and Technology, Austria

Luncheon **Ticketed Event**

12:30 PM-2:00 PM

Room:Grand Ballroom II - Ballroom Level

Please visit the SIAM Registration Desk if you require a ticket.

Sunday, January 5

ALENEX: Session 2

2:00 PM-4:05 PM

Room:Broadway III/IV - Plaza Level

Chair: Catherine McGeoch, Amherst College, USA

2:00-2:20 Multi-Pivot Quicksort: Theory and Experiments
Shrinu Kushagra, *Aurick Qiao*, Alejandro Lopez-Ortiz, and J. Ian Munro, University of Waterloo, Canada

2:25-2:45 A Back-to-Basics Empirical Study of Priority Queues
Daniel H. Larkin, Princeton University, USA; Siddhartha Sen, Microsoft Research, USA; Robert Tarjan, Princeton University and Microsoft Research, USA

2:50-3:10 An Exact Approach To Upward Crossing Minimization
Robert Zeranski, Friedrich-Schiller-Universität Jena, Germany; *Markus Chimani*, University of Osnabrueck, Germany

3:15-3:35 Practical Experience with Hanani-Tutte for Testing C-Planarity
Petra Mutzel, University of Dortmund, Germany; *Carsten Gutwenger*, Technische Universität Dortmund, Germany; Marcus Schaefer, DePaul University, USA

3:40-4:00 Order Constraints for Single Machine Scheduling with Non-Linear Cost
Christoph Dürr and *Oscar C. Vásquez*, Université Pierre et Marie Curie - Paris VI, France

Sunday, January 5

CP4

Session 2A

2:00 PM-4:05 PM

Room:Grand Ballroom I - Ballroom Level

Chair: James R. Lee, University of Washington, USA

2:00-2:20 An Almost-Linear-Time Algorithm for Approximate Max Flow in Undirected Graphs, and Its Multicommodity Generalizations
Jonathan Kelner, *Yin Tat Lee*, Lorenzo Orecchia, and Aaron Sidford, Massachusetts Institute of Technology, USA

2:25-2:45 Computing Cut-Based Hierarchical Decompositions in Almost Linear Time
Harald Räcke, *Chintan Shah*, and Hanjo Täubig, Technische Universität München, Germany

2:50-3:10 Near Linear Time Approximation Schemes for Uncapacitated and Capacitated B-Matching Problems in Nonbipartite Graphs
Kook Jin Ahn, Google, Inc., USA; Sudipto Guha, University of Pennsylvania, USA

3:15-3:35 Improved Bounds and Algorithms for Graph Cuts and Network Reliability
David Harris, University of Maryland, USA; Aravind Srinivasan, University of Maryland, College Park, USA

3:40-4:00 Towards (1+ε)-Approximate Flow Sparsifiers
Alexandr Andoni, Microsoft Research, USA; Anupam Gupta, Carnegie Mellon University, USA; Robert Krauthgamer, Weizmann Institute of Science, Israel

Sunday, January 5

CP5

Session 2B

2:00 PM-4:05 PM

Room:Galleria North - Ballroom Level

Chair: Petra Berenbrink, Simon Fraser University, Canada

2:00-2:20 Uniform Random Sampling of Simple Branched Coverings of the Sphere by Itself

Enrica Duchi and Dominique Poulalhon, Université Paris-Diderot, France; *Gilles Schaeffer*, CNRS & Ecole Polytechnique, France

2:25-2:45 Mcmc Sampling Colourings and Independent Sets of *G(n,d/n)* Near Uniqueness Threshold

Charilaos Efthymiou, Goethe University Frankfurt, Germany

2:50-3:10 Arboricity and Spanning-Tree Packing in Random Graphs with an Application to Load Balancing

Pu Gao, University of Toronto, Canada; *Xavier Pérez Giménez* and Cristiane M. Sato, University of Waterloo, Canada

3:15-3:35 Clustering and Mixing Times for Segregation Models on Z^2

Prateek Bhakta, Sarah Miracle, and Dana Randall, Georgia Institute of Technology, USA

3:40-4:00 A Simple FPTAS for Counting Edge Covers

Chengyu Lin and *Jingcheng Liu*, Shanghai Jiao Tong University, China; Pinyan Lu, Microsoft Research Asia

Sunday, January 5

CP6

Session 2C

2:00 PM-4:05 PM

Room:Galleria South - Ballroom Level

Chair: Per Austrin, KTH Royal Institute of Technology, Sweden

2:00-2:20 Space Complexity of List H-Coloring: a Dichotomy

Laszlo Egri, Academy of Science, Budapest, Hungary; Pavol Hell, Simon Fraser University, Canada; Benoit Larose, Concordia University, Canada; *Arash Rafiey*, Simon Fraser University, Canada

2:25-2:45 Positivity Problems for Low-Order Linear Recurrence Sequences

Joel Ouaknine and James Worrell, Oxford University, United Kingdom

2:50-3:10 Polynomial Solvability of Variants of the Trust-Region Subproblem

Daniel Bienstock and Alexander Michalka, Columbia University, USA

3:15-3:35 Polynomiality for Bin Packing with a Constant Number of Item Types

Michel Goemans and *Thomas Rothvoss*, Massachusetts Institute of Technology, USA

3:40-4:00 The Complexity of Order Type Isomorphism

Greg Aloupis, Université Libre de Bruxelles, Belgium; John Iacono, Polytechnic Institute of New York University, USA; *Stefan Langerman*, Université Libre de Bruxelles, Belgium; Ozgur Ozkan, Polytechnic Institute of New York University, USA; Stefanie Wuhrer, Saarland University, Germany

Coffee Break

4:05 PM-4:30 PM

Room:Plaza Foyer - Plaza Level

Sunday, January 5

ALENEX: Session 3

4:30 PM-6:35 PM

Room:Broadway III/IV - Plaza Level

Chair: Renato F. Werneck, Microsoft Research Silicon Valley, USA

4:30-4:50 Enumerating Fundamental Normal Surfaces: Algorithms, Experiments and Invariants

Benjamin A. Burton, University of Queensland, Australia

4:55-5:15 Connection Scan Accelerated

Ben Strasser and Dorothea Wagner, Karlsruhe Institute of Technology, Germany

5:20-5:40 Precomputation Techniques for the Stochastic on-Time Arrival Problem

Guillaume Sabran, Ecole Polytechnique, France; *Samitha Samaranayake* and Alexandre Bayen, University of California, Berkeley, USA

5:45-6:05 Fast Shortest-Path Distance Queries on Road Networks by Pruned Highway Labeling

Takuya Akiba and Yoichi Iwata, University of Tokyo, Japan; Ken-ichi Kawarabayashi, National Institute of Informatics, Japan; *Yuki Kawata*, University of Tokyo, Japan

6:10-6:30 Flow-Based Guidebook Routing

Sabine Storandt and Hannah Bast, Albert-Ludwigs-Universitat Freiburg, Germany

Sunday, January 5

CP7

Session 3A

4:30 PM-6:35 PM

Room:Grand Ballroom I - Ballroom Level

Chair: Kamesh Munagala, Duke University, USA

4:30-4:50 Dynamic Task Allocation in Asynchronous Shared Memory

Dan Alistarh, Massachusetts Institute of Technology, USA; James Aspnes, Yale University, USA; Michael A. Bender, Stony Brook University, USA; *Rati Gelashvili*, Massachusetts Institute of Technology, USA; Seth Gilbert, National University of Singapore, Singapore

4:55-5:15 Competitive Analysis Via Regularization

Niv Buchbinder, Tel Aviv University, Israel; *Shahar Chen* and Joseph (Seffi) Naor, Technion - Israel Institute of Technology, Israel

5:20-5:40 First Come First Served for Online Slot Allocation and Huffman Coding

Monik Khare, Yellowpages.com, USA; Claire Mathieu, CNRS, Ecole Normale Supérieure, France and Brown University, USA; *Neal E. Young*, University of California, Riverside, USA

5:45-6:05 Online Steiner Tree with Deletions

Anupam Gupta, Carnegie Mellon University, USA; Amit Kumar, IIT Delhi, India

6:10-6:30 Maintaining Assignments Online: Matching, Scheduling, and Flows

Anupam Gupta, Carnegie Mellon University, USA; Amit Kumar, IIT Delhi, India; *Clifford Stein*, Columbia University, USA

Sunday, January 5

CP8

Session 3B

4:30 PM-6:35 PM

Room:Galleria North - Ballroom Level

Chair: David M. Mount, University of Maryland, USA

4:30-4:50 (Nearly) Sample-Optimal Sparse Fourier Transform

Piotr Indyk, *Michael Kapralov*, and Eric Price, Massachusetts Institute of Technology, USA

4:55-5:15 Learning Sparse Polynomial Functions

Alexandr Andoni, Rina Panigrahy, Gregory Valiant, and Li Zhang, Microsoft Research, USA

5:20-5:40 Learning Entangled Single-Sample Gaussians

Flavio Chierichetti, Sapienza – Università di Roma, Italy; Anirban Dasgupta, Yahoo! Research, USA; Ravi Kumar and *Silvio Lattanzi*, Google, Inc., USA

5:45-6:05 Exploiting Metric Structure for Efficient Private Query Release

Zhiyi Huang, Stanford University, USA; Aaron Roth, University of Pennsylvania, USA

6:10-6:30 On the Compatibility of Quartet Trees

Noga Alon, Tel Aviv University, Israel; *Sagi Snir* and Raphael Yuster, University of Haifa, Israel

Sunday, January 5

CP9

Session 3C

4:30 PM-6:35 PM

Room:Galleria South - Ballroom Level

Chair: Gerth S. Brodal, Aarhus University, Denmark

4:30-4:50 A New Perspective on Vertex Connectivity

Keren Censor-Hillel, Technion - Israel Institute of Technology, Israel; *Mohsen Ghaffari*, Massachusetts Institute of Technology, USA; Fabian Kuhn, University of Freiburg, Germany

4:55-5:15 Packing A-Paths in Group-Labelled Graphs via Linear Matroid Parity

Yutaro Yamaguchi, University of Tokyo, Japan

5:20-5:40 Independent Set in P_5-Free Graphs in Polynomial Time

Daniel Lokshtanov, *Martin Vatshelle*, and Yngve Villanger, University of Bergen, Norway

5:45-6:05 Large Induced Subgraphs Via Triangulations and CMSO

Fedor Fomin, University of Bergen, Norway; *Ioan Todinca*, Universite d'Orleans, France; Yngve Villanger, University of Bergen, Norway

6:10-6:30 Counting Thin Subgraphs Via Packings Faster Than Meet-in-the-Middle Time

Andreas Björklund, Lund University, Sweden; *Petteri Kaski*, Aalto University, Finland; Lukasz Kowalik, University of Warsaw, Poland

Intermission

6:35 PM-6:45 PM

ALENEX and ANALCO Business Meeting

6:45 PM-7:45 PM

Room:Broadway III/IV - Plaza Level

Monday, January 6

Registration

8:00 AM-5:00 PM

Room:Plaza Foyer - Plaza Level

Continental Breakfast

8:30 AM

Room:Plaza Foyer - Plaza Level

ANALCO: Session 1

9:00 AM-10:40 AM

Room:Broadway III/IV - Plaza Level

Chair: Hosam M. Mahmoud, George Washington University, USA

9:00-9:20 Typical Depth of a Digital Search Tree Built on a General Source

Brigitte Vallee and Kanal Hun, CNRS, GREYC Laboratory, France

9:25-9:45 Expected External Profile of Patricia Tries

Abram Magner, Purdue University, USA; Charles Knessl, University of Illinois, Chicago, USA; Wojciech Szpankowski, Purdue University, USA

9:50-10:10 On the Asymptotic Number of *BCK(2)*-Terms

Olivier Bodini, Université Paris XIII, France; Bernhard Gittenberger, Technische Universitaet Wien, Austria

10:15-10:35 A Statistical View on Exchanges in Quickselect

Benjamin Dadoun, École Normale Supérieure de Cachan, France; Ralph Neininger, J.W. Goethe-Universität, Germany

Monday, January 6

CP10

Session 4A

9:00 AM-11:05 AM

Room:Grand Ballroom I - Ballroom Level

Chair: Kamesh Munagala, Duke University, USA

9:00-9:20 Polynomial Time Approximation Schemes for the Traveling Repairman and Other Minimum Latency Problems

Rene A. Sitters, Vrije Universiteit Amsterdam, The Netherlands

9:25-9:45 Approximating k-Center in Planar Graphs

David Eisenstat and *Philip Klein*, Brown University, USA; Claire Mathieu, CNRS, Ecole Normale Supérieure, France and Brown University, USA

9:50-10:10 A Polynomial-Time Approximation Scheme for Fault-Tolerant Distributed Storage

Constantinos Daskalakis, Massachusetts Institute of Technology, USA; Anindya De, Simons Institute, USA; *Ilias Diakonikolas*, University of Edinburgh, United Kingdom; Ankur Moitra, Massachusetts Institute of Technology, USA; Rocco A. Servedio, Columbia University, USA

10:15-10:35 A QPTAS for Maximum Weight Independent Set of Polygons with Polylogarithmically Many Vertices

Anna Adamaszek and Andreas Wiese, MPII Saarbrücken, Germany

10:40-11:00 On the Optimality of Approximation Schemes for the Classical Scheduling Problem

Lin Chen, Zhejiang University, China; Klaus Jansen, University of Kiel, Germany; Guochuan Zhang, Zhejiang University, China

Monday, January 6

CP11

Session 4B

9:00 AM-11:05 AM

Room:Galleria North - Ballroom Level

Chair: Gerth S. Brodal, Aarhus University, Denmark

9:00-9:20 Improved Concentration Bounds for Count-Sketch

Gregory Minton and *Eric Price*, Massachusetts Institute of Technology, USA

9:25-9:45 Annotations for Sparse Data Streams

Amit Chakrabarti, Dartmouth College, USA; Graham Cormode, University of Warwick, United Kingdom; Navin Goyal, Microsoft Research, India; *Justin Thaler*, University of California, Berkeley, USA

9:50-10:10 Relative Errors for Deterministic Low-Rank Matrix Approximations

Mina Ghashami and Jeff Phillips, University of Utah, USA

10:15-10:35 An Optimal Lower Bound for Distinct Elements in the Message Passing Model

David Woodruff, IBM Almaden Research Center, USA; *Qin Zhang*, Indiana University Bloomington, USA

10:40-11:00 Approximating Matching Size from Random Streams

Michael Kapralov, Massachusetts Institute of Technology, USA; Sanjeev Khanna, University of Pennsylvania, USA; Madhu Sudan, Microsoft Research New England, USA

Monday, January 6

CP12

Session 4C

9:00 AM-11:05 AM

Room:Galleria South - Ballroom Level

Chair: Petra Berenbrink, Simon Fraser University, Canada

9:00-9:20 Intrinsic Universality in Tile Self-Assembly Requires Cooperation

Pierre-Etienne Meunier, California Institute of Technology, USA; Matthew Patitz, University of Arkansas, USA; Scott Summers, University of Wisconsin, Oshkosh, USA; Guillaume Theyssier, Universite de Savoie, France; *Andrew Winslow*, Tufts University, USA; Damien Woods, California Institute of Technology, USA

9:25-9:45 Timing in Chemical Reaction Networks

David Doty, California Institute of Technology, USA

9:50-10:10 Faster Agreement Via a Spectral Method for Detecting Malicious Behavior

Valerie King, University of Victoria, Canada; *Jared Saia*, University of New Mexico, USA

10:15-10:35 Tight Bounds for Rumor Spreading with Vertex Expansion

George Giakkoupis, INRIA, France

10:40-11:00 Tight Lower Bounds for Greedy Routing in Higher-Dimensional Small-World Grids

Martin Dietzfelbinger, Technische Universität Ilmenau, Germany; Philipp Woelfel, University of Calgary, Canada

Coffee Break

11:05 AM-11:30 AM

Room:Plaza Foyer - Plaza Level

Monday, January 6

IP2

Recent Developments in the Sparse Fourier Transform

11:30 AM-12:30 PM

Room:Grand Ballroom I - Ballroom Level

Chair: Chandra Chekuri, University of Illinois at Urbana-Champaign, USA

The Fast Fourier Transform (FFT) is a widely used numerical algorithm. It computes the Discrete Fourier Transform (DFT) of an n-dimensional signal in O(n log n) time. It is not known whether its running time can be improved. However, in many applications, most of the Fourier coefficients of a signal are “small” or equal to zero, i.e., the output of the transform is (approximately) sparse. In this case, it is known that one can compute the set of non-zero coefficients much faster, even in sub-linear time. In this talk I will give an overview of recent highly efficient algorithms for computing the Sparse Fourier Transform. I will also give a few examples of applications impacted by these developments.

Piotr Indyk

Massachusetts Institute of Technology, USA

Lunch Break

12:30 PM-2:00 PM

Attendees on their own

Monday, January 6

ANALCO: Session 2

2:00 PM-3:40 PM

Room:Broadway III/IV - Plaza Level

Chair: Michael Drmota, Technische Universitat Vienna, Austria

2:00-2:20 A Bijection for Plane Graphs and Its Applications

Gwendal Collet, Ecole Polytechnique, France; Olivier Bernardi, Brandeis University, USA; Eric Fusy, Ecole Polytechnique, France

2:25-2:45 Clump Combinatorics, Automata, and Word Asymptotics

Mireille A. Regnier, INRIA, France; Billy Fang, Princeton University, USA; *Daria Iakovishina*, Ecole Polytechnique, France

2:50-3:10 Permuted Random Walk Exits Typically in Linear Time.

Shirshendu Ganguly, University of Washington, USA; Yuval Peres, Microsoft Research, USA

3:15-3:35 Tight Analysis of Randomized Rumor Spreading in Complete Graphs

Marvin Künnemann and Benjamin Doerr, Max-Planck-Institut fuer Informatik, Germany

Monday, January 6

CP13

Session 5A

2:00 PM-4:05 PM

Room:Grand Ballroom I - Ballroom Level

Chair: James R. Lee, University of Washington, USA

2:00-2:20 On the Lattice Isomorphism Problem

Ishay Haviv, Academic College of Tel-Aviv, Israel; Oded Regev, New York University, USA

2:25-2:45 Integer Quadratic Programming in the Plane

Alberto Del Pia, IBM T.J. Watson Research Center, USA; Robert Weismantel, ETH Zürich, Switzerland

2:50-3:10 Dantzig's Pivoting Rule for Shortest Paths, Deterministic Mdps, and Minimum Cost to Time Ratio Cycles

Thomas D. Hansen, Stanford University, USA; Haim Kaplan and Uri Zwick, Tel Aviv University, Israel

3:15-3:35 Optimization Despite Chaos: Convex Relaxations to Complex Limit Sets Via Poincaré Recurrence

Georgios Piliouras and Jeff S. Shamma, Georgia Institute of Technology, USA

3:40-4:00 Improved Upper Bounds for Random-Edge and Random-Jump on Abstract Cubes

Thomas D. Hansen, Stanford University, USA; Mike Paterson, University of Warwick, United Kingdom; Uri Zwick, Tel Aviv University, Israel

Monday, January 6

CP14

Session 5B

2:00 PM-4:05 PM

Room:Galleria North - Ballroom Level

Chair: Per Austrin, KTH Royal Institute of Technology, Sweden

2:00-2:20 Smoothed Analysis of Local Search for the Maximum-Cut Problem

Michael Etscheid and Heiko Röglin, University of Bonn, Germany

2:25-2:45 Bilu-Linial Stable Instances of Max Cut and Minimum Multiway Cut

Konstantin Makarychev, Microsoft Research, USA; *Yury Makarychev*, Toyota Technological Institute at Chicago, USA; Aravindan Vijayaraghavan, Carnegie Mellon University, USA

2:50-3:10 A Constructive Algorithm for the Lovász Local Lemma on Permutations

David Harris, University of Maryland, USA; Aravind Srinivasan, University of Maryland, College Park, USA

3:15-3:35 Pipage Rounding, Pessimistic Estimators and Matrix Concentration

Nicholas Harvey, University of British Columbia, Canada; *Neil Olver,* VU University, Amsterdam, Netherlands

3:40-4:00 Maximizing Social Influence in Nearly Optimal Time

Christian Borgs, Microsoft Research, USA; Michael Brautbar, Massachusetts Institute of Technology, USA; Jennifer Chayes and *Brendan Lucier*, Microsoft Research, USA

Monday, January 6

CP15

Session 5C

2:00 PM-4:05 PM

Room:Galleria South - Ballroom Level

Chair: Tamal Dey, Ohio State University, USA

2:00-2:20 Cache-Adaptive Algorithms

Roozbeh Ebrahimi, Stony Brook University, USA

2:25-2:45 Near-Optimal Labeling Schemes for Nearest Common Ancestors

Stephen Alstrup and *Esben B. Halvorsen*, University of Copenhagen, Denmark; Kasper G. Larsen, Aarhus University, Denmark

2:50-3:10 Concurrent Range Reporting in Two-Dimensional Space

Peyman Afshani, Aarhus University, Denmark; Cheng Sheng and Yufei Tao, Chinese University of Hong Kong, Hong Kong; *Bryan T. Wilkinson*, Aarhus University, Denmark

3:15-3:35 Selection and Sorting in the 'Restore' Model

Timothy M. Chan and *J. Ian Munro*, University of Waterloo, Canada; Venkatesh Raman, Institute of Mathematical Sciences, India

3:40-4:00 Disjoint Set Union with Randomized Linking

Ashish Goel, Stanford University, USA; Sanjeev Khanna, University of Pennsylvania, USA; Daniel H. Larkin, Princeton University, USA; *Robert E. Tarjan*, Princeton University and Microsoft Research, USA

Coffee Break

4:05 PM-4:30 PM

Room:Plaza Foyer - Plaza Level

Monday, January 6

ANALCO: Session 3

4:30 PM-6:10 PM

Room:Broadway III/IV - Plaza Level

Chair: Mark Daniel Ward, Purdue University, USA

4:30-4:50 Small Superpatterns for Dominance Drawing

Michael J. Bannister, *William Devanny*, and David Eppstein, University of California, Irvine, USA

4:55-5:15 On The Average-Case Complexity of the Bottleneck Tower of Hanoi Problem

Shay Solomon, Weizmann Institute of Science, Israel; Noam Solomon, Tel Aviv University, Israel

5:20-5:40 Survivors in Leader Election Algorithms

Ravi Kalpathy and *Hosam M. Mahmoud*, George Washington University, USA; Walter Rosenkrantz, University of Massachusetts, Amherst, USA

5:45-6:05 On the Average Number of Edges in Theta Graphs

Pat Morin and Sander Verdonschot, Carleton University, Canada

Monday, January 6

CP16

Session 6A

4:30 PM-6:35 PM

Room:Grand Ballroom I - Ballroom Level

Chair: David M. Mount, University of Maryland, USA

4:30-4:50 Beyond Locality-Sensitive Hashing

Alexandr Andoni, Microsoft Research, USA; Piotr Indyk, Massachusetts Institute of Technology, USA; Huy Nguyen, Princeton University, USA; *Ilya Razenshteyn*, Massachusetts Institute of Technology, USA

4:55-5:15 Cutting Corners Cheaply, Or How to Remove Steiner Points

Lior Kamma and Robert Krauthgamer, Weizmann Institute of Science, Israel; Huy Nguyen, Princeton University, USA

5:20-5:40 Better Approximation Algorithms for the Graph Diameter

Shiri Chechik, Microsoft Research, USA; Daniel H. Larkin, Princeton University, USA; Liam Roditty, Bar-Ilan University, Israel; Grant Schoenebeck, University of Michigan, USA; Robert E. Tarjan, Princeton University and Microsoft Research, USA; Virginia Vassilevska Williams, Stanford University, USA

5:45-6:05 A Subquadratic-Time Algorithm for Decremental Single-Source Shortest Paths

Monika Henzinger and *Sebastian Krinninger*, University of Vienna, Austria; Danupon Nanongkai, Nanyang Technological University, Singapore

6:10-6:30 Fault Tolerant Approximate BFS Structures

Merav Parter and David Peleg, Weizmann Institute of Science, Israel

Monday, January 6

CP17

Session 6B

4:30 PM-6:35 PM

Room:Galleria North - Ballroom Level

Chair: Kamesh Munagala, Duke University, USA

4:30-4:50 New Approximations for Reordering Buffer Management

Sungjin Im, University of California, Merced, USA; *Benjamin Moseley*, Toyota Technological Institute at Chicago, USA

4:55-5:15 Ranking on Arbitrary Graphs: Rematch via Continuous LP with Monotone and Boundary Condition Constraints

T-H. Hubert Chan, Fei Chen, Xiaowei Wu, and Zhichao Zhao, University of Hong Kong, China

5:20-5:40 Primal Dual Gives Almost Optimal Energy Efficient Online Algorithms

Nikhil R. Devanur, Microsoft Research, USA; *Zhiyi Huang*, Stanford University, USA

5:45-6:05 Hallucination Helps: Energy Efficient Virtual Circuit Routing

Antonios Antoniadis, University of Pittsburgh, USA; Sungjin Im, Duke University, USA; *Ravishankar Krishnaswamy*, Princeton University, USA; Benjamin Moseley, Toyota Technological Institute at Chicago, USA; Viswanath Nagarajan, IBM T.J. Watson Research Center, USA; Kirk Pruhs, University of Pittsburgh, USA; Cliff Stein, Columbia University, USA

6:10-6:30 Improvements and Generalizations of Stochastic Knapsack and Multi-Armed Bandit Approximation Algorithms

Will Ma, Massachusetts Institute of Technology, USA

Monday, January 6

CP18

Session 6C

4:30 PM-6:35 PM

Room:Galleria South - Ballroom Level

Chair: Artur Czumaj, University of Warwick, United Kingdom

4:30-4:50 Hereditary Properties of Permutations Are Strongly Testable

Tereza Klimosova and Daniel Kral, University of Warwick, United Kingdom

4:55-5:15 Testing Equivalence Between Distributions Using Conditional Samples

Clément Canonne, Columbia University, USA; Dana Ron, Tel Aviv University, Israel; Rocco A. Servedio, Columbia University, USA

5:20-5:40 Optimal Algorithms for Testing Closeness of Discrete Distributions

Siu On Chan, Microsoft Research New England, USA; *Ilias Diakonikolas*, University of Edinburgh, United Kingdom; Gregory Valiant, Stanford University, USA; Paul Valiant, Brown University, USA

5:45-6:05 Testing Surface Area

Pravesh Kothari, University of Texas at Austin, USA; Amir Nayyeri and Ryan O'Donnell, Carnegie Mellon University, USA; *Chenggang Wu*, Tsinghua University, P. R. China

6:10-6:30 A Cubic Algorithm for Computing Gaussian Volume

Ben Cousins and Santosh Vempala, Georgia Institute of Technology, USA

Intermission

6:35 PM-6:45 PM

SODA Business Meeting and Awards Presentation

6:45 PM-7:45 PM

Room:Grand Ballroom I - Ballroom Level

See page 6 for Paper Award details.

Complimentary beer and wine will be served.

Tuesday, January 7

Registration

8:00 AM-5:00 PM

Room:Plaza Foyer - Plaza Level

Continental Breakfast

8:30 AM

Room:Plaza Foyer - Plaza Level

CP19

Session 7A

9:00 AM-11:05 AM

Room:Grand Ballroom I - Ballroom Level

Chair: Artur Czumaj, University of Warwick, United Kingdom

9:00-9:20 Non-Uniform Graph Partitioning

Robert Krauthgamer, Weizmann Institute of Science, Israel; Seffi Naor, Technion - Israel Institute of Technology, Israel; *Roy Schwartz*, Microsoft Research, USA; Kunal Talwar, Microsoft Research Silicon Valley, USA

9:25-9:45 Approximation Algorithm for Sparsest K-Partitioning

Anand Louis, Georgia Institute of Technology, USA; Konstantin Makarychev, Microsoft Research, USA

9:50-10:10 Partitioning into Expanders

Shayan Oveis Gharan, University of California, Berkeley, USA; Luca Trevisan, Stanford University, USA

10:15-10:35 Flow-Based Algorithms for Local Graph Clustering

Lorenzo Orecchia and Zeyuan Allen Zhu, Massachusetts Institute of Technology, USA

10:40-11:00 Streaming Balanced Graph Partitioning Algorithms for Random Graphs

Isabelle Stanton, Google, Inc., USA

Tuesday, January 7

CP20

Session 7B

9:00 AM-11:05 AM

Room:Galleria North - Ballroom Level

Chair: Nitish Korula, Google Research, USA

9:00-9:20 The Complexity of Optimal Mechanism Design

Costis Daskalakis, Alan Deckelbaum, and *Christos Tzamos*, Massachusetts Institute of Technology, USA

9:25-9:45 The Complexity of Optimal Multidimensional Pricing

Xi Chen, Columbia University, USA; Ilias Diakonikolas, University of Edinburgh, United Kingdom; *Dimitris Paparas*, Xiaorui Sun, and Mihalis Yannakakis, Columbia University, USA

9:50-10:10 On Computability of Equilibria in Markets with Production

Jugal Garg and Vijay V. Vazirani, Georgia Institute of Technology, USA

10:15-10:35 Constrained Signaling in Auction Design

Shaddin Dughmi, University of Southern California, USA; Nicole Immorlica, Northwestern University, USA; Aaron Roth, University of Pennsylvania, USA

10:40-11:00 Prophet Inequalities with Limited Information

Pablo Azar, Massachusetts Institute of Technology, USA; Robert Kleinberg, Cornell University, USA; *Matt Weinberg*, Massachusetts Institute of Technology, USA

Tuesday, January 7

CP21

Session 7C

9:00 AM-11:05 AM

Room:Galleria South - Ballroom Level

Chair: David M. Mount, University of Maryland, USA

9:00-9:20 A Size-Sensitive Discrepancy Bound for Set Systems of Bounded Primal Shatter Dimension

Esther Ezra, Courant Institute of Mathematical Sciences, New York University, USA

9:25-9:45 Optimal Deterministic Shallow Cuttings for 3D Dominance Ranges

Peyman Afshani, Aarhus University, Denmark; Konstantinos A. Tsakalidis, Hong Kong University of Science and Technology, Hong Kong

9:50-10:10 Four Soviets Walk the Dog---with An Application to Alt's Conjecture

Kevin Buchin, TU Eindhoven, The Netherlands; Maike Buchin, Ruhr-Universität Bochum, Germany; *Wouter Meulemans*, TU Eindhoven, The Netherlands; Wolfgang J. Mulzer, Freie Universitaet Berlin, Germany

10:15-10:35 Fast Computation of Output-Sensitive Maxima in a Word Ram

Peyman Afshani, Aarhus University, Denmark

10:40-11:00 Making Octants Colorful and Related Covering Decomposition Problems

Jean Cardinal, Université Libre de Bruxelles, Belgium; Kolja Knauer, Université Montpellier II, France; Piotr Micek, Jagiellonian University, Poland; Torsten Ueckerdt, Karlsruhe Institute of Technology, Germany

Coffee Break

11:05 AM-11:30 AM

Room:Plaza Foyer - Plaza Level

Tuesday, January 7

IP3

Interlacing Families: Mixed Characteristic Polynomials and the Kadison-Singer Problem

11:30 AM-12:30 PM

Room:Grand Ballroom I - Ballroom Level

Chair: James Lee, University of Washington, USA

We introduce a new technique for demonstrating the existence of combinatorial objects that we call the "Method of Interlacing Polynomials". We then use this technique to prove a conjecture in discrepancy theory posed by Nik Weaver. Weaver's conjecture implies the truth of the Paving Conjecture of Akemann and Anderson, which in turn provides a solution to the fifty year old problem of Kadison and Singer. Our main technical result is an upper bound on the largest root of the expected characteristic polynomial of a sum of random symmetric rank-1 matrices. We use this bound to prove that there exists a balanced partition of certain sets of vectors. This result can be viewed as a strengthening of the "matrix Chernoff bounds" of Ahlswede and Winter, Rudelson and Vershynin, and Tropp. This is joint work with Adam Marcus and Nikhil Srivastava.

Daniel Spielman
Yale University, USA

Lunch Break

12:30 PM-2:00 PM

Attendees on their own

Tuesday, January 7

CP22

Session 8A

2:00 PM-4:05 PM

Room:Grand Ballroom I - Ballroom Level

Chair: Alina Ene, Princeton University, USA

2:00-2:20 Submodular Maximization with Cardinality Constraints

Niv Buchbinder, Tel Aviv University, Israel; *Moran Feldman*, EPFL, Switzerland; Joseph Naor, Technion - Israel Institute of Technology, Israel; Roy Schwartz, Microsoft Research, USA

2:25-2:45 Approximation Algorithms for Stochastic Boolean Function Evaluation and Stochastic Submodular Set Cover

Amol Deshpande, University of Maryland, USA; Lisa Hellerstein and *Devorah Kletenik*, Polytechnic Institute of New York University, USA

2:50-3:10 Maximizing Bisubmodular and k-Submodular Functions

Justin Ward, University of Warwick, United Kingdom; Stanislav Zivny, University of Oxford, United Kingdom

3:15-3:35 Influence Maximization in Undirected Networks

Sanjeev Khanna, University of Pennsylvania, USA; *Brendan Lucier*, Microsoft Research, USA

3:40-4:00 Fast Algorithms for Maximizing Submodular Functions

Ashwinkumar Badanidiyuru, Cornell University, USA; Jan Vondrak, IBM Almaden Research Center, USA

Tuesday, January 7

CP23

Session 8B

2:00 PM-4:05 PM

Room:Galleria North - Ballroom Level

Chair: Gerth S. Brodal, Aarhus University, Denmark

2:00-2:20 New Constructions of RIP Matrices with Fast Multiplication and Fewer Rows

Jelani Nelson, Harvard University, USA; Eric Price, Massachusetts Institute of Technology, USA; *Mary Wootters*, University of Michigan, USA

2:25-2:45 Model-Based Sketching and Recovery with Expanders

Bubacarr Bah, Luca Baldassarre, and Volkan Cevher, École Polytechnique Fédérale de Lausanne, Switzerland

2:50-3:10 Approximation-Tolerant Model-Based Compressive Sensing

Chinmay Hegde, Piotr Indyk, and *Ludwig Schmidt*, Massachusetts Institute of Technology, USA

3:15-3:35 On Sketching Matrix Norms and the Top Singular Vector

Yi Li, University of Michigan, USA; Huy Nguyen, Princeton University, USA; David Woodruff, IBM Almaden Research Center, USA

3:40-4:00 Bicriteria Data Compression

Andrea Farruggia, Paolo Ferragina, Antonio Frangioni, and Rossano Venturini, University of Pisa, Italy

Tuesday, January 7

CP24

Session 8C

2:00 PM-4:05 PM

Room:Galleria South - Ballroom Level

Chair: Petra Berenbrink, Simon Fraser University, Canada

2:00-2:20 Point Line Cover: The Easy Kernel Is Essentially Tight

Stefan Kratsch, Technical University Berlin, Germany; Geevarghese Philip, Max Planck Institute for Informatics, Germany; Saurabh Ray, Ben Gurion University, Israel

2:25-2:45 Hardness of Finding Independent Sets in 2-Colorable and Almost 2-Colorable Hypergraphs

Rishi Saket, IBM T.J. Watson Research Center, USA; Subhash Khot, New York University, USA

2:50-3:10 Parameters of Two-Prover-One-Round Game and The Hardness of Connectivity Problems

Bundit Laekhanukit, McGill University, Canada

3:15-3:35 Hypercontractive Inequalities Via SOS, and the Frankl-Rodl Graph

Manuel Kauers, RISC, Austria; Ryan O'Donnell, Carnegie Mellon University, USA; Li-Yang Tan, Columbia University, USA; *Yuan Zhou*, Carnegie Mellon University, USA

3:40-4:00 Hardness of Robust Graph Isomorphism, Lasserre Gaps, and Asymmetry of Random Graphs

Ryan O'Donnell and *John Wright*, Carnegie Mellon University, USA; Chenggang Wu, Tsinghua University, P. R. China; Yuan Zhou, Carnegie Mellon University, USA

Coffee Break

4:05 PM-4:30 PM

Room:Plaza Foyer - Plaza Level

Tuesday, January 7

CP25

Session 9A

4:30 PM-6:35 PM

Room:Grand Ballroom I - Ballroom Level

Chair: Bruce Shepherd, McGill University, Canada

4:30-4:50 The Generalized Terminal Backup Problem

Attila Bernath, University of Warsaw, Poland; *Yusuke Kobayashi*, University of Tokyo, Japan

4:55-5:15 Approximating Minimum Cost Connectivity Orientation and Augmentation

Mohit Singh, Microsoft Research, USA; Laszlo Vegh, London School of Economics, United Kingdom

5:20-5:40 Analyzing the Optimal Neighborhood: Algorithms for Budgeted and Partial Connected Dominating Set Problems

Samir Khuller, Manish Purohit, and *Kanthi K. Sarpatwar*, University of Maryland, College Park, USA

5:45-6:05 Improved Algorithms for Vertex Cover with Hard Capacities on Multigraphs and Hypergraphs

Wang Chi Cheung, Michel Goemans, and *Sam Chiu-Wai Wong*, Massachusetts Institute of Technology, USA

6:10-6:30 Minimum *d*-Dimensional Arrangement with Fixed Points

Anupam Gupta, Carnegie Mellon University, USA; *Anastasios Sidiropoulos*, Ohio State University, USA

Tuesday, January 7

CP26

Session 9B

4:30 PM-6:35 PM

Room:Galleria North - Ballroom Level

Chair: Per Austrin, KTH Royal Institute of Technology, Sweden

4:30-4:40 Linear Time Parameterized Algorithms Via Skew-Symmetric Multicuts

Ramanujan M. S., University of Bergen, Norway; Saket Saurabh, Institute of Mathematical Sciences, India

4:40-4:50 Linear-Time FPT Algorithms via Network Flow

Yoichi Iwata and Keigo Oka, University of Tokyo, Japan; Yuichi Yoshida, National Institute of Informatics, Japan

4:55-5:15 Half-Integrality, LP-Branching and FPT Algorithms

Magnus Wahlström, Royal Holloway, University of London, United Kingdom

5:20-5:40 Tight Bounds for Planar Strongly Connected Steiner Subgraph with Fixed Number of Terminals (and Extensions)

Rajesh H. Chitnis and MohammadTaghi Hajiaghayi, University of Maryland, College Park, USA; Daniel Marx, Hungarian Academy of Sciences, Hungary

5:45-6:05 A Near-Optimal Planarization Algorithm

Bart M. P. Jansen and Daniel Lokshtanov, University of Bergen, Norway; Saket Saurabh, Institute of Mathematical Sciences, India

6:10-6:30 A Subexponential Parameterized Algorithm for Subset TSP on Planar Graphs

Philip Klein, Brown University, USA; *Dániel Marx*, Hungarian Academy of Sciences, Hungary

Tuesday, January 7

CP27

Session 9C

4:30 PM-6:35 PM

Room:Galleria South - Ballroom Level

Chair: James R. Lee,University of Washington, USA

4:30-4:50 Broadcast Throughput in Radio Networks: Routing Vs. Network Coding

Noga Alon, Tel Aviv University, Israel; *Mohsen Ghaffari* and Bernhard Haeupler, Massachusetts Institute of Technology, USA; Majid Khabbazian, University of Alberta, Canada

4:55-5:15 Causal Erasure Channels

Raef Bassily and Adam Smith, Pennsylvania State University, USA

5:20-5:40 Optimal Rate List Decoding of Folded Algebraic-Geometric Codes over Constant-Sized Alphabets

Venkatesan Guruswami, Carnegie Mellon University, USA; Chaoping Xing, NTU Singapore, Singapore

5:45-6:05 Finding Orthogonal Vectors in Discrete Structures

Ryan Williams and *Huacheng Yu*, Stanford University, USA

6:10-6:30 Efficient Quantum Protocols for XOR Functions

Shengyu Zhang, Chinese University of Hong Kong, Hong Kong

Abstracts

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ANALCO14 Meeting on Analytic Algorithmics and Combinatorics

January 6, 2014
Hilton Portland & Executive Tower
Portland, Oregon, USA

ALENEX14

Meeting on
Algorithm Engineering & Experiments

January 5, 2014
Hilton Portland & Executive Tower
Portland, Oregon, USA

Abstracts for ALENEX and ANALCO appear in the beginning of the section, under "CP0", and are alphabetized by the speaker's last name.

Abstracts are printed as submitted by the authors.

IP1

Shape, Homology, Persistence, and Stability

My personal journey to the fascinating world of geometric forms started 30 years ago with the invention of alpha shapes in the plane. It took about 10 years before we generalized the concept to higher dimensions, we produced working software with a graphics interface for the 3-dimensional case, and we added homology to the computations. Needless to say that this foreshadowed the inception of persistent homology, because it suggested the study of filtrations to capture the scale of a shape or data set. Importantly, this method has fast algorithms. The arguably most useful result on persistent homology is the stability of its diagrams under perturbations.

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IP2

Recent Developments in the Sparse Fourier Transform

The Fast Fourier Transform (FFT) is a widely used numerical algorithm. It computes the Discrete Fourier Transform (DFT) of an n-dimensional signal in O(n log n) time. It is not known whether its running time can be improved. However, in many applications, most of the Fourier coefficients of a signal are "small" or equal to zero, i.e., the output of the transform is (approximately) sparse. In this case, it is known that one can compute the set of non-zero coefficients much faster, even in sub-linear time. In this talk I will give an overview of recent highly efficient algorithms for computing the Sparse Fourier Transform. I will also give a few examples of applications impacted by these developments.

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IP3

Interlacing Families: Mixed Characteristic Polynomials and the Kadison-Singer Problem

We introduce a new technique for demonstrating the existence of combinatorial objects that we call the "Method of Interlacing Polynomials'. We then use this technique to prove a conjecture in discrepancy theory posed by Nik Weaver. Weaver's conjecture implies the truth of the Paving Conjecture of Akemann and Anderson, which in turn provides a solution to the fifty year old problem of Kadison and Singer. Our main technical result is an upper bound on the largest root of the expected characteristic polynomial of a sum of random symmetric rank-1 matrices. We use this bound to prove that there exists a balanced partition of certain sets of vectors. This result can be viewed as a strengthening of the "matrix Chernoff bounds" of Ahlswede and Winter, Rudelson and Vershynin, and Tropp. This is joint work with Adam Marcus and Nikhil Srivastava.

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CP0

Distributed Computation of Persistent Homology

Advances in algorithms for computing persistent homology have reduced the computation time drastically – as long as the algorithm does not exhaust the available memory. Following up on a recently presented parallel method for persistence computation on shared memory systems, we demonstrate that a simple adaption of the standard reduction algorithm leads to a variant for distributed systems. Our algorithmic design ensures that the data is distributed over the nodes without redundancy; this permits the computation of much larger instances than on a single machine. The parallelism often speeds up the computation compared to sequential and even parallel shared memory algorithms. In our experiments, we were able to compute the persistent homology of filtrations with more than a billion (10^9) elements within seconds on a cluster with 32 nodes using less than 10GB of memory per node.

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CP0

On the Asymptotic Number of $BCK(2)$-Terms

We investigate the asymptotic number of a particular class of closed lambda-terms. This class is a generalization of a class of terms related to the axiom system BCK which is well known in combinatory logic. We determine the asymptotic number of terms, when their size tends to infinity, up to a constant multiplicative factor and discover a surprising asymptotic behaviour involving an exponential with fractional powers in the exponent.

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CP0

On the Scalability of Computing Triplet and Quartet Distances

We present an experimental evaluation of the algorithms by Brodal *et al.* [SODA 2013] for computing the triplet and quartet distance measures between two leaf labelled rooted and unrooted trees of arbitrary degree, respectively. In our experimental evaluation of the algorithms the typical overhead is about 2 KB and 10 KB per node in the input trees for triplet and quartet computations, respectively. This allows us to compute the distance measures for trees with up to millions of nodes.

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CP0

Enumerating Fundamental Normal Surfaces: Algorithms, Experiments and Invariants

Computational knot theory and 3-manifold topology have seen significant breakthroughs in recent years, despite the fact that many key algorithms have complexity bounds that are exponential or greater. In this setting, experimentation is essential for understanding the limits of practicality, as well as for gauging the relative merits of competing algorithms. Here we focus on normal surface theory, a key tool in low-dimensional computational topology. In particular, we aim to compute fundamental normal surfaces, which form an integral basis for a high-dimensional polyhedral cone. We develop, implement and experimentally compare a primal and a dual algorithm, both of which combine domain-specific techniques with classical Hilbert basis algorithms. Our experiments indicate that we can solve extremely large problems that were once though intractable. As a practical application, we fill gaps from the KnotInfo database by computing 398 previously-unknown crosscap numbers of knots.

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CP0

An Exact Approach To Upward Crossing Minimization

The upward crossing number problem asks for a drawing of the graph into the plane with the minimum number of edge crossings where the edges are drawn as monotonously increasing curves w.r.t. the y-axis. While there is a large body of work on solving this central graph drawing problem heuristically, we present the first approach to solve the problem to proven optimality. Our approach is based on a reformulation of the problem as a boolean formula that can be iteratively tightened and resolved. In our experiments, we show the practical applicability and limits of our approach.

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CP0

A Bijection for Plane Graphs and Its Applications

This paper is concerned with the counting and random sampling of plane graphs (simple planar graphs embedded in the plane). Our main result is a bijection between the class of plane graphs with triangular outer face, and a class of oriented binary trees. The number of edges and vertices of the plane graph can be tracked through the bijection.

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CP0

A Statistical View on Exchanges in Quickselect

In this paper we study the number of key exchanges required by Hoare's FIND algorithm (also called Quickselect) when operating on a uniformly distributed random permutation and selecting an independent uniformly distributed rank. After normalization we give a limit theorem where the limit law is a perpetuity characterized by a recursive distributional equation. To make the limit theorem usable for statistical methods and statistical experiments we provide an explicit rate of convergence in the Kolmogorov–Smirnov metric, a numerical table of the limit law's distribution function and an algorithm for exact simulation from the limit distribution. We also investigate the limit law's density. This case study provides a program applicable to other cost measures, alternative models for the rank selected and more balanced choices of the pivot element such as median-of-$2t+1$ versions of Quickselect as well as further variations of the algorithm.

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CP0

Small Superpatterns for Dominance Drawing

We exploit the connection between dominance drawings of directed acyclic graphs and permutations, in both directions, to provide improved bounds on the size of universal point sets for certain types of dominance drawing and on superpatterns for certain natural classes of permutations. In particular we show that there exist universal point sets for dominance drawings of the Hasse diagrams of width-two partial orders of size $O(n^{3/2})$, universal point sets for dominance drawings of st-outerplanar graphs of size $O(n \log n)$, and universal point sets for dominance drawings of directed trees of size $O(n^2)$. We show that 321-avoiding permutations have superpatterns of size $O(n^{3/2})$, riffle permutations (321-, 2143-, and 2413-avoiding permutations) have superpatterns of size $O(n)$, and the concatenations of sequences of riffles and their inverses have superpatterns of size $O(n \log n)$. Our analysis includes a calculation of the leading constants in these bounds.

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CP0

Permuted Random Walk Exits Typically in Linear Time.

Given a permutation σ of the integers $\{-n, -n+1, \ldots, n\}$ we consider the Markov chain X_σ, which jumps from k to $\sigma(k \pm 1)$ equally likely if $k \neq -n, n$. We prove that the expected hitting time of $\{-n, n\}$ starting from any point is $\Theta(n)$ with high probability when σ is a uniformly chosen permutation. We prove this by showing that with high probability, the digraph of allowed transitions is an Eulerian expander; we then utilize general estimates of hitting times in directed Eulerian expanders.

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CP0

Practical Experience with Hanani-Tutte for Testing C-Planarity

We propose an algorithm for c-planarity testing which is correct and efficient, but not, in general, complete, i.e., there are input instances on which the algorithm declines to give an answer. At the core of this algorithm is an algebraic criterion with the following properties: (1) The criterion is a necessary condition for c-planarity; (2) for special graph classes, including c-connected graphs, it is also sufficient; and (3) it can be tested efficiently in polynomial time. The algebraic criterion is not sufficient in general; however, we can extend it to a (still efficient) algorithm that verifies the answer of the criterion by building a c-planar embedding of the input graph. Our practical experiments show that this algorithm works well in practice.

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CP0

Clump Combinatorics, Automata, and Word Asymptotics

Given a set of words and a probability model for random texts, we are interested in the behavior of occurrences of the words in a random text. Clumps are shown here to play a central role in these problems. They can be used to calculate relevant quantities, such as the probability that a random text contains a given number of pattern word occurrences. We provide combinatorial properties that greatly simplify the classical enumeration of these texts by inclusion-exclusion approaches. We describe two clump automata that can be used to efficiently calculate generating functions.

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CP0

Fast Shortest-Path Distance Queries on Road Networks by Pruned Highway Labeling

We propose a new labeling method for shortest-path and distance queries on road networks. We present a new framework (i.e. data structure and query algorithm) referred to as *highway-based labelings* and a preprocessing algorithm for it named *pruned highway labeling*. Our proposed method has several appealing features from different aspects in the literature. The experimental results show that the proposed method is much faster than the previous state-of-the-art labeling method in the preprocessing time.

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CP0

Tight Analysis of Randomized Rumor Spreading in Complete Graphs

We present a tight analysis of the basic randomized rumor spreading process in complete graphs introduced by Frieze and Grimmett (1985), where in each round of the process each node knowing the rumor gossips the rumor to a node chosen uniformly at random. The process starts with a single node knowing the rumor. We show that the number S_n of rounds required to spread a rumor in a complete graph with n nodes is very closely described by $\log_2 n$ plus $(1/n)$ times the completion time of the coupon collector process. This in particular gives very precise bounds for the expected runtime of the process, namely $\lfloor \log_2 n \rfloor +$

$\ln n - 1.116 \leq \mathrm{E}[S_n] \leq \lceil \log_2 n \rceil + \ln n + 2.765 + o(1).$

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CP0

A Back-to-Basics Empirical Study of Priority Queues

The theory community has proposed several new heap variants in the recent past which have remained largely untested experimentally. We take the field back to the drawing board, with straightforward implementations of both classic and novel structures using only standard, well-known optimizations. We study the behavior of each structure on a variety of inputs, including artificial workloads, workloads generated by running algorithms on real map data, and workloads from a discrete event simulator used in recent systems networking research. We provide observations about which characteristics are most correlated to performance. For example, we find that the L1 cache miss rate appears to be strongly correlated with wallclock time. We also provide observations about how the input sequence affects the relative performance of the different heap variants. Overall, our findings suggest that while the conventional wisdom holds in some cases, it is sorely mistaken in others.

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CP0

Expected External Profile of Patricia Tries

We analyze the expected number of leaves at level k for PATRICIA tries on n binary strings generated by a memoryless source. We study three natural ranges of k with respect to n. The most interesting range is k growing logarithmically with n, where we apply Mellin transforms, analytic depoissonization, and the saddle point method. The analysis features an intricate Mellin transform that satisfies a recursive functional equation, which presents interesting analytic challenges.

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CP0

Survivors in Leader Election Algorithms

We consider the number of survivors in a broad class of fair leader election algorithms after a number of election rounds. We give sufficient conditions for the number of survivors to converge to a product of independent identically distributed random variables. The number of terms in the product is determined by the round number considered. Each individual term in the product is a limit of a scaled random variable associated with the splitting protocol. The proof is established via convergence (to 0) of the first-order Wasserstein distance from the product limit. In a broader context, the paper is a case study of a class of stochastic recursive equations. We give two illustrative examples, one with binomial splitting protocol (for which we show that a normalized version is asymptotically Gaussian), and one with power distribution splitting protocol.

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CP0

On the Average Number of Edges in Theta Graphs

Not available at the time of publication.

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CP0

Top-K Substring Matching for Auto-Completion

Given the user's input as a query, auto-completion selects the top-k strings with the highest scores from the strings matching the query in a dictionary. In this paper, we present a novel approach to solve the top-k substring matching problem for auto-completion using a small space. Experimental results show that our algorithm can suggest top-k completion sufficiently fast, while taking much less space than a compressed full-text index of the dictionary.

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CP0

Triangle Listing Algorithms: Back from the Diversion

We present a unifying framework for all common algorithms listing the triangles of a graph. This framework shows that most of them run in $\mathcal{O}(a(G)m)$ time, where $a(G)$ is the arboricity of G – an upper bound that had been proven only for the algorithm of Chiba and Nishizeki (*SIAM J. Computing*, 1985). More importantly, we show

by experimentation that this latter algorithm, if implemented carefully, actually outperforms all subsequently proposed algorithms.

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CP0

Multi-Pivot Quicksort: Theory and Experiments

The idea of multi-pivot quicksort has recently received attention after Yaroslavskiy proposed a dual pivot quicksort algorithm that outperforms standard quicksort under the Java JVM. More recently, this algorithm has been analysed in terms of comparisons and swaps by Wild and Nebel. We perform the previous experiments using a native C implementation, removing extraneous effects of the JVM. Additionally, we provide analyses on cache behavior of these algorithms. We then provide strong evidence that cache behavior is causing most of the performance differences. Lastly, we build upon prior work in multi-pivot quicksort and propose a 3-pivot variant that performs very well in theory and practice.

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CP0

Precomputation Techniques for the Stochastic on-Time Arrival Problem

We consider the stochastic on-time arrival (SOTA) problem of finding the optimal routing strategy to reach a destination within a pre-specified time budget and provide the first results on preprocessing techniques to speed up the query time. We start by identifying some properties of the SOTA problem that limit the preprocessing techniques that can be used in this setting, and define the stochastic variants of two techniques that can be adapted to the SOTA problem, namely reach and arc-flags. We present the preprocessing and query algorithms for each technique, and also an extension to the standard reach method that provides additional pruning. Finally, we explain the limitations of this approach due to the cost of the preprocessing phase and present a fast heuristic preprocessing scheme. Numerical results for San Francisco, Luxembourg and a synthetic network show up to an order of magnitude improvement in the query time for short queries, with larger gains expected for longer queries.

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CP0

On The Average-Case Complexity of the Bottleneck Tower of Hanoi Problem

The Bottleneck Tower of Hanoi (BTH) problem, posed in 1981 by Wood, is a natural generalization of the classic Tower of Hanoi (TH) problem. There, a generalized placement rule allows a larger disk to be placed higher than a smaller one if their size difference is less than a given parameter $k \geq 1$. The objective is to compute a shortest move-sequence transferring a legal (under the above rule) configuration of n disks on three pegs to another legal configuration. In SOFSEM'07, Dinitz and the second author established tight asymptotic bounds for the worst-case complexity of the BTH problem, for all n and k. Moreover, they proved that the average-case complexity is asymptotically the same as the worst-case complexity, for all $n > 3k$ and $n \leq k$, and conjectured that the same phenomenon also occurs in the complementary range $k < n \leq 3k$. In this paper we settle this conjecture of Dinitz and the second author in the affirmative.

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CP0

Flow-Based Guidebook Routing

Using public transit to get from A to B, one is typically confronted with the agony of choice: Considering Pareto-costs (including travel time and number of transfers), there are often several optimal journeys for a given departure time. Over a day or week, the number of possible journeys accumulates, with some routes being useful for long periods of time while others are only valid for a single departure. Such large solution sets (often containing many very similar ones) lead to difficulties to present a reasonable subset to the user and also increase query times and space consumption of routing algorithms. In this paper, we aim for computing so called guidebook routes, which are characterised by being *stable* over long periods. The goal is to detect a small set of guidebook routes, such that for any departure time going by guidebook provides a reasonable journey with the costs exceeding the optimal ones not too much.

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CP0

Connection Scan Accelerated

We study the problem of efficiently computing journeys in timetable networks. Our algorithm optimally answers profile queries, computing all journeys given a time interval. Our study demonstrates that queries can be answered optimally on large country-scale timetable networks within several milliseconds and fast delay integration is possible. Previous work either had to drop optimality or only considered comparatively small timetable networks. Our technique is a combination of the Connection Scan Algorithm and multi-level overlay graphs.

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CP0

Typical Depth of a Digital Search Tree Built on a General Source

The digital search tree (dst) plays a central role in compression algorithms. This important structure is a mixing of a digital structure with a binary search tree. Its probabilistic analysis is thus involved, even in the case when the text is produced by a simple source (a memoryless source, or a Markov chain). After the seminal paper of Flajolet and Sedgewick (1986), many papers, published between 1990 and 2005, dealt with general simple sources, and perform the analysis of the main parameters of dst's (namely, path length, profile, typical depth). Here, we are interested in a more realistic analysis, when the words are emitted by a general source. There exist previous analyses that have been performed for general sources, but the case of dst's has not yet been considered. The idea of this study is due to Philippe Flajolet and the first steps of the work were performed with him, during the end of 2010. Our paper is dedicated to his memory.

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CP0

Order Constraints for Single Machine Scheduling with Non-Linear Cost

Typically in a scheduling problem we are given jobs of different processing times p_j and different priority weights w_j, and need to schedule them on a single machine in order to minimize a specific cost function. In this paper we consider the non-linear objective function $\sum w_j C_j^\beta$, where C_j is the completion time of job j and $\beta > 0$ is some arbitrary real constant. Except for $\beta = 1$ the complexity status of this problem is open. Past research mainly focused on the quadratic case ($\beta = 2$) and proposed different techniques to speed up exact algorithms. This paper proposes new pruning rules and generalizations of existing rules to non-integral β. An experimental study evaluates the impact of the proposed rules on the exact algorithm A*.

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CP0

Simplifying Massive Planar Subdivisions

We present the first I/O- and practically-efficient algorithm for simplifying a planar subdivision, such that no point is moved more than a given distance ε_{xy} and such that neighbor relations between faces (homotopy) are preserved. Under some practically realistic assumptions, our algorithm uses $\mathcal{O}(\mathrm{SORT}(N))$ I/Os, where N is the size of the decomposition and $\mathrm{SORT}(N)$ is the number of I/Os need to sort in the standard external-memory model of computation.

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CP1

Better Approximation Bounds for the Joint Replenishment Problem

We provide new approximation results for the Joint Replenishment Problem (JRP). In the offline case, we give an 1.791-approximation algorithm, breaking the current barrier of 1.8, and we show that for the variant with linear costs, the LP integrality gap is at least 1.09. In the online case, we show that the competitive ratio for JRP is at least 2.754 and we prove the optimal ratio of 2 for the version of JRP with deadlines.

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CP1

Improved Approximation Algorithm for Two-Dimensional Bin Packing

We study the two-dimensional bin packing problem with and without rotations. Here we are given a set of two-dimensional rectangular items I and the goal is to pack these into a minimum number of unit square bins. We consider the *orthogonal packing* case where the edges of the items must be aligned parallel to the edges of the bin. Our main result is a 1.405-approximation for two-dimensional bin packing with and without rotation, which improves upon a recent 1.5 approximation due to Jansen and Prädel. We also show that a wide class of rounding based algorithms cannot improve upon the factor of 1.5.

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CP1

A Constant Factor Approximation Algorithm for Fault-Tolerant k-Median

In this paper, we consider the fault-tolerant k-median problem and give the *first* constant factor approximation algorithm for it. In the fault-tolerant generalization of classical k-median problem, each client j needs to be assigned to at least $r_j \geq 1$ distinct open facilities. The service cost of j is the sum of its distances to the r_j facilities, and the k-median constraint restricts the number of open facilities to at most k. Previously, a constant factor was known only for the special case when all r_js are the same, and a logarithmic approximation ratio was known for the general case. We also consider the fault-tolerant facility location problem, where the service cost of j can be a weighted sum of its distance to the r_j facilities. We give a simple constant factor approximation algorithm, generalizing several previous results which only work for nonincreasing weight vectors.

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CP1

Better Algorithms and Hardness for Broadcast Scheduling Via a Discrepancy Approach

We study the broadcast scheduling problem with the objective of minimizing the average response time. We give an $\tilde{O}(\log^{1.5} n)$ approximation algorithm for the problem improving upon the previous $\tilde{O}(\log^2 n)$ approximation. We also show an $\Omega(\log^{1/2-\varepsilon} n)$ hardness result, and an integrality gap of $\Omega(\log n)$ for the natural LP relaxation for the problem. Prior to our work, only NP-Hardness and a (tiny) constant integrality gap was known.

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CP1

A Mazing $2+\varepsilon$ Approximation for Unsplittable Flow on a Path

We study the unsplittable flow on a path problem (UFP), which arises naturally in many applications such as bandwidth allocation, job scheduling, and caching. Here we are given a path with nonnegative edge capacities and a set of tasks, which are characterized by a subpath, a demand, and a profit. The goal is to find the most profitable subset of tasks whose total demand does not violate the edge capacities. In this paper we present a PTAS for δ-large tasks, for any constant $\delta > 0$. Key to this result is a complex geometrically inspired dynamic program. Each task is represented as a segment underneath the capacity curve, and we identify a proper maze-like structure so that each *corridor* of the maze is *crossed* by only $O(1)$ tasks in the optimal solution. The maze has a tree topology, which guides our dynamic program. Our result implies a $2+\varepsilon$ approximation for UFP, for any constant $\varepsilon > 0$.

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CP2

Minimum Common String Partition Parameterized by Partition Size Is Fixed-Parameter Tractable

The NP-hard Minimum Common String Partition problem asks whether two strings x and y can each be partitioned into at most k substrings such that both partitions use exactly the same substrings in a different order. We present the first fixed-parameter algorithm for Minimum Common String Partition using only parameter k.

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CP2

Interval Deletion Is Fixed-Parameter Tractable

We study the minimum *interval deletion* problem, which asks for the removal of a set of at most k vertices to make a graph on n vertices into an interval graph. We present a parameterized algorithm of runtime $10^k \cdot n^{O(1)}$ for this problem, thereby showing its fixed-parameter tractability.

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CP2

Finding Small Patterns in Permutations in Linear Time

Given two permutations σ and π, the Permutation Pattern problem asks if σ is a subpattern of π. We show that the problem can be solved in time $2^{O(\ell^2 \log \ell)} \cdot n$, where $\ell = |\sigma|$ and $n = |\pi|$. In other words, the problem is fixed-parameter tractable parameterized by the size of the subpattern to be found. We introduce a novel type of decompositions for permutations and a corresponding width measure. We present a linear-time algorithm that either finds σ as a subpattern of π, or finds a decomposition of π whose width is bounded by a function of $|\sigma|$. Then we show how to solve the Permutation Pattern problem in linear time if a bounded-width decomposition is given in the input.

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CP2

An Excluded Grid Theorem for Digraphs with Forbidden Minors

In 1997, Reed and later Johnson, Robertson, Seymour and Thomas conjectured the existence of a function f of k such that every digraph of directed tree-width at least $f(k)$ contains a directed grid of order k. In this paper we prove the conjecture for the case of digraphs excluding a fixed undirected graph as a minor. For algorithmic applications our theorem is particularly interesting as it covers those classes of digraphs to which, on undirected graphs, theories based on the excluded grid theorem such as bidimensionality theory apply.

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CP2

Efficient Computation of Representative Sets with Applications in Parameterized and Exact Algorithms

We demonstrate how the efficient construction of representative families can be a powerful tool for designing single-exponential parameterized and exact exponential time algorithms.

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CP3

Implicit Manifold Reconstruction

Let P be a dense set of points sampled from an m-dimensional compact smooth manifold Σ in $\mathbb{R}^d$. We show how to construct an implicit function $\varphi : \mathbb{R}^d \to \mathbb{R}^{d-m}$ from P so that the zero-set S_φ of φ contains a homeomorphic approximation of Σ. The Hausdorff distance between Σ and this homeomorphic approximation is at most ε^τ for any fixed $\tau < 2$. Moreover, for every point x at distance ε^τ or less from Σ, the normal space of S_φ at x makes an $O(\varepsilon^{(\tau-1)/2})$ angle with the normal space of Σ at the point nearest to x. The function φ has local support, which makes local homeomorphic reconstruction possible without a complete sampling.

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CP3

Robust Satisfiability of Systems of Equations

We study the problem of *robust satisfiability* of systems of nonlinear equations, namely, whether for a given continuous function $f : K \to \mathbb{R}^n$ on a finite simplicial complex K and $\alpha > 0$, it holds that each function $g : K \to \mathbb{R}^n$ such that $\|g - f\|_\infty \leq \alpha$, has a root in K. Via a reduction to the extension problem of maps into a sphere, we show that this problem is decidable if $\dim K \leq 2n - 3$. This is a substantial extension of previous computational applications of *topological degree* and related concepts in numerical and interval analysis. Via a reverse reduction we prove that the problem is undecidable when $\dim K \geq 2n - 2$, where the threshold comes from the *stable range* in homotopy theory. For the lucidity of our exposition, we focus on the setting when f is piecewise linear. Such functions can approximate general continuous functions, and thus we get approximation schemes and undecidability of the robust satisfiability in other possible settings.

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CP3

Solving 1-Laplacians of Convex Simplicial Complexes in Nearly Linear Time: Collapsing and Expanding a Topological Ball

We present an efficient algorithm for solving a linear system arising from the 1-Laplacian of a collapsible simplicial complex with a known collapsing sequence. When combined with a result of Chillingworth, our algorithm is applicable to convex simplicial complexes embedded in R^3. The running time of our algorithm has nearly-linear dependency on the size of the complex, and logarithmic dependency on its numerical properties. Our algorithm is based on projection operators for higher dimensional objects, and combinatorial steps for transferring between them. The former relies on decomposing flows into circulations and potential flows using fast solvers for graph Laplacians, and the latter relates Gaussian elimination to topological properties of simplicial complexes.

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CP3

On the Computational Complexity of Betti Numbers: Reductions from Matrix Rank

We give evidence for the difficulty of computing Betti numbers of simplicial complexes over a finite field. We do this by reducing the rank computation for sparse matrices with m non-zero entries to computing Betti numbers of simplicial complexes consisting of at most a constant times m simplices. Together with the known reduction in the other direction, this implies that the two problems have the same computational complexity.

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CP3

Approximating Local Homology from Samples

Recently, multi-scale notions of local homology (a variant of persistent homology) have been used to study the local structure of spaces around a given point from a point cloud sample. Current reconstruction guarantees rely on constructing embedded complexes which become difficult to construct in higher dimensions. We show that the persistence diagrams used for estimating local homology can be approximated using families of Vietoris-Rips complexes, whose simpler construction are robust in any dimension. To the best of our knowledge, our results, for the first time make applications based on local homology, such as stratification learning, feasible in high dimensions.

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CP4

Near Linear Time Approximation Schemes for Uncapacitated and Capacitated B-Matching Problems in Nonbipartite Graphs

We present the first fully polynomial approximation schemes for the maximum weighted (uncapacitated or capacitated) b–Matching problem for nonbipartite graphs that run in time (near) linear in the number of edges, that is, given any $\delta > 0$ the algorithm produces a $(1-\delta)$ approximation in $O(m \operatorname{poly}(\delta^{-1}, \log n))$ time. We provide fractional solutions for the standard linear programming formulations for these problems and subsequently also provide fully polynomial (near) linear time approximation schemes for rounding the fractional solutions.

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CP4

Towards $(1+\epsilon)$-Approximate Flow Sparsifiers

A useful approach to compress a large network G is to represent it with a flow-sparsifier, ie, a small network H that supports the same flows as G, up to a factor $q \geq 1$ called the quality of sparsifier. Specifically, we assume the network G contains a set of k terminals T, shared with the network H, i.e., $T \subseteq V(G) \cap V(H)$, and we want H to preserve all multicommodity flows that can be routed between the terminals T. The challenge is to construct H that is small. These questions have received a lot of attention in recent years, leading to some known tradeoffs between the sparsifier quality q and its size $|V(H)|$. Nevertheless, it remains an outstanding question whether every G admits a flow-sparsifier H with quality $q = 1+\epsilon$, or even $q = O(1)$, and size $|V(H)| \leq f(k,\epsilon)$ (in particular, independent of $|V(G)|$ and edge capacities). Making a first step in this direction, we present new constructions for several scenarios:

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CP4

Improved Bounds and Algorithms for Graph Cuts and Network Reliability

Karger (*SIAM Journal on Computing*, 1999) developed the first fully-polynomial approximation scheme to estimate the probability that a graph G becomes disconnected, given that its edges are removed independently with probability p. This algorithm runs in $n^{5+o(1)}\epsilon^{-3}$ time. We improve this in two key ways. First, there is a certain key sub-problem encountered by Karger, for which a generic estimation procedure is employed. We show that a more efficient algorithm can be used. Second, we show better bounds on the number of edge cuts which are likely to fail. Karger's analysis depends on bounds for various graph parameters; we show that these bounds cannot be simultaneously tight. These techniques improve the runtime to $n^{3+o(1)}\epsilon^{-2}$. A key driver of Karger's approach is bounding the number of small cuts: we also show how to improve this when the min-cut size is "small' and odd, augmenting, in part, a result of Bixby (*Bull. AMS*, 1974).

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CP4

An Almost-Linear-Time Algorithm for Approximate Max Flow in Undirected Graphs, and Its Multicommodity Generalizations

In this paper, we present an almost linear time algorithm for solving approximate maximum flow in undirected graphs. In particular, given a graph with m edges we show how to produce a $1-\epsilon$ approximate maximum flow in time $O(m^{1+o(1)}\epsilon^{-2})$. Furthermore, we present this algorithm as part of a general framework that also allows us to achieve a running time of $O(m^{1+o(1)}k^2\epsilon^{-2})$ for the maximum concurrent k-commodity flow problem, the first such algorithm with an almost linear dependence on m.

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CP4

Computing Cut-Based Hierarchical Decompositions in Almost Linear Time

We present a fast construction for the hierarchical tree decompositions that lie at the heart of oblivious routing strategies and that form the basis for approximation and online algorithms for various cut problems in graphs. Given an undirected graph $G = (V,E,c)$, we compute a single tree $T = (V_T, E_T, c_T)$ s.t. T approximates the cut-structure of G up to a factor of $O(\log^4 n)$. The best existing construction by Harrelson et al. just guarantees a polynomial running time but offers a better approximation guarantee of $O(\log^2 n \log\log n)$. In other words, for a graph $G = (V,E)$ with a subset S of terminals, we compute a tree T with at most $2|S|$ vertices such that T is a flow-sparsifier for S in G with quality $O(\log^2 |V| \log^2 |S|)$. Our algorithm runs in time $O(\text{polylog}\, n \cdot T(m, 1/\log^3 |V|))$ where $T(m,\epsilon)$ is the time for computing an approximate maxflow. The latter is almost linear due to the recent results of Sherman and Kelner et al.

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CP5

Clustering and Mixing Times for Segregation Models on $\mathbb{Z}^2$

The Schelling segregation model attempts to explain racial segregation in cities. Schelling considered residents of two types, where one prefers neighbors of the same type. He showed through simulations that even mild preferences of this type can lead to segregation if residents move whenever they are unhappy. We generalize the Schelling model to include a broad class of influence dynamics, called the General Influence Model. We show that in this model, the dynamics will be rapidly mixing and cities will be integrated if the racial bias is sufficiently low. We show complementary results for two broad classes of influence functions: Increasing Bias Functions, where one's likelihood of moving increases each time someone of the same color leaves, and Threshold Bias Functions, reminiscent of Schelling's original model. For both classes, we show that when the bias is sufficiently high, the dynamics take exponential time to mix, a large "ghetto' will form, and we will have segregation.

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CP5

Mcmc Sampling Colourings and Independent Sets of $G(n, d/n)$ Near Uniqueness Threshold

Sampling from the Gibbs distribution is a well-studied problem in CS. We focus on the k-colouring model and the hard-core model with fugacity λ, when the underlying graph is a random graph $G(n, p)$, for $p = d/n$ and fixed d. Our approach is based on the Markov Chain Monte Carlo method, i.e. Glauber (block) dynamics. We show a dramatic improvement on the bounds for rapid mixing in terms of colours and the fugacity for the corresponding models.

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CP5

A Simple FPTAS for Counting Edge Covers

An edge cover of a graph is a set of edges such that every vertex has at least an adjacent edge in it. Previously, approximation algorithm for counting edge covers is only known for 3 regular graphs and it is randomized. We design a very simple deterministic fully polynomial-time approximation scheme (FPTAS) for counting the number of edge covers for any graph. Our main technique is correlation decay, which is a powerful tool to design FPTAS for counting problems. In order to get FPTAS for general graphs without degree bound, we make use of a stronger notion called computationally efficient correlation decay, which is introduced in [Li, Lu, Yin SODA 2012].

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CP5

Arboricity and Spanning-Tree Packing in Random Graphs with an Application to Load Balancing

We study the arboricity A and the maximum number T of edge-disjoint spanning trees of the classical random graph $G(n, p)$. For all $p(n) \in [0, 1]$, we show that, with high probability, T is precisely the minimum between δ and $\lfloor m/(n-1) \rfloor$, where δ is the smallest degree of the graph and m denotes the number of edges. Moreover, we explicitly determine a sharp threshold value for p such that: above this threshold, T equals $\lfloor m/(n-1) \rfloor$ and A equals $\lceil m/(n-1) \rceil$; and below this threshold, T equals δ, and we give a two-value concentration result for the arboricity A in that range. Finally, we include a stronger version of these results in the context of the random graph process where the edges are sequentially added one by one. A direct application of our result gives a sharp threshold for the maximum load being at most k in the two-choice load balancing problem, where $k \to \infty$.

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CP5

Uniform Random Sampling of Simple Branched Coverings of the Sphere by Itself

We present the first polynomial uniform random sampling algorithm for simple branched coverings of degree n of the sphere by itself. More precisely, our algorithm generates in linear time *increasing quadrangulations*, which are equivalent combinatorial structures. Our result is based on the identification of some canonical *labelled* spanning trees, and yields a constructive proof of a celebrated formula of Hurwitz for the number of some factorizations of permutations in transpositions. The previous approaches were either non constructive or lead to exponential time algorithms for the sampling problem.

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CP6

Polynomial Solvability of Variants of the Trust-Region Subproblem

We consider an optimization problem of the form

$$\begin{aligned} \min \quad & x^T Q x + c^T x \\ \text{s.t.} \quad & \|x - \mu_h\| \le r_h, \quad h \in S, \\ & \|x - \mu_h\| \ge r_h, \quad h \in K, \\ & x \in P, \end{aligned}$$

where $P \subseteq \mathbb{R}^n$ is a polyhedron defined by m inequalities and Q is general and the $\mu_h \in \mathbb{R}^n$ and the r_h quantities are given. In the case $|S| = 1$, $|K| = 0$ and $m = 0$ one obtains the classical trust-region subproblem; a strongly NP-hard problem which has been the focus of much interest because of applications to combinatorial optimization and nonlinear programming. We prove that for each fixed pair $|S|$ and $|K|$ our problem can be solved in polynomial time provided that either (1) $|K| > 0$ and the number of faces of P that intersect $\bigcap_h \{x \in \mathbb{R}^n : \|x - \mu_h\| \leq r_h, \quad 1 \leq j \leq p\}$ is polynomially bounded, or (2) $|K| = 0$ and m is bounded.

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CP6

On the Lattice Isomorphism Problem

We study the Lattice Isomorphism Problem (LIP) and present an algorithm solving it in time $n^{O(n)}$ times a polynomial in the input size, where n is the rank of the input lattices. A crucial component is a new generalized isolation lemma, which can isolate n linearly independent vectors in a given subset of Z^n and might be useful elsewhere. We also prove that LIP lies in the complexity class SZK.

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CP6

The Complexity of Order Type Isomorphism

The order type of a point set in R^d maps each $(d+1)$-tuple of points to its orientation (e.g., clockwise or counterclockwise in R^2). Two point sets X and Y have the same order type if there exists a mapping f from X to Y for which every $(d+1)$-tuple $(a_1, a_2, \ldots, a_{d+1})$ of X and the corresponding tuple $(f(a_1), f(a_2), \ldots, f(a_{d+1}))$ in Y have the same orientation. In this paper we investigate the complexity of determining whether two point sets have the same order type. We provide an $O(n^d)$ algorithm for this task, thereby improving upon the $O(n^{\lfloor 3d/2 \rfloor})$ algorithm of Goodman and Pollack (1983). The algorithm uses only order type queries and also works for abstract order types (or acyclic oriented matroids). Our algorithm is optimal, both in the abstract setting and for realizable points sets if the algorithm only uses order type queries.

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CP6

Positivity Problems for Low-Order Linear Recurrence Sequences

We consider two decision problems for linear recurrence sequences (LRS) over the integers, namely the *Positivity Problem* (are all terms of a given LRS positive?) and the *Ultimate Positivity Problem* (are all but finitely many terms of a given LRS positive?). We show decidability of both problems for LRS of order 5 or less, with complexity in the Counting Hierarchy for Positivity, and in polynomial time for Ultimate Positivity. Moreover, we show by way of hardness that extending the decidability of either problem to LRS of order 6 would entail major breakthroughs in analytic number theory, more precisely in the field of Diophantine approximation of transcendental numbers.

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CP6

Space Complexity of List H-Coloring: a Dichotomy

The Dichotomy Conjecture for constraint satisfaction problems (CSPs) states that every CSP is in P or is NP-complete (Feder-Vardi, 1993). It has been verified for conservative problems (also known as list homomorphism problems) by A. Bulatov (2003). We augment this result by showing that for digraph templates H, every conservative CSP, denoted LHOM(H), is solvable in logspace or is hard for NL. More precisely, we introduce a digraph structure we call a circular N, and prove the following dichotomy: if H contains no circular N then LHOM(H) admits a logspace algorithm, and otherwise LHOM(H) is hard for NL. Our algorithm operates by reducing the lists in a complex manner based on a novel decomposition of an auxiliary digraph, combined with repeated applications of Reingold's algorithm for undirected reachability (2005). Moreover, we show that the presence of a circular N can be decided in time polynomial in the size of H. We also prove an algebraic version of this dichotomy.

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CP7

Competitive Analysis Via Regularization

We provide a framework for designing competitive online

algorithms using *regularization*, a widely used technique in online learning, particularly in online convex optimization. An online algorithm that uses regularization serves requests by computing a solution, in each step, to an objective function involving a smooth convex regularization function. Applying the technique of regularization allows us to obtain new results in the domain of competitive analysis. In our new framework we exhibit a general $O(\log m)$-competitive deterministic algorithm for generating a fractional solution that satisfies a time-varying set of online covering and precedence constraints, where m is the number of variables. This framework allows to incorporate both service costs (over time) and setup costs into a host of applications. We then provide an $O(\log m \log n)$-competitive randomized algorithm for the online set cover problem with service cost.

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CP7

Dynamic Task Allocation in Asynchronous Shared Memory

Task allocation is a classic distributed problem in which a set of p potentially faulty processes must cooperate to perform a set of tasks. This paper considers a new *dynamic* version of the problem, in which tasks are injected adversarially during an asynchronous execution. We give the first asynchronous shared-memory algorithm for dynamic task allocation, and we prove that our solution is optimal within logarithmic factors. The main algorithmic idea is a randomized concurrent data structure called a *dynamic to-do tree*, which allows processes to pick new tasks to perform at random from the set of available tasks, and to insert tasks at random empty locations in the data structure.

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CP7

Online Steiner Tree with Deletions

In the online Steiner tree problem, the input is a set of vertices that appear one-by-one (with a metric between them), and we have to maintain a low-cost Steiner tree on the current set of vertices. What if the set of vertices sees both additions and deletions, and we are allowed to change a small number of existing edges at each point in time? In this paper we improve on prior results, giving online algorithms that maintains a constant-competitive Steiner tree under only deletions (where we change only a constant number of edges upon each request. We also give an algorithm that maintains a Steiner tree in the fully-dynamic model (both vertex insertions and deletions), where we make a constant number of changes per request in an amortized sense.

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CP7

Maintaining Assignments Online: Matching, Scheduling, and Flows

We consider matching and scheduling problems, where objects can be reassigned, and we want to minimize the number of reassignments done. For online matching, where the left vertices arrive online and must be matched to the right vertices, we give an algorithm that reassigns the left vertices an (amortized) constant number of times, and maintains a constant factor to the optimal load on the right vertices. For restricted machine scheduling with arbitrary sized jobs, we give an algorithm that maintains load which is $O(\log \log mn)$ times the optimum, and reassigns each job an (amortized) constant number of times. Finally, in a digraph with a single source, where sinks arrive online and want to send unit flow to the source with minimum the congestion on the edges. Suppose there is an offline flow such that the total length of the flow paths is F^*. We give an algorithm that reroutes flow along $O(F^*)$ edges and achieves a $O(1)$-approximation to the congestion.

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CP7

First Come First Served for Online Slot Allocation and Huffman Coding

Can one choose a good Huffman code without knowing the distribution? Online Slot Allocation (OSA) models this and similar problems: There are n slots with known costs. Requests for items are drawn i.i.d. from a hidden distribution p. After the first request to each item i, the algorithm (knowing the slot costs and previous requests, but not p) must place i in a vacant slot j_i. The goal is to minimize $\sum_{i=1}^{n} p_i\, c(j_i)$. The optimal offline algorithm puts the jth most probable item in the jth cheapest slot. The optimal online algorithm, First Come First Served (FCFS), puts the jth distinct requested item in the jth cheapest slot.

The optimal competitive ratio for any online algorithm is $1 + H_{n-1} \sim \ln n$ for general costs and 2 for concave costs. For logarithmic cost, FCFS gives cost opt + $O(\log \text{opt})$. For Huffman coding, FCFS allocates codewords on the fly while guaranteeing cost opt $+ 2\log_2(1 + \text{opt}) + 2$.

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CP8

Learning Sparse Polynomial Functions

We study the question of learning a sparse multi-variate polynomial over the real domain. In particular, for some unknown polynomial $f(\vec{x})$ of degree-d and k monomials, we show how to reconstruct f, within error ϵ, given only a set of examples $\bar{x}_i$ drawn uniformly from the n-dimensional cube (or an n-dimensional Gaussian distribution), together with evaluations $f(\bar{x}_i)$ on them. The result holds even in the "noisy setting', where we have only values $f(\bar{x}_i) + g$ where g is noise (say, modeled as a Gaussian random variable). The runtime of our algorithm is polynomial in $n, k, 1/\epsilon$ and C_d where C_d depends only on d. Note that, in contrast, in the "boolean version' of this problem, where $\bar{x}$ is drawn from the hypercube, the problem is at least as hard as the "noisy parity problem,' where we do not know how to break the $n^{\Omega(d)}$ time barrier, even for $k = 1$, and some believe it may be impossible to do so.

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CP8

Exploiting Metric Structure for Efficient Private Query Release

We consider the problem of privately answering queries defined on databases which are collections of points belonging to some metric space. We give simple, computationally efficient algorithms for answering *distance queries* defined over an arbitrary metric. Distance queries are specified by points in the metric space, and ask for the average distance from the query point to the points contained in the database, according to the specified metric. Our algorithms run efficiently in the database size and the dimension of the space, and operate in both the online query release setting, and the offline setting in which they must in polynomial time generate a fixed data structure which can answer *all* queries of interest. This represents one of the first subclasses of linear queries for which *efficient* algorithms are known for the private query release problem, circumventing known hardness results for generic linear queries.

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CP8

(Nearly) Sample-Optimal Sparse Fourier Transform

We consider the problem of computing a k-sparse approximation to the discrete Fourier transform of an n-dimensional signal. Our main result is a randomized algorithm that computes such an approximation using $O(k \log n (\log\log n)^{O(1)})$ signal samples in time $O(k \log^2 n (\log\log n)^{O(1)})$, assuming that the entries of the signal are polynomially bounded. The sampling complexity improves over the recent bound of $O(k \log n \log(n/k))$ given in [HIKP12], and matches the lower bound of $\Omega(k \log(n/k)/\log\log n)$ from the same paper up to $\text{poly}(\log\log n)$ factors when $k = O(n^{1-\delta})$ for a constant $\delta > 0$.

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CP8

Learning Entangled Single-Sample Gaussians

We introduce a new model of Gaussian mixtures, motivated by the setting where the data points correspond to ratings on a set of items provided by users who have widely varying expertise, and each user can rate an item at most once. In this mixture model, each item i has a true quality μ_i, each user has a variance (lack of expertise) σ_j^2, and the rating of a user j on an item i consists of a *single* sample independently drawn from the Normal distribution $N(\mu_i, \sigma_j^2)$. The aim is to learn the unknown item qualities μ_i's as precisely as possible. We study the single item case and obtain efficient algorithms for the problem, complemented by near-matching lower bounds; we also obtain preliminary results for the multiple items case.

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CP8

On the Compatibility of Quartet Trees

Phylogenetic tree reconstruction is a fundamental biological problem. Quartet trees are the minimal informational unit for phylogenetic classification. Here we focus on the compatibility of quartet sets. We provide several results addressing the question of what can be inferred about the compatibility of a set from its subsets. In particular we show that there are quartet sets Q of size $m = cn \log n$ in which every subset of cardinality $c'n/\log n$ is consistent, and yet no fraction of more than $1/3 + \epsilon$ of Q is consistent.

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CP9

A New Perspective on Vertex Connectivity

Edge connectivity and vertex connectivity are two fundamental concepts in graph theory. Although by now there is a good understanding of the structure of graphs based on their edge connectivity, our knowledge in the case of vertex connectivity is much more limited. An essential tool in capturing edge connectivity are the classical results of Tutte and Nash-Williams about edge-disjoint spanning trees. We argue that connected dominating set partitions and packings are the natural analogues of edge-disjoint spanning trees in the context of vertex connectivity and we use them to obtain structural results about vertex connectivity in the spirit of those for the edge connectivity. Using this new perspective, we also prove results about vertex connectivity under vertex sampling, similar to the results of Karger about edge-connectivity under edge sampling. Our results also find applications in networking and yield routing-based broadcast algorithms with optimal throughput.

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CP9

Counting Thin Subgraphs Via Packings Faster Than Meet-in-the-Middle Time

Vassilevska and Williams (STOC 2009) showed how to count simple paths on k vertices and matchings on $k/2$ edges in an n-vertex graph in time $n^{k/2+O(1)}$. Two different algorithms with the same runtime were given by Koutis and Williams (ICALP 2009), and Björklund *et al.* (ESA 2009), via $n^{st/2+O(1)}$-time algorithms for counting t-tuples of pairwise disjoint sets drawn from a given family of s-sized subsets of an n-element universe. Alon and Gutner (TALG 2010) showed that these problems have $\Omega(n^{\lfloor st/2 \rfloor})$ and $\Omega(n^{\lfloor k/2 \rfloor})$ lower bounds when counting by color coding. We show that the "meet-in-the-middle' exponent $st/2$ can be beaten and give an algorithm that counts in time $n^{0.4547st+O(1)}$ for t a multiple of three. This implies algorithms for counting occurrences of a fixed subgraph on k vertices and pathwidth $p \ll k$ in an n-vertex graph in $n^{0.4547k+2p+O(1)}$ time.

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CP9

Large Induced Subgraphs Via Triangulations and CMSO

Consider the following optimization problem. Let φ be a Counting Monadic Second Order Logic formula and t be an integer. Given a graph $G = (V, E)$, the task is to find a maximum induced subgraph $G[F]$ of treewidth at most t, that models φ. Using the theory of potential maximal cliques, we show that the problem can be solved in polynomial time for classes of graphs with polynomially many minimal separators, and in time $O(1.7347^n)$ for arbitrary graphs.

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CP9

Independent Set in P_5-Free Graphs in Polynomial

Time

We give the first polynomial time algorithm for Independent Set on P_5-free graphs. Our algorithm also works for the Weighted Independent Set problem.

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CP9

Packing A-Paths in Group-Labelled Graphs via Linear Matroid Parity

Some frameworks of packing A-paths in group-labelled graphs include various interesting problems such as Mader's disjoint $\mathcal{S}$-paths problem and packing odd-length A-paths. We discuss the fast solvability of these frameworks like that of Mader's problem via a reduction to the linear matroid parity problem due to Schrijver (2003). This paper characterizes the groups in quiestion, which is a complete answer to the question, "when can we extend such a reduction technique to the generalized frameworks?"

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CP10

A QPTAS for Maximum Weight Independent Set of Polygons with Polylogarithmically Many Vertices

The Maximum Weight Independent Set of Polygons (MWISP) problem is a fundamental problem in computational geometry. Given a set of weighted polygons in the two-dimensional plane, the goal is to find a set of pairwise non-overlapping polygons with maximum total weight. Despite a lot of research, the general case of the problem is not well-understood yet. Currently the best known polynomial time algorithm achieves an approximation ratio of n^{ϵ}, and it is not even clear whether the problem is APX-hard. We present a $(1+\epsilon)$-approximation algorithm, assuming that each polygon in the input has at most a polylogarithmic number of vertices. Our algorithm has quasi-polynomial running time, i.e., it runs in time $2^{\text{poly}(\log n, 1/\varepsilon)}$.

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CP10

On the Optimality of Approximation Schemes for the Classical Scheduling Problem

We consider the classical scheduling problem on parallel identical machines to minimize the makespan, and achieve the following results under the Exponential Time Hypothesis (ETH).

- The scheduling problem on a constant number m of identical machines, denoted as $Pm||C_{max}$, is known to admit an FPTAS of running time $O(n) + (1/\epsilon)^{O(m)}$. We prove it is essentially the best possible in the sense that a $(1/\epsilon)^{O(m^{1-\delta})} + n^{O(1)}$ time FPTAS for any $\delta > 0$ implies that ETH fails.
- The scheduling problem on an arbitrary number of identical machines, denoted as $P||C_{max}$, is known to admit a PTAS of running time $2^{O(1/\epsilon^2 \log^3(1/\epsilon))} + n^{O(1)}$. We prove it is nearly optimal in the sense that a $2^{O((1/\epsilon)^{1-\delta})} + n^{O(1)}$ time PTAS for any $\delta > 0$ implies that ETH fails.

We also obain lower bounds of exact algorithms for the scheduling problem that almost matches upper bounds.

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CP10

A Polynomial-Time Approximation Scheme for Fault-Tolerant Distributed Storage

We consider a problem which has received considerable attention in systems literature because of its applications to routing in delay tolerant networks and replica placement in distributed storage systems. In abstract terms the problem can be stated as follows: Given a random variable X generated by a known product distribution over $\{0,1\}^n$ and a target value $0 \le \theta \le 1$, output a non-negative vector w, with $\|w\|_1 \le 1$, which maximizes the probability of the event $w \cdot X \ge \theta$. We provide an additive EPTAS for this problem which, for constant-bounded product distributions, runs in $\text{poly}(n) \cdot 2^{\text{poly}(1/\varepsilon)}$ time and outputs an ε-approximately optimal solution vector w for this problem. Our approach is inspired by recent results from the complexity-theoretic study of linear threshold functions.

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CP10

Approximating k-Center in Planar Graphs

We consider variants of the metric k-center problem. Imagine you must choose locations for k firehouses in a city so as to minimize the maximum distance of any house from the nearest firehouse. An instance is specified by a graph with arbitrary nonnegative edge-lengths, a set of vertices that can serve as firehouses (i.e. centers) and a set of vertices that represent houses. For general graphs, this problem is exactly equivalent to the metric k-center problem, which is APX-hard. We give a polynomial-time bicriteria approximation scheme when the input graph is a planar graph. We also give polynomial-time bicriteria approximation schemes for several generalizations: if, instead of all houses, we wish to cover a specified proportion of the houses; if the candidate locations for firehouses have rental costs and we wish to minimize, not the number of firehouses but the sum of their rental costs; and if the input graph is not planar but of bounded genus.

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CP10

Polynomial Time Approximation Schemes for the Traveling Repairman and Other Minimum Latency Problems.

We give a polynomial time, $(1+\epsilon)$-approximation algorithm (PTAS) for the traveling repairman problem in the Euclidean plane, on weighted planar graphs, and on weighted trees. This improves on the known quasi-polynomial time approximation schemes for these problems. Further, we give a PTAS for the scheduling problem of minimizing total weighted completion time on a single machine under interval order precedence constraints. This improves on the known 3/2-approximation for this problem.

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CP11

Relative Errors for Deterministic Low-Rank Matrix Approximations

We consider processing an $n \times d$ matrix A in a stream with row-wise updates according to a recent algorithm called Frequent Directions(Liberty,KDD 2013). This algorithm maintains an $\ell \times d$ matrix Q deterministically. We show that if one sets $\ell = \lceil k + k/\epsilon \rceil$ and returns Q_k, we achieve:

$$\|A - \pi_{Q_k}(A)\|_F^2 \leq (1+\epsilon)\|A - A_k\|_F^2$$

where $\pi_{Q_k}(A)$ is the projection of A onto rowspace of Q_k.

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CP11

Approximating Matching Size from Random Streams

We present a streaming algorithm that makes one pass over the edges of an unweighted graph presented in *random* order, and produces a polylogarithmic approximation to the size of the maximum matching in the graph, while using only polylogarithmic space. Prior to this work the only approximations known were a folklore $\tilde{O}(\sqrt{n})$ approximation with polylogarithmic space in an n vertex graph and a constant approximation with $\Omega(n)$ space. Our work thus gives the first algorithm where both the space and approximation factors are smaller than any polynomial in n.

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CP11

Improved Concentration Bounds for Count-Sketch

We present a refined analysis of the classic Count-Sketch streaming heavy hitters algorithm [CCF02]. Count-Sketch uses $O(k \log n)$ linear measurements to estimate a vector $x \in \mathbb{R}^n$. Our main result is that the average error is substantially smaller than the maximum error. We also give high probability results for the recovery of distributions with suitable decay, such as a power law or lognormal. We complement our results with simulations of Count-Sketch on a power law distribution. The empirical evidence indicates that our theoretical bounds give a precise characterization of the algorithm's performance: the asymptotics are correct and the associated constants are small. Our proof shows that any symmetric random variable with finite variance and positive Fourier transform concentrates at least as well as a Gaussian. This result, which may be of independent interest, gives good concentration even when the noise does not converge to a Gaussian.

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CP11

Annotations for Sparse Data Streams

We continue the study of annotated data streams. In this setting, a verifier (cloud user), lacking the resources to store and manipulate his massive input locally, accesses a powerful but untrusted prover (cloud service). The verifier must work within the restrictive data streaming paradigm. The prover, who can annotate the data stream, must both supply the final answer and convince the verifier of its correctness. While optimal protocols are now known for several basic problems, such optimality holds only for streams whose length is commensurate with the size of the data universe. In contrast, many real-world data sets are relatively *sparse* (e.g. graphs that contain only $o(n^2)$ edges). We design the first protocols that allow both the annotation and the space usage to be sublinear in the number of stream updates rather than the size of the data universe. We solve significant problems, including variations of Frequency Moments and several natural problems on graphs.

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CP11

An Optimal Lower Bound for Distinct Elements in the Message Passing Model

In the message-passing model of communication, there are k players each with their own private input, who try to compute or approximate a function of their inputs by sending messages to one another over private channels. We consider the setting in which each player holds a subset S_i of elements of a universe of size n, and their goal is to output a $(1+\varepsilon)$-approximation to the total number of distinct elements in the union of the sets S_i with constant probability, which can be amplified by independent repetition. This problem has applications in data mining, sensor networks, and network monitoring.

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CP12

Tight Lower Bounds for Greedy Routing in Higher-Dimensional Small-World Grids

We consider Kleinberg's small world graph model [STOC 2000]: a D-dimensional grid $\{0,\ldots,n-1\}^D$ augmented by a constant number of additional unidirectional edges per node, chosen independently at random according to the same probability distribution. Kleinberg showed that if $D=2$ and v is the long range contact of u with a probability proportional to $\|u-v\|_1{}^{-2}$, the "greedy' routing algorithm leads to an expected number of hops of $O\big((\log n)^2\big)$. We prove that greedy routing does not perform asymptotically better for any distribution in which the probability that node u has long range contact v is only a function of $\|u-v\|_1$, as long as D is constant. For this, we introduce a novel proof technique, involving a so-called *budget game*, which is a simple process in one dimension. We prove a tight lower bound for such a budget game and then obtain a lower bound for greedy routing by a reduction.

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CP12

Timing in Chemical Reaction Networks

Chemical reaction networks (CRNs) formally model chemistry in a well-mixed solution. CRNs are formally equivalent to a model of distributed computing known as population protocols, results transfer readily between the two models. We show that if a CRN respects *finite density* (at most O(n) additional molecules can be produced from n initial molecules), then starting from any *dense* initial state (all molecular species initially present have count Omega(n), where n is the initial molecular count and volume), *every* producible species is produced in constant time with high probability. This implies that no such CRN can be a "timer", able to produce a molecule, but doing so only after a time that is an unbounded function of the input size. This has consequences regarding an open question of Angluin, Aspnes, and Eisenstat concerning the ability of population protocols to perform fast, reliable leader election and to simulate arbitrary algorithms from a uniform initial state.

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CP12

Tight Bounds for Rumor Spreading with Vertex Expansion

We establish a bound for the classic PUSH-PULL rumor spreading protocol on general graphs, in terms of the vertex expansion of the graph. We show that $O(\log^2(n)/\alpha)$ rounds suffice with high probability to spread a rumor from any single node to all n nodes, in any graph with vertex expansion at least α. This bound matches a known lower bound, and settles the natural question on the relationship between rumor spreading and vertex expansion asked by Chierichetti, Lattanzi, and Panconesi (SODA 2010). Further, some of the arguments used in the proof may be of independent interest, as they give new insights, for example, on how to choose a small set of nodes in which to plant the rumor initially, to guarantee fast rumor spreading.

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CP12

Faster Agreement Via a Spectral Method for Detecting Malicious Behavior

We address the problem of Byzantine agreement, to bring processors to agreement on a bit in the presence of a it strong adversary. This adversary has full information of the state of all processors, the ability to control message scheduling in an asynchronous model, and the ability to control the behavior of a constant fraction of processors which it may choose adaptively. We use a novel technique for detecting malicious behavior via spectral analysis. In particular, our algorithm uses coin flips from individual processors to repeatedly try to generate a fair global coin. The corrupted processors can bias this global coin by generating biased individual coin flips. However, we can detect which processors generate biased coin flips by analyzing the top right singular vector of a matrix containing the sums of coin flips generated by each processor. Entries in this singular vector with high absolute value correspond to processors that are trying to bias the global coin.

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CP12

Intrinsic Universality in Tile Self-Assembly Requires Cooperation

We prove a negative result on the power of a model of algorithmic self-assembly for which finding general techniques and results has been notoriously difficult. Specifically, we prove that Winfree's abstract Tile Assembly Model is not intrinsically universal when restricted to use noncooperative tile binding. Noncooperative self-assembly, also known as "temperature 1', is where all tiles bind if they match on at least one side. Cooperative self-assembly, on the other hand, requires that some tiles bind on at least two sides. Our result shows that the change from non-cooperative to cooperative binding qualitatively improves the dynamics and behaviors found in these models of nanoscale self-assembly. In addition to the negative result, we exhibit a 3D noncooperative self-assembly tile set capable of simulating any 2D noncooperative self-assembly system. This implies that, in a restricted sense, non-cooperative self-assembly is intrinsically universal for itself.

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CP13

Integer Quadratic Programming in the Plane

We show that the problem of minimizing a quadratic polynomial with integer coefficients over the integer points in a general two-dimensional rational polyhedron is solvable in time bounded by a polynomial in the input size.

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CP13

Improved Upper Bounds for Random-Edge and Random-Jump on Abstract Cubes

Upper bounds are given for the complexity of two very natural randomized algorithms for finding the *sink* of an *Acyclic Unique Sink Orientation* (AUSO) of the n-cube. For Random-Edge, we obtain an upper bound of about 1.80^n, improving upon the the previous upper bound of about $2^n/n^{\log n}$ obtained by Gärtner and Kaibel. For Random-Jump, we obtain an upper bound of about $(3/2)^n$, improving upon the previous upper bound of about 1.72^n obtained by Mansour and Singh. AUSOs provide an appealing combinatorial abstraction of linear programming and other computational problems such as finding optimal strategies for turn-based *Stochastic Games*.

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CP13

Dantzig's Pivoting Rule for Shortest Paths, Deterministic Mdps, and Minimum Cost to Time Ratio Cycles

Dantzig's pivoting rule is one of the most studied pivoting rules for the simplex algorithm. Orlin showed that $O(mn^2 \log n)$ Dantzig's pivoting steps suffice to solve *shortest paths* problems. Post and Ye recently showed that $O(m^2n^3 \log^2 n)$ Dantzig's steps suffice to solve *deterministic MDPs* with a uniform discount factor. We improve both these bounds by a factor of n. Finally, we show how to reduce the problem of finding a *minimum cost to time ratio cycle* to the problem of finding an optimal policy for a discounted deterministic MDP with varying discount factors that tend to 1. This gives a strongly polynomial time algorithm for the problem that does not use Megiddo's parametric search technique.

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CP13

Optimization Despite Chaos: Convex Relaxations to Complex Limit Sets Via Poincaré Recurrence

Decentralized systems, such as evolutionary dynamics in network extensions of zero-sum games, can give rise to complex behavior patterns. The challenge of any analytic investigation is to identify and characterize persistent properties despite the irregularities of such systems. We combine ideas from dynamical systems and game theory to produce topological characterizations of system trajectories. These trajectories are complex and do not necessarily converge to limit points or even limit cycles. We provide relaxed convex descriptions that can be computed in polynomial time. This allows us to compute extremal values of system features (e.g. expected utility of an agent) within these relaxations. Finally, we use information theoretic conservation laws along with Poincaré recurrence theory to argue about the optimality of our techniques.

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CP13

Polynomiality for Bin Packing with a Constant Number of Item Types

We consider the bin packing problem with d different item sizes s_i and item multiplicities a_i, where all numbers are given in binary encoding. This problem formulation is also known as the *1-dimensional cutting stock problem.* In this work, we provide an algorithm which, for constant d, solves bin packing in polynomial time. This was an open problem for all $d \geq 3$. In fact, for constant d our algorithm solves the following problem in polynomial time: given two d-dimensional polytopes P and Q, find the smallest number of integer points in P whose sum lies in Q.

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CP14

Maximizing Social Influence in Nearly Optimal Time

Diffusion is a fundamental graph process, underpinning such phenomena as epidemic disease contagion and the spread of innovation by word-of-mouth. We address the algorithmic problem of finding a set of k initial seed nodes in a network so that the expected size of the resulting cascade is maximized, under the standard *independent cascade* model of network diffusion. Runtime is a primary consideration for this problem due to the massive size of the relevant input networks. We provide a fast algorithm for the influence maximization problem, obtaining the near-optimal approximation factor of $(1 - \frac{1}{e} - \epsilon)$, for any $\epsilon > 0$, in time $O((m + n)\epsilon^{-3} \log n)$. Our algorithm is runtime-optimal (up to a logarithmic factor) and substantially improves upon the previously best-known algorithms which run in time $\Omega(mnk \cdot \text{POLY}(\epsilon^{-1}))$. Furthermore, our algorithm can be modified to allow early termination: if it is terminated after $O(\beta(m + n) \log n)$ steps for some $\beta < 1$ (which can depend on n), then it returns a solution with approximation factor $O(\beta)$. Finally, we show that this runtime is optimal (up to logarithmic factors) for any β and fixed seed size k.

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CP14

Smoothed Analysis of Local Search for the Maximum-Cut Problem

Although the Maximum-Cut Problem is PLS-complete, local search heuristics for this problem perform well in practice. We study local search in the framework of smoothed analysis in which inputs are subject to a small amount of random noise. We show that the smoothed number of iterations is bounded by a polynomial in $n^{\log n}$ and ϕ where ϕ denotes the perturbation parameter. This shows that worst-case instances are fragile and unlikely to occur in practice.

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CP14

A Constructive Algorithm for the Lovász Local Lemma on Permutations

While there has been significant progress on algorithmic aspects of the Lovász Local Lemma (LLL) in recent years, a noteworthy exception is when the LLL is used in the context of random permutations: the "lopsided" version of the LLL is usually at play here, and we do not yet have subexponential-time algorithms. We resolve this by developing a randomized polynomial-time algorithm for such applications. A noteworthy application is for Latin Transversals: the best-known general result here (Bissacot et al., improving on Erdős and Spencer), states that any $n \times n$ matrix in which each entry appears at most $(27/256)n$ times, has a Latin transversal. We present the first polynomial-time algorithm to construct such a transversal. Our ap-

proach also yields RNC algorithms: for Latin transversals, as well as the first efficient ones for the strong chromatic number and (special cases of) acyclic edge-coloring.

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CP14

Pipage Rounding, Pessimistic Estimators and Matrix Concentration

Pipage rounding is a dependent random sampling technique that has several interesting properties. One property that has been useful in applications is negative correlation of the resulting vector. There are some further properties that would be interesting to derive, but do not follow from negative correlation. In particular, recent concentration results for sums of independent random matrices are not known to extend to a negatively dependent setting. We introduce a technique called concavity of pessimistic estimators. This technique allows us to show concentration of submodular functions and concentration of matrix sums under pipage rounding. We provide an application to spectrally-thin trees, a spectral analog of the thin trees that played a crucial role in the recent breakthrough on ATSP. We show an algorithm that, given a graph where every edge has effective conductance at least κ, returns an $O(\kappa^{-1} \cdot \log n / \log \log n)$-spectrally-thin tree.

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CP14

Bilu-Linial Stable Instances of Max Cut and Minimum Multiway Cut

We investigate the notion of stability proposed by Bilu and Linial. We obtain an exact robust algorithm for γ-stable Max Cut instances with $\gamma \geq c\sqrt{\log n} \log \log n$ for some $c > 0$. We also prove that there is no robust polynomial-time algorithm for instances when γ is less than the best approximation factor for Sparsest Cut. That suggests that solving γ-stable instances with $\gamma = o(\sqrt{\log n})$ might be difficult or even impossible. Additionally, we present an algorithm for 4-stable instances of Minimum Multiway Cut. We also study a relaxed notion of weak stability.

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CP15

Cache-Adaptive Algorithms

We introduce the cache-adaptive model, which generalizes the external-memory model to apply to environments in which the amount of memory available to an algorithm changes over time. We prove that if an optimal cache-oblivious algorithm has a particular recursive structure, then it is also an optimal cache-adaptive algorithm. Cache-oblivious algorithms having this form include Floyd-Warshall all pairs shortest paths, naïve recursive matrix multiplication, matrix transpose, and Gaussian elimination. While the cache-oblivious sorting algorithm Lazy Funnel Sort does not have this recursive structure, we prove that it is nonetheless optimally cache-adaptive. We give paging algorithms for the case where the cache size changes dynamically. LRU with 4-memory and 4-speed augmentation is competitive with optimal. Moreover, Belady's algorithm remains optimal even when the cache size changes.

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CP15

Near-Optimal Labeling Schemes for Nearest Common Ancestors

We consider NCA labeling schemes: given a rooted tree T, label the nodes of T with binary strings such that, given the labels of any two nodes, one can determine, by looking only at the labels, the label of their nearest common ancestor. For trees with n nodes we present upper and lower bounds establishing that labels of size $(2 \pm \epsilon) \log_2 n$, $\epsilon < 1$ are both sufficient and necessary. Our lower bound separates NCA from ancestor labeling schemes.

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CP15

Selection and Sorting in the 'Restore' Model

We consider the classical selection and sorting problems in a model where the initial permutation of the input has to be *restored* after completing the computation. While the requirement of the restoration is stringent compared to the classical versions of the problems, this model is more relaxed than a read-only memory where the input elements are not allowed to be moved within the input array. We show that for a sequence of n integers, selection can be done in $O(n)$ time using $O(\lg n)$ words. For sorting n integers in this model, we present an $O(n \lg n)$-time algorithm using $O(\lg n)$ words of extra space, and we show how to match the time bound of any word-RAM integer-sorting algorithms using $O(n^{\varepsilon})$ words of extra space. Such time-space tradeoffs are provably not possible for general "indivisible' input elements.

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CP15

Disjoint Set Union with Randomized Linking

A classic result in the analysis of data structures is that path compression with linking by rank solves the disjoint set union problem in almost-constant amortized time per operation. Recent experiments suggest that in practice, a naïve linking method works just as well if not better than linking by rank, in spite of being theoretically inferior. How can this be? We prove that *randomized* linking is asymptotically as efficient as linking by rank. This result provides theory that matches the experiments, which implicitly do randomized linking as a result of the way the input instances are generated.

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CP15

Concurrent Range Reporting in Two-Dimensional Space

In the *concurrent range reporting* problem, the input is L disjoint sets $S_1, ..., S_L$ of points with a total of N points. The goal is to preprocess the sets into a structure such that, given a query range r and an arbitrary set $Q \subseteq \{1, ..., L\}$, we can efficiently report all the points in $S_i \cap r$ for each $i \in Q$. We focus on the one- and two-dimensional cases of the problem. We prove that in the pointer-machine model (as well as comparison models such as the real RAM model), answering queries requires $\Omega(|Q| \log(L/|Q|) + \log N + K)$ time in the worst case, where K is the number of output points. In one dimension, we achieve this query time with a linear-space dynamic data structure that requires optimal $O(\log N)$ time to update. In the static case, for three-sided two-dimensional ranges, we get close to within an inverse Ackermann ($\alpha(\cdot)$) factor: we answer queries in $O(|Q| \log(L/|Q|)\alpha(L) + \log N + K)$ time.

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CP16

Better Approximation Algorithms for the Graph Diameter

The diameter of the graph is a fundamental graph parameter. In a seminal result Aingworth, Chekuri, Indyk and Motwani [SICOMP'99] designed an algorithm that computes in $\tilde{O}(n^2 + m\sqrt{n})$ time an estimate $\tilde{D}$ for the diameter D, such that $\lfloor 2D/3 \rfloor - (M-1) \leq \tilde{D} \leq D$, where M is the maximum edge weight in the graph. In recent work, Roditty and Vassilevska W. [STOC 13] gave an algorithm that has the same approximation guarantee but improves the runtime to $\tilde{O}(m\sqrt{n})$. For weighted graphs however, this approximation guarantee can be meaningless, as M can be arbitrarily large. In this paper we exhibit two algorithms that achieve a genuine 3/2-approximation for the diameter, one running in $\tilde{O}(m^{3/2})$ time, and one running in $\tilde{O}(mn^{2/3})$ time. In addition, we address the question of obtaining an additive c-approximation for the diameter. We present essentially tight lower bounds assuming the Strong Exponential Time Hypothesis.

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CP16

Cutting Corners Cheaply, Or How to Remove Steiner Points.

Our main result is that the Steiner Point Removal (SPR) problem can always be solved with polylogarithmic distortion, which resolves in the affirmative a question posed by Chan, Xia, Konjevod, and Richa (2006). Specifically, we prove that for every edge-weighted graph $G = (V, E, w)$ and a subset of terminals $T \subseteq V$, there is a graph $G' = (T, E', w')$ that is isomorphic to a minor of G, such that for every two terminals $u, v \in T$, the shortest-path distances between them in G and in G' satisfy $d_{G,w}(u, v) \leq$

$d_{G',w'}(u,v) \leq O(\log^6 |T|) \cdot d_{G,w}(u,v)$. Our proof features a new variant of metric decomposition.

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CP16

A Subquadratic-Time Algorithm for Decremental Single-Source Shortest Paths

We study dynamic $(1+\epsilon)$-approximation algorithms for the single-source shortest paths problem in an unweighted undirected n-node m-edge graph under edge deletions. The fastest algorithm for this problem is an algorithm with $O(n^{2+o(1)})$ total update time and constant query time by Bernstein and Roditty (SODA 2011). In this paper, we improve the total update time to $O(n^{1.8+o(1)} + m^{1+o(1)})$ while keeping the query time constant. This running time is essentially tight when $m = \Omega(n^{1.8})$ since we need $\Omega(m)$ time even in the static setting. For smaller values of m, the running time of our algorithm is *subquadratic*, and is the first that breaks through the quadratic time barrier.

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CP16

Fault Tolerant Approximate BFS Structures

This paper addresses the problem of designing a *fault-tolerant* (α,β) approximate BFS structure, namely, a subgraph H of the network G satisfying $(s,v,H\setminus F) \leq \alpha\cdot(s,v,G\setminus F)+\beta$ for every $v\in V$. We first consider *multiplicative* $(\alpha,0)$ FT-ABFS structures and present an algorithm that given an n-vertex unweighted undirected graph G and a source s constructs a $(3,0)$ FT-ABFS structure rooted at s with at most $3n$ edges . We then consider *additive* $(1,\beta)$ FT-ABFS structures. In contrast to the linear size of $(\alpha,0)$ FT-ABFS structures, we show that for every $\beta\in[1,O(\log n)]$ there exists an n-vertex graph G with a source s for which any $(1,\beta)$ FT-ABFS structure rooted at s has $\Omega(n^{1+\epsilon(\beta)})$ edges, for some function $\epsilon(\beta)\in(0,1)$. Our lower bounds are complemented by an upper bound.

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CP16

Beyond Locality-Sensitive Hashing

We present a new data structure for the c-approximate near neighbor problem (ANN) in the Euclidean space. For n points in $\mathbb{R}^d$, our algorithm achieves $O(n^{\rho}+d\log n)$ query time and $O(n^{1+\rho}+d\log n)$ space, where $\rho <= 7/(8c^2) + O(1/c^3)+o(1)$. This is the first improvement over the result by Andoni and Indyk (FOCS 2006) and the first data structure that bypasses a locality-sensitive hashing lower bound proved by O'Donnell, Wu and Zhou (ICS 2011). By a standard reduction we obtain a data structure for the Hamming space and ℓ_1 norm with $\rho <= 7/(8c) + O(1/c^{3/2}) + o(1)$, which is the first improvement over the result of Indyk and Motwani (STOC 1998).

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CP17

Ranking on Arbitrary Graphs: Rematch via Continuous LP with Monotone and Boundary Condition Constraints

We revisit the well-known oblivious matching problem on general graphs, in which an adversary fixes a graph whose edges are oblivious to the algorithm. We analyze the famous Ranking algorithm, and form an LP with monotone and boundary constraints. We solve its continuous LP relaxation to give the currently best performance ratio 0.523.

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CP17

Primal Dual Gives Almost Optimal Energy Efficient Online Algorithms

We consider the problem of online scheduling of jobs on unrelated machines with dynamic speed scaling to minimize the sum of energy and weighted flow time. We give an algorithm with an almost optimal competitive ratio for arbitrary power functions. For power functions of the form $f(s) = s^{\alpha}$ for some constant $\alpha > 1$, we get a competitive ratio of $O(\frac{\alpha}{\log\alpha})$, improving upon a previous competitive ratio of $O(\alpha^2)$ by Anand et al., along with a matching lower bound of $\Omega(\frac{\alpha}{\log\alpha})$. Further, in the resource augmentation model, with a $1+\epsilon$ speed up, we give a $2(\frac{1}{\epsilon}+1)$ competitive algorithm, improving the bound of $1+O(\frac{1}{\epsilon^2})$ by Gupta et al. Unlike the previous results most of which used an amortized local competitiveness argument or dual fitting methods, we use a primal-dual method, which is useful not only to analyze the algorithms but also to design the algorithm itself.

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CP17

Hallucination Helps: Energy Efficient Virtual Circuit Routing

We consider virtual circuit routing protocols, with an objective of minimizing energy, in a network of components that are speed scalable, and that may be shutdown when idle. We give a polynomial-time offline algorithm for multicommodity routing, that has approximation ratio $O(\log^\alpha k)$, where k is the number of demand pairs. The key step of the algorithm design is a random sampling technique that we call *hallucination*. The algorithm extends rather naturally to an online algorithm. The analysis of the online algorithm introduces a natural "priority' multicommodity flow problem, and bounds the priority multicommodity flow-cut gap. We also explain how our hallucination technique can be used to achieve an $(O(\log km), O(\log km))$ bicriteria approximation result for the problem of buying a minimum cost collection of unit-capacitated edges to support a concurrent multicommodity flow, where m is the number of links in the network.

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CP17

Improvements and Generalizations of Stochastic Knapsack and Multi-Armed Bandit Approximation Algorithms

In 2011, A. Gupta et al. obtained an LP-based $\frac{1}{48}$-approximation algorithm for the multi-armed bandit (MAB) problem without the martingale assumption. We improve the algorithm to a $\frac{4}{27}$-approximation, with simpler analysis. Our algorithm also generalizes to the case of MAB superprocesses with (stochastic) multi-period actions, yielding new results in the budgeted learning framework of Guha and Munagala. Also, we obtain a $(\frac{1}{2} - \varepsilon)$-approximation for the variant of MAB where preemption (playing an arm, switching to another arm, then coming back to the first arm) is not allowed. This contains the stochastic knapsack problem of Dean, Goemans, and Vondrák with correlated rewards, improving the $\frac{1}{16}$ and $\frac{1}{8}$ approximations of A. Gupta et al. for the cases with and without cancellation, respectively, providing to our knowledge the first tight algorithm for these problems that matches the integrality gap of 2.

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CP17

New Approximations for Reordering Buffer Management

In this paper we consider the buffer reordering management problem. In this model there are n elements that arrive over time with different colors. There is a buffer that can store up to k elements and when the buffer becomes full an element must be output. If an element is output that has a color different from the previous element, a cost depending on the color must be paid. This cost could be uniform or non-uniform over colors; these are called unweighted and weighted cases, respectively. The goal is to reorder elements within the buffer before outputting them to minimize the total cost incurred. Our main result is a randomized $O(\log\log k\gamma)$-approximation for the weighted case. Here γ is the ratio of the maximum to minimum weight. We also revisit the unweighted case and give an improved randomized -approximation which improves (modestly) upon the approximation guarantee given previously.

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CP18

Testing Equivalence Between Distributions Using Conditional Samples

We study a recently introduced framework for property testing of probability distributions, by considering distribution testing algorithms that have access to a *conditional sampling oracle*. This is an oracle that takes as input a subset S of the domain $[N]$ of the unknown probability distribution D and returns a draw from the conditional distribution D restricted to S. This model allows considerable flexibility in the design of distribution testing algorithms; in particular, testers in this model can be adaptive. In this paper we focus on algorithms for two fundamental distribution testing problems: testing whether $D = D^*$

for an explicitly provided D^*, and testing whether two unknown D_1 and D_2 are equivalent. While these problems have $\Omega(\sqrt{N})$ sample complexity in the standard model we give poly$(\log N, 1/\epsilon)$-query algorithms (and in some cases poly$(1/\epsilon)$ independent of N) for both in our conditional sampling setting.

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CP18

A Cubic Algorithm for Computing Gaussian Volume

We present randomized algorithms for sampling the standard Gaussian distribution restricted to a convex set and for estimating the Gaussian measure of a convex set, in the general membership oracle model. The complexity of the integration algorithm is $O^*(n^3)$ while the complexity of the sampling algorithm is $O^*(n^3)$ for the first sample and $O^*(n^2)$ for every subsequent sample. These bounds improve on the corresponding state-of-the-art by a factor of n. Our improvement comes from several aspects: better isoperimetry, smoother annealing, avoiding transformation to isotropic position and the use of the "speedy walk" in the analysis.

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CP18

Optimal Algorithms for Testing Closeness of Discrete Distributions

We study the question of closeness testing for two discrete distributions. More precisely, given samples from two distributions p and q over an n-element set, we wish to distinguish whether $p = q$ versus p is at least ϵ-far from q, in either ℓ_1 or ℓ_2 distance. Batu et al [**?**, **?**] gave the first sublinear time algorithms for these problems, which matched the lower bounds of [**?**] up to a logarithmic factor in n, and a polynomial factor of ϵ. In this work, we present simple (and new) testers for both the ℓ_1 and ℓ_2 settings, with sample complexity that is information-theoretically optimal, to constant factors, both in the dependence on n, and the dependence on ϵ; for the ℓ_1 testing problem we establish that the sample complexity is $\Theta(\max\{n^{2/3}/\epsilon^{4/3}, n^{1/2}/\epsilon^2\})$.

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CP18

Hereditary Properties of Permutations Are Strongly Testable

We show that for every hereditary permutation property P and every $\varepsilon > 0$, there exists an integer M such that if a permutation π is ε-far from P in the Kendall's tau distance, then a random subpermutation of π of order M has the property P with probability at most ε. This settles an open problem whether hereditary permutation properties are strongly testable, i.e., testable with respect to the Kendall's tau distance, which is considered to be the edit distance for permutations.

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CP18

Testing Surface Area

We give an $O(1/\epsilon)$-query property testing algorithm which distinguishes whether an unknown set has surface area at most A or (is ϵ-far from) surface area at least $(4/\pi)A$. Our result works under n-dimensional Lebesgue measure or n-dimensional Gaussian measure. Previous work only treated the 1-dimensional case. We improve previous results for the 1-dimensional case and give the first results for higher n and evades the "curse of dimensionality'.

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CP19

Approximation Algorithm for Sparsest K-Partitioning

Given a graph G, the sparsest-cut problem asks to find the set of vertices S which has the least expansion defined as

$$\phi_G(S) := \frac{w(E(S,\bar{S}))}{\min\{w(S), w(\bar{S})\}},$$

where w is the total edge weight of a subset. Here we study the natural generalization of this problem: given an integer k, compute a k-partition $\{P_1, \ldots, P_k\}$ of the vertex set so as to minimize

$$\phi_k(\{P_1,\ldots,P_k\}) := \max_i \phi_G(P_i).$$

Our main result is a polynomial time bi-criteria approximation algorithm which outputs a $(1-\varepsilon)k$-partition of the vertex set such that each piece has expansion at most $O_\varepsilon(\sqrt{\log n \log k})$ times OPT. We also study balanced versions of this problem.

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CP19

Flow-Based Algorithms for Local Graph Clustering

Given a subset A of vertices of an undirected graph G, the cut-improvement problem asks us to find a subset S similar to A but with smaller conductance. An algorithm for this problem was given by Andersen and Lang in 2008 and requires maximum flow computations over the whole graph G. In this paper, we introduce LocalImprove, the first cut-improvement algorithm that is LOCAL, i.e., that runs in time dependent on the size of the input set A rather than that of G. LocalImprove closely matches the same theoretical guarantee as Andersen-Lang. The main application of LocalImprove is to design better local-graph-partitioning algorithms. Zhu, Lattanzi and Mirrokni showed in 2013 that random-walk based local algorithms can obtain an improved-Cheeger's like conductance performance, while we show in the regime when their improved Cheeger's outperforms Cheeger's, we can use LocalImprove to obtain an O(1) approximation. This yields the first flow-based local algorithm for graph partitioning.

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CP19

Partitioning into Expanders

There is a basic fact in algebraic graph theory that for any graph $G = (V, E), lambda_k > 0$ if and only if G has at most $k-1$ connected components. We prove a robust version of this fact. For some $1 <= l <= k-1$, V can be partitioned into l sets $P_1, \ldots, P_l$ such that each P_i is a low-conductance set in G and induces a high conductance induced subgraph.

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CP19

Non-Uniform Graph Partitioning

We consider the problem of Non-Uniform Graph Partitioning, where the input is an edge-weighted undirected graph $G = (V, E)$ and k capacities $n_1, \ldots, n_k$, and the goal is to find a partition $\{S_1, S_2, \ldots, S_k\}$ of V satisfying $|S_j| \leq n_j$ for all $1 \leq j \leq k$, that minimizes the total weight of edges crossing between different parts. We present a bicriteria approximation algorithm for Non-Uniform Graph Partitioning that approximates the objective within $O(\log n)$ factor while deviating from the required capacities by at most a constant factor. Our approach is to apply stopping-time based concentration results to a simple randomized rounding of a configuration LP. These concentration bounds are needed as the commonly used techniques of bounded differences and bounded conditioned variances do not suffice.

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CP19

Streaming Balanced Graph Partitioning Algorithms for Random Graphs

With recent advances in storage technology, it is now possible to store the vast amounts of data generated by cloud computing applications. The sheer size of big data motivates the need for streaming algorithms that can compute approximate solutions without full random access to all of the data. In this paper, we consider the problem of loading a graph onto a distributed cluster with the goal of optimizing later computation. We model this as computing an approximately balanced k-partitioning of a graph in a streaming fashion with only one pass over the data. We give lower bounds on this problem, showing that no algorithm can obtain an $o(n)$ approximation with a random or adversarial stream ordering.

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CP20

Constrained Signaling in Auction Design

We consider the problem of an auctioneer who faces the task of selling a good to a set of buyers, when the auctioneer does not have the capacity to describe to the buyers the exact identity of the good that he is selling. Instead, he must come up with a constrained signalling scheme: a mapping from goods to signals, that satisfies the constraints of his setting. For example, the auctioneer may be able to communicate only a bounded length message for each good, or he might be legally constrained in how he can advertise the item being sold. Each candidate signaling scheme induces an incomplete-information game among the buyers, and the goal of the auctioneer is to choose the signaling scheme and accompanying auction format that optimizes welfare. In this paper, we use techniques from submodular function maximization and no-regret learning to give algorithms for computing constrained signaling schemes for a variety of constrained signaling problems.

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CP20

On Computability of Equilibria in Markets with Production

Although production is an integral part of the Arrow-Debreu market model, and of most economies, almost all of the work in theoretical computer science has so far concentrated on markets without production. Our paper takes a significant step towards understanding computation of equilibria in markets with production. For markets with separable, piecewise-linear concave (SPLC) utilities and SPLC production, we obtain an LCP formulation that captures exactly the set of equilibria and we give a complementary pivot algorithm for finding one. This settles a question asked by Eaves in 1975. Since this is a path-following algorithm, we obtain a proof of membership of this problem in PPAD, using Todd, 1976. We further give a proof of PPAD-hardness for this problem. Experiments show that our algorithm is practical and does not suffer from issues of numerical instability. Also, it is strongly polynomial when the number of goods or the number of agents and firms is constant.

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CP20

The Complexity of Optimal Multidimensional Pricing

We resolve the complexity of revenue-optimal deterministic auctions in the unit-demand single-buyer Bayesian setting, i.e., the optimal item pricing problem, when the buyer's values for the items are independent. We show that the problem of computing a revenue-optimal pricing can be solved in polynomial time for distributions of support size 2 and its decision version is NP-complete for distributions of support size 3 as well for identical distributions.

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CP20

The Complexity of Optimal Mechanism Design

Myerson's seminal work provides a computationally efficient revenue-optimal auction for selling one item to multiple bidders. Generalizing this work to selling multiple items at once has been a central question in economics and algorithmic game theory, but its complexity has remained poorly understood. We answer this question by showing that a revenue-optimal auction in multi-item settings cannot be found and implemented computationally efficiently, unless $\mathtt{ZPP} \supseteq P^{\#\mathrm{P}}$. This is true even for a single additive bidder whose values for the items are independently distributed on two rational numbers with rational probabilities. Our result is very general: we show that it is hard to compute any encoding of an optimal auction of any format that can be implemented in expected polynomial time. In particular, under well-believed complexity-theoretic assumptions, revenue-optimization in very simple multi-item settings can only be tractably approximated.

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CP20

Prophet Inequalities with Limited Information

In the classical prophet inequality, a gambler observes a sequence of stochastic rewards and must decide, for each reward, whether to keep it and stop the game or to forfeit the reward forever and reveal the next value. The gambler's goal is to obtain a constant fraction of the expected reward that the optimal offline algorithm would get. Recently, prophet inequalities have been generalized to settings where the gambler can choose k elements, and, more generally, where he can choose any independent set in a matroid. However, all the existing algorithms require the gambler to know the distribution from which the rewards are drawn. We construct the first single-sample prophet inequalities for many settings of interest, whose guarantees all match the best possible asymptotically even with full knowledge of the distribution. In addition, we apply these results to design the first posted-price and multi-dimensional auction mechanisms with limited information in certain settings.

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CP21

Fast Computation of Output-Sensitive Maxima in

a Word Ram

In this paper, we study the problem of computing the maxima of a set of points in three dimensions and show that in a word RAM and given a set of n points with integer coordinates, the maxima can be found in $O\left(n \log\log_{n/h} n\right)$ deterministic time in which h is the output size. For $h = n^{1-\alpha}$ this is $O(n\log(1/\alpha))$. This improves the previous $O(n \log\log h)$ time algorithm and can be considered surprising since it gives a linear time algorithm when $\alpha > 0$ is a constant, which is faster than the current best deterministic and randomized integer sorting algorithms. We also observe that improving this running time at least requires faster integer sorting algorithms. Additionally, we show that the same deterministic running time could be achieved for performing n point location queries in an arrangement of size h. Finally, our maxima result can be extended to higher dimensions by paying a $\log_{n/h} n$ factor penalty per dimension.

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CP21

Making Octants Colorful and Related Covering Decomposition Problems

We give new positive results on the long-standing open problem of geometric covering decomposition for homothetic polygons. In particular, we prove that for any positive integer k, every finite set of points in $\mathbb{R}^3$ can be colored with k colors so that every translate of the negative octant containing at least k^6 points contains at least one of each color. The best previously known bound was doubly exponential in k. This yields, among other corollaries, the first polynomial bound for the decomposability of multiple coverings by homothetic triangles. We also prove that no algorithm can dynamically maintain a decomposition of a multiple covering by intervals under insertion of new intervals, even in a semi-online model.

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CP21

A Size-Sensitive Discrepancy Bound for Set Systems of Bounded Primal Shatter Dimension

Let $(X, \S)$ be a set system on an n-point set X. We consider the scenario where, for any subset $X' \subseteq X$ of size $m \leq n$ and for any parameter $1 \leq k \leq m$, the number of restrictions of the sets of $\S$ to X' of size at most k is only $O(m^{d_1} k^{d-d_1})$, for fixed integers $d > 0$ and $1 \leq d_1 \leq d$. In this case we show that $(X, \S)$ admits a discrepancy bound of $O^*(|S|^{1/2-d_1/(2d)} n^{(d_1-1)/(2d)})$, for each $S \in \S$, where $O^*(\cdot)$ hides a polylogarithmic factor in n. This bound is tight up to a polylogarithmic factor and the corresponding coloring can be computed in expected polynomial time using the very recent machinery of Lovett and Meka for constructive discrepancy minimization. Our bound improves and generalizes the bounds obtained from the machinery of Har-Peled and Sharir (and the follow-up work of Sharir ans Zaban) for points and halfspaces in d-space for $d \geq 3$.

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CP21

Four Soviets Walk the Dog—with An Application to Alt's Conjecture

Given two polygonal curves in the plane, there are many ways to define a notion of similarity between them. One measure that is extremely popular is the Fréchet distance. Since it has been proposed by Alt and Godau in 1992, many variants and extensions have been studied. Nonetheless, even more than 20 years later, the original $O(n^2 \log n)$ algorithm by Alt and Godau for computing the Fréchet distance remains the state of the art (here n denotes the number of vertices on each curve). This has led Helmut Alt to conjecture that the associated decision problem is 3SUM-hard. Building on recent work by Agarwal et al, we give a randomized algorithm to compute the Fréchet distance between two polygonal curves in time $O(n^2\sqrt{\log n}(\log\log n)^{3/2})$ on a pointer machine and in time $O(n^2(\log\log n)^2)$ on a word RAM. Furthermore, we provide evidence that the decision problem may not be 3SUM-hard after all.

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CP21

Optimal Deterministic Shallow Cuttings for 3D Dominance Ranges

Many problems in range searching admit efficient static data structures by the applying shallow cuttings. We present efficient deterministic algorithms that construct optimal size (single and multiple) shallow cuttings for orthogonal dominance ranges on a set of of n 3d points. A single shallow cutting takes $O(n \log n)$ worst case time and $O(n)$ space. We construct a logarithmic number of shallow cuttings of the input simultaneously, in the same complexity. This is optimal in the comparison and the algebraic comparison models, and an important step forward, since only polynomial guarantees were previously achieved for the deterministic construction of shallow cuttings, even in three dimensions. Our methods yield the first worst case efficient preprocessing algorithms for a series of important orthogonal range searching problems in the pointer machine and the word-RAM models, where such shallow cuttings are utilised to support the queries efficiently.

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CP22

Fast Algorithms for Maximizing Submodular Functions

In this paper we develop algorithms that match the best known approximation guarantees, but with significantly improved running times, for maximizing a monotone submodular function subject to various constraints. Our first result is a simple algorithm that gives a $(1 - 1/e - \epsilon)$-approximation for a cardinality constraint using $O(\frac{n}{\epsilon} \log \frac{n}{\epsilon})$ queries, and a $1/(p + 2\ell + 1 + \epsilon)$-approximation for the intersection of a p-system and ℓ knapsack constraints using $O(\frac{n}{\epsilon^2} \log^2 \frac{n}{\epsilon})$ queries. The main idea behind these algorithms serves as a building block in our more sophisticated algorithms. Our main result is a new variant of the continuous greedy algorithm, which interpolates between the classical greedy algorithm and a truly continuous algorithm. We show how this algorithm can be implemented for matroid and knapsack constraints using $\tilde{O}(n^2)$ oracle calls to the objective function.

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CP22

Submodular Maximization with Cardinality Constraints

We consider the problem of maximizing a (non-monotone) submodular function subject to a cardinality constraint. When at most k elements can be chosen, we improve the current best $1/e - o(1)$ approximation to a factor that is in the range $[1/e + 0.004, 1/2]$. When exactly k elements must be chosen, we improve the current best $1/4 - o(1)$ approximation to a factor that is in the range $[0.356, 1/2]$. Additionally, some of our algorithms have a time complexity of only $O(nk)$.

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CP22

Approximation Algorithms for Stochastic Boolean Function Evaluation and Stochastic Submodular Set Cover

We present approximation algorithms for two problems: Stochastic Boolean Function Evaluation (SBFE) and Stochastic Submodular Set Cover (SSSC). Our results for SBFE problems are obtained by reducing them to SSSC problems through the construction of appropriate utility functions. We give a new algorithm for the SSSC problem that we call Adaptive Dual Greedy. We use this algorithm to obtain a 3-approximation algorithm solving the SBFE problem for linear threshold functions. We also get a 3-approximation algorithm for the closely related Stochastic Min-Knapsack problem, and a 2-approximation for a natural special case of that problem. In addition, we prove a new approximation bound for a previous algorithm for the SSSC problem, Adaptive Greedy. We consider an approach to SBFE using existing techniques, which we call the Q-value approach. We present some uses of the Q-approach but prove its limitations as well.

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CP22

Influence Maximization in Undirected Networks

We consider the problem of finding k vertices of maximum total influence in an undirected network, under the independent cascade model of influence. It is known to be NP-hard to achieve an approximation factor better than $(11/e)$ in directed networks. We show that this barrier can be overcome in undirected networks: the greedy algorithm obtains a $(1 - 1/e + c)$ approximation to the set of optimal influence, for some constant $c > 0$.

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CP22

Maximizing Bisubmodular and k-Submodular Functions

We consider the problem of maximizing bisubmodular and, more generally, k-submodular functions in the value oracle model. We provide the first approximation guarantees for maximizing a general bisubmodular or k-submodular function. We give an analysis of the naive random algorithm as well as a randomized greedy algorithm inspired

by the recent randomized greedy algorithm of Buchbinder et al. [FOCS'12] for unconstrained submodular maximization. We show that this algorithm approximates any k-submodular function to a factor of $1/(1+\sqrt{k/2})$. In the case of bisubmodular functions, we achieve an approximation guarantee 1/2 and show that it is the best possible.

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CP23

Model-Based Sketching and Recovery with Expanders.

Linear sketching and recovery of sparse vectors with randomly constructed sparse matrices has numerous applications in several areas, including compressive sensing, data stream computing, graph sketching, and combinatorial group testing. This paper considers the same problem with the added twist that the sparse coefficients of the unknown vector exhibit further correlations as determined by a known sparsity model. We prove that exploiting model-based sparsity in sketching provably reduces the sketch size without sacrificing recovery quality. In this context, we present the first polynomial time algorithm for recovering model sparse signals from linear sketches obtained via sparse adjacency matrices of expander graphs with rigorous performance guarantees. The computational cost of our algorithm depends on the difficulty of projecting onto the model-sparse set. For the sparsity models we describe in this paper, such projections can be obtained in linear time. Finally, we provide numerical experiments to illustrate the theoretical results in action.

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CP23

Bicriteria Data Compression

We introduce the Bicriteria `LZ77`-Parsing problem. The goal is to determine an `LZ77` parsing which minimizes the compressed space occupancy, provided that the decompression time is bounded by T (or vice-versa). We solve this problem efficiently, up to a negligible additive constant, in $O(n \log^2 n)$ time and optimal $O(n)$ words of working space. Experiments show that our compressor is very competitive w.r.t. highly engineered competitors such as Snappy, `lzma`, `bzip2`.

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CP23

On Sketching Matrix Norms and the Top Singular Vector

In this paper, we study the problem of sketching matrix norms. We consider two sketching models. The first is bilinear sketching, in which there is a distribution over pairs of $r \times n$ matrices S and $n \times s$ matrices T such that for any fixed $n \times n$ matrix A, from $S \cdot A \cdot T$ one can approximate $\|A\|_p$ up to an approximation factor $\alpha \geq 1$ with constant probability, where $\|A\|_p$ is a matrix norm. The second is general linear sketching, in which there is a distribution over linear maps $L : \mathbf{R}^{n^2} \to \mathbf{R}^k$, such that for any fixed $n \times n$ matrix A, from $L(A)$ one can approximate $\|A\|_p$ up to a factor α. We study some of the most frequently occurring Schatten p-norms for $p \in \{0, 1, 2, \infty\}$, which correspond to the rank of A, the trace, Frobenius, and the operator norm, respectively.

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CP23

Approximation-Tolerant Model-Based Compressive Sensing

Results in compressive sensing show that one can recover a k-sparse signal from $m = O(k \log(n/k))$ measurements. The framework of model-based compressive sensing reduces the number of measurements even further to $O(k)$ by limiting the supports of x to a subset of all possible supports. Unfortunately, for the framework to apply, one needs an algorithm that given a signal x, solves the following optimization problem exactly: $\arg\min_{\Omega \in \mathcal{M}} \|x_{[n]\setminus\Omega}\|_2$. This requirement poses an obstacle for extending the framework to a richer class of models. In this paper, we remove this obstacle and show how to extend the model-based compressive sensing framework so that it requires only *approximate* solutions to the aforementioned optimization problem. Further, we apply our framework to the *Constrained Earth Mover's Distance (CEMD)* model, obtaining a sparse recovery scheme that uses significantly less than $O(k \log(n/k))$ measurements.

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CP23

New Constructions of RIP Matrices with Fast Multiplication and Fewer Rows

In this paper, we present novel constructions of matrices with the restricted isometry property (RIP) that support fast matrix-vector multiplication. Our guarantees are the best known, and can also be used to obtain the best known guarantees for fast Johnson-Lindenstrauss transforms.

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CP24

Point Line Cover: The Easy Kernel Is Essentially Tight

In the NP-hard Point Line Cover problem the task is to cover a given set of n points in the plane with at most k lines. There is a straightforward P-time reduction to k^2 points. Settling an open problem of Lokshtanov we prove that this cannot be significantly improved unless the polynomial hierarchy collapses. A key feature is the use of an active oracle protocol to efficiently transfer an instance with n points.

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CP24

Parameters of Two-Prover-One-Round Game and The Hardness of Connectivity Problems

Optimizing parameters of Two-Prover-One-Round Game (2P1R) is an important task in PCPs literature as it would imply a smaller PCP with the same or stronger soundness. While this is a basic question in PCPs community, the connection between the parameters of PCPs and hardness of approximations is sometimes obscure to approximation algorithm community. In this paper, we investigate the connection between the parameters of 2P1R and the hardness of approximating the class of so-called connectivity problems. Based on recent development on 2P1R by Chan (STOC 2013) and techniques in PCPs literature, we improve hardness results of connectivity problems that are in the form k^σ, for some constant $\sigma > 0$, to hardness of the form k^c for some explicit constant c, where k is a connectivity parameter. In addition, we show how to convert these hardness into hardness of the form $\mathcal{D}^{c'}$, where $\mathcal{D}$ is the number of demand pairs (or the number of terminals).

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CP24

Hardness of Finding Independent Sets in 2-Colorable and Almost 2-Colorable Hypergraphs

This work studies the hardness of finding independent sets in hypergraphs which are either 2-colorable, or $(1-\varepsilon)$-almost 2-colorable, i.e. removing an ε fraction of its vertices and all incident hyperedges makes the hypergraph 2-colorable. Our results are:

- For any constant $\gamma > 0$, there is $\xi > 0$, such that, given a 4-uniform hypergraph on n vertices which is $(1-\varepsilon)$-almost 2-colorable for $\varepsilon = 2^{-(\log n)^\xi}$, it is quasi-NP-hard to find an independent set of $n/\left(2^{(\log n)^{1-\gamma}}\right)$ vertices.
- For any constants $\varepsilon, \delta > 0$, given a $(1-\varepsilon)$-almost 2-colorable 3-uniform hypergraph on n vertices, it is NP-hard to find an independent set of δn vertices. Assuming the *d-to-1 Games Conjecture*, this holds for $\varepsilon = 0$, i.e. 2-colorable 3-uniform hypergraphs.

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CP24

Hardness of Robust Graph Isomorphism, Lasserre Gaps, and Asymmetry of Random Graphs

Given two graphs which are almost isomorphic, is it possible to find a bijection which preserves most of the edges between the two? This is the problem of Robust Graph Isomorphism, an approximation variation of the Graph Isomorphism problem. We show that no polynomial-time algorithm solves this problem, conditioned on Feige's Random 3XOR Hypothesis. In addition, we show that the Lasserre SDP hierarchy needs a linear number of rounds to distinguish two isomorphic graphs from two far-from-isomorphic graphs.

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CP24

Hypercontractive Inequalities Via SOS, and the Frankl-Rodl Graph

Our main result is a formulation and proof of the reverse hypercontractive inequality in the sum-of-squares (SOS) proof system. As a consequence we show that for any constant $0 < \gamma \leq 1/4$, the SOS/Lasserre SDP hierarchy at degree $4\lceil \frac{1}{4\gamma} \rceil$ certifies the statement "the maximum independent set in the Frankl–Rödl graph FR_n^γ has fractional size $o(1)$'. Here $\mathrm{FR}_n^\gamma = (V, E)$ is the graph with $V = \{0,1\}^n$ and $(x, y) \in E$ whenever $\mathrm{dist}(x, y) = (1 - \gamma)n$ (an even integer). Finally, we also give an SOS proof of (a generalization of) the sharp $(2, q)$-hypercontractive inequality for any even integer q.

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CP25

The Generalized Terminal Backup Problem

We consider the following network design problem, that we call the Generalized Terminal Backup Problem. Given a graph (or a hypergraph) $G_0 = (V, E_0)$, a set of (at least 2) terminals $T \subseteq V$, costs $c(uv) \geq 0$ for every pair $u, v \in V$, and a requirement $r(t)$ for every $t \in T$, find a minimum cost multigraph $G = (V, E)$ such that $\lambda_{G_0+G}(t, T-t) \geq r(t)$ for any $t \in T$. We give a polynomial time algorithm for the case when c is node-induced. We also solve the problem when G_0 is the empty graph.

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CP25

Analyzing the Optimal Neighborhood: Algorithms for Budgeted and Partial Connected Dominating Set Problems

We study natural generalizations of the classical connected dominating set (CDS) problem to the partial and budgeted versions. We develop surprisingly simple approximation algorithms for both these versions. For partial CDS, we are required to dominate a specified number of vertices, and we obtain the first $O(\log \Delta)$ approximation algorithm. For budgeted CDS, where the goal is to maximize coverage subject to a budget constraint, we obtain a $\frac{1}{13}(1 - \frac{1}{e})$ approximation algorithm. Finally, we extend our results to a more general setting that has capacitated and weighted profit versions of both partial and budgeted CDS as special cases. While our algorithms themselves are simple, the results make a surprising use of the greedy set cover framework in defining a useful profit function.

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CP25

Minimum d-Dimensional Arrangement with Fixed Points

In the Minimum d-Dimensional Arrangement Problem (d-DIMAP) we are given a weighted graph, and the goal is to find a 1-1 map of the vertices into $\mathbb{Z}^d$ minimizing the total weighted stretch of the edges. This problem arises in VLSI placement and chip design. Motivated by these applications, we consider a generalization of d-DIMAP, where the positions of some k of the vertices (pins) is *fixed* and specified as part of the input. We are asked to extend this partial map to all the vertices, again minimizing the weighted stretch of edges. This generalization, which we refer to as d-DIMAP+, arises naturally in these application domains. We give approximation algorithms for this problem, based on a strengthening of the *spreading-metric* LP for d-DIMAP. We complement our upper bounds by integrality gaps, and inapproximability results.

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CP25

Approximating Minimum Cost Connectivity Orientation and Augmentation

We investigate problems addressing combined connectivity augmentation and orientations settings. We give a polynomial time 6-approximation algorithm for finding a minimum cost subgraph of an undirected graph G that admits an orientation covering a non-negative crossing G-supermodular demand function, as defined by Frank. An important example is (k,l)-edge-connectivity, a common generalization of global and rooted edge-connectivity. Our algorithm is based on a non-standard application of the iterative rounding method. We observe that the standard linear program with cut constraints is not amenable and use an alternative linear program with partition and co-partition constraints instead. The proof requires a new type of uncrossing technique on partitions and co-partitions.

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CP25

Improved Algorithms for Vertex Cover with Hard Capacities on Multigraphs and Hypergraphs

We present improved approximation algorithms for the minimum unweighted Vertex Cover problem with Hard Capacity constraints. On multigraphs, we improve the approximation ratio from 38 to 2.155, and on f-hypergraphs from $\max\{6f, 65\}$ to $2f$. Our algorithms consist of a two-step process, each based on rounding an appropriate LP. For multigraphs, the analysis in the second step relies on identifying a *matching structure* within any extreme point solution.

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CP26

Tight Bounds for Planar Strongly Connected Steiner Subgraph with Fixed Number of Terminals (and Extensions)

Feldman and Ruhl (FOCS '99; SICOMP '06) gave a novel $n^{O(k)}$ algorithm for the Strongly Connected Steiner Subgraph (SCSS) problem, where n is the number of vertices and k is the number of terminals. We explore how much easier the problem becomes on planar directed graphs (or more generally graphs excluding a fixed minor). In particular, we show

- A $2^{O(k \log k)} \cdot n^{O(\sqrt{k})}$ algorithm for planar SCSS.
- A matching lower bound by showing that planar SCSS does not have an $f(k) \cdot n^{o(\sqrt{k})}$ algorithm for any function f, unless the Exponential Time Hypothesis (ETH) fails.
- Assuming ETH, SCSS in general graphs does not have an $f(k) \cdot n^{o(k/\log k)}$ algorithm for any function f.
- Assuming ETH, there is no $f(k) \cdot n^{o(k)}$ time algorithm for the Directed Steiner Forest problem on acyclic planar graphs. This matches the upper bound of $n^{O(k)}$ for DSF due to Feldman and Ruhl

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CP26

Linear-Time FPT Algorithms via Network Flow

In the area of parameterized complexity, to cope with NP-Hard problems, we introduce a parameter k besides the input size n, and we aim to design algorithms (called FPT algorithms) that run in $O(f(k)n^d)$ time for some function $f(k)$ and constant d. Though FPT algorithms have been successfully designed for many problems, typically they are not sufficiently fast because of huge $f(k)$ and d. In this paper, we give FPT algorithms with small $f(k)$ and d for many important problems including Odd Cycle Transversal and Almost 2-SAT by exploiting network flows. More specifically, we can choose $f(k)$ as a single exponential (4^k) and d as one, that is, linear in the input size. To the best of our knowledge, our algorithms achieve linear time complexity for the first time for these problems.

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CP26

A Near-Optimal Planarization Algorithm

The k-Vertex Planarization problem asks whether a graph G can be made planar by deleting k vertices. We show that the problem can be solved in time $2^{O(k \log k)} \cdot n$, thereby improving on an earlier algorithm by Kawarabayashi (FOCS 2009) with running time $\Omega(2^{k^{\Omega(k^3)}}) \cdot n$. While earlier planarization algorithms relied heavily on deep results from the graph minors project, our techniques are elementary and practically self-contained.

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CP26

Linear Time Parameterized Algorithms Via Skew-Symmetric Multicuts

A skew-symmetric graph $(D = (V, A), \sigma)$ is a directed graph D with an involution σ on the set of vertices and arcs. In the d-skew symmetric multicut problem where we are given a skew-symmetric graph D, a family $\mathcal{T}$ of d-sized subsets of vertices and an integer k, the objective is to decide if there is a set $X \subseteq A$ of k arcs such that every set J in the family has a vertex v such that v and $\sigma(v)$ are in different strongly connected components of $(V, A \setminus (X \cup \sigma(X))$. This problem generalizes numerous well studied classical problems including Odd Cycle Transversal and 2-SAT deletion. We give an algorithm for this problem which runs in time $O((4d)^k(m+n+\ell))$, where m is the number of arcs in the graph, n the number of vertices and ℓ the length of the family given in the input. As corollaries, we obtain linear time FPT algorithms for OCT and 2-SAT deletion. This is joint work with Saket Saurabh.

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CP26

A Subexponential Parameterized Algorithm for Subset TSP on Planar Graphs

Given a graph G and a subset S of vertices, the SUBSET TSP problem asks for a shortest closed walk in G visiting all vertices of S. The problem can be solved in time $2^k \cdot n^{O(1)}$ using the classical dynamic programming algorithms of Bellman and of Held and Karp, where $k = |S|$ and $n = |V(G)|$. Our main result is showing that the problem can be solved in time $(2^{O(\sqrt{k}\log k)} + W) \cdot n^{O(1)}$ if G is a planar graph with weights that are integers no greater than W. Our algorithm consists of two steps: (1) find a locally optimal solution, and (2) use it to guide a dynamic program. The proof of correctness of the algorithm depends on a treewidth bound on a graph obtained by combining an optimal solution with a locally optimal solution.

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CP26

Half-Integrality, LP-Branching and FPT Algorithms

We give a new, CSP-based approach to constructing LP-branching FPT algorithms. Instead of directly deriving Nemhauser-Trotter-style half-integrality, as previous work, we view half-integrality as a *discrete* relaxation of the search space (e.g., from $\{0,1\}^n$ to $\{0,1/2,1\}^n$) with certain properties, which can be found with CSP tools. As an application of the framework, we give the first single-exponential algorithm for GROUP FEEDBACK VERTEX SET and SUBSET FEEDBACK VERTEX SET, and significantly improved algorithms for UNIQUE LABEL COVER.

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CP27

Causal Erasure Channels

We introduce the causal erasure model and provide new upper bounds (impossibility results) and lower bounds (analyses of codes) on the achievable rate. Our bounds separate the achievable rate in the causal erasures setting from the rates achievable in two related models: random erasure channels (strictly weaker) and fully adversarial erasure channels (strictly stronger). Our results contrast with existing results on correcting causal bit-flip errors (as opposed to erasures). For the separations we provide, the analogous separations for bit-flip models are either not known at all or much weaker.

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CP27

Broadcast Throughput in Radio Networks: Routing Vs. Network Coding

The *broadcast throughput* in a network is defined as the average number of messages that can be transmitted per unit time from a given source to all other nodes. It has been shown that certain wired networks have asymptotically higher broadcast throughput when using network coding, where messages can be coded together in intermediate nodes, compared to the classical approach of routing, where messages are regarded as atomic tokens. Whether such a gap exists for wireless networks has been an open question of great interest. We show that there is a family of n-nodes radio networks in which the asymptotic throughput achievable via routing is a $\Theta(\log\log n)$ factor smaller than that of the optimal network coding algorithm. We also provide new tight upper and lower bounds showing that the asymptotic worst-case broadcast throughput is $\Theta(\frac{1}{\log n})$ messages-per-round for both routing and network coding.

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CP27

Optimal Rate List Decoding of Folded Algebraic-Geometric Codes over Constant-Sized Alphabets

We construct a new list-decodable family of asymptotically good algebraic-geometric codes over fixed alphabets. The function fields underlying these codes are constructed using class field theory, and designed to have an automorphism of large order that is used to “fold” the AG code. This generalizes earlier work by the first author on folded AG codes based on cyclotomic function fields. The recent linear-algebraic approach to list decoding can be applied to our new codes, and crucially, we use the Chebotarev density theorem to establish a polynomial upper bound on the list-size. Our construction yields algebraic codes over constant-sized alphabets that can be list decoded up to the Singleton bound. Previous such results over constant-sized alphabets were either based on concatenation or involved taking a subcode of AG codes. In contrast, our result shows that these folded AG codes themselves have the claimed list decoding property.

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CP27
Finding Orthogonal Vectors in Discrete Structures

Hopcroft's problem in d dimensions asks: given two sets of n vectors each in $\mathbb{R}^{d+1}$, is there a pair of vectors (one from each set) that are orthogonal? This problem has a long history and many applications. Known algorithms need at least $f(d) \cdot n^{2-1/O(d)}$ time for fast-growing f, and $n^{2-\varepsilon} \cdot \mathrm{poly}(d)$ time looks currently out of reach. We give randomized algorithms and almost matching lower bounds (modulo a breakthrough in SAT algorithms) for Hopcroft's problem over the ring of integers modulo m, and over finite fields. The algorithms arise from studying the communication problem of whether two lists of vectors (one held by Alice, one by Bob) contain an orthogonal pair of vectors (one from each list). We show the randomized communication complexity of the problem is related to the sizes of matching vector families. Building on these ideas, we give a very simple and efficient output-sensitive algorithm for matrix multiplication.

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CP27
Efficient Quantum Protocols for XOR Functions

We show that for any Boolean function f, the bounded-error quantum communication complexity $Q_\epsilon(f \circ \oplus)$ of XOR functions $f(x \oplus y)$ satisfies that

$$Q_\epsilon(f \circ \oplus) = O\big(2^d \big(\log \|\hat{f}\|_{1,\epsilon} + \log \frac{n}{\epsilon}\big) \log(1/\epsilon)\big),$$

where d is the GF[2]-degree of f, and $\|\hat{f}\|_{1,\epsilon} = \min_{g:\|f-g\|_\infty \le \epsilon} \|\hat{g}\|_1$. This matches a previous lower bound by Lee and Shraibman for f with low GF[2]-degree. The result also confirms the quantum version of the Log-rank Conjecture for low-degree XOR functions. In addition, we show that the exact quantum communication complexity

$$Q_E(f) = O(2^d \log \|\hat{f}\|_0),$$

where $\|\hat{f}\|_0$ is the number of nonzero Fourier coefficients of f. This matches a previous lower bound by Buhrman and de Wolf for low-degree XOR functions.

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ACM-SIAM Symposium on Discrete Algorithms

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