IP0

Dénes König Prize Lecture: Ramsey Numbers of Graphs and Hypergraphs

Determining or estimating Ramsey numbers is one of the central problems in combinatorics. In this talk we discuss recent progress on some longstanding conjectures in this area which have played an important role in the development of Ramsey theory.

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IP1

Binary Matroid Minors

The graph minors project is a sequence of extraordinary theorems proved by Neil Robertson and Paul Seymour in the 1980s. The banner theorem of that project is that every minor-closed family of graphs is characterized by a finite set of excluded minors. The project also has a number of remarkable algorithmic consequences, for example, the membership testing problem can be efficiently solved for any minor-closed class of graphs. Much of the work in the graph minors project goes into proving a technical theorem that constructively characterizes all minor-closed classes of graphs. The graph minors project can be interpreted in the context of matroid theory by considering the class of graphic matroids. Over the past decade, in joint work with Bert Gerards and Geoff Whittle, we have extended much of the graph minors project from the class of graphic matroids to the class of binary matroids. This talk will be introductory, no prior knowledge of matroid theory is assumed. We give a broad overview of the results and focus on potential applications to graph theory, coding theory, and quantum computing.

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IP2

The Combinatorics of Discrete Random Matrices

In random matrix theory, both continuous random matrix ensembles (e.g. the gaussian unitary ensemble, GUE) and discrete random matrix ensembles (e.g. the Bernoulli ensemble of random sign matrices, or the adjacency matrices of random graphs) are of interest. However, the discrete case contains additional difficulties that are not present in the continuous case. For instance, it is obvious that continuous random square matrices are almost surely invertible, but this is not true in the discrete case. Nevertheless, in recent years several tools of an additive combinatorics nature have been developed to close the gap between our understanding of discrete random matrices and continuous random matrices, and in particular inverse Littlewood-Offord theory, which roughly speaking asserts that discrete random walks behave much like their continuous counterparts, except in highly arithmetically structured cases, such as when the step sizes of the random walk all lie in an arithmetic progression. We survey these developments, and their applications, in this talk.

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IP3

Extremal Problems for Convex Lattice Polytopes

In this survey I will present several extremal problems, and some solutions, concerning convex lattice polytopes. A typical example is to determine the minimal volume that a convex lattice polytope can have if it has exactly n vertices. Other examples are the minimal surface area, or the minimal lattice width in the same class of polytopes. These problems are related to a question of V I Arnold from 1980 asking for the number of (equivalence classes of) lattice polytopes of volume V in d-dimensional space, where two convex lattice polytopes are equivalent if one can be carried to the other by a lattice preserving affine transformation.

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IP4

Optimizing in a Strategic World: A Survey of Recent Research in Algorithmic Game Theory

The goal of discrete optimization is to design systems with optimal or near-optimal performance. In the age of the Internet, however, we must take into account the fact that many of the users of our systems are driven by an economic goal, and interact with varying degrees of collaboration and competition. Moreover, the strategic nature of interactions in online dynamic marketplaces means that the roll-out of a new algorithm designed with the expectation of improved performance can end up degrading performance due to unanticipated responses by strategic users. The field of algorithmic game theory addresses this issue, as well as a wide variety of other problems at the intersection of game theory, economics and computer science. In this talk, we survey recent research and open problems in this field.

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IP5

The Method of Multiplicities

In 2008, Zeev Dvir achieved a breakthrough in combinatorial geometry by giving a stunningly simple, and sharp, bound on the size of "Kakeya Sets" in F_q^n, the n-dimensional vector space over the finite field on q elements. (A Kakeya set in any vector space is a set that contains a line in every direction.) Dvir proved this bound by setting up an n-variate low-degree non-zero polynomial that vanished on every point in the set, and then used the algebraic nature of a Kakeya set to argue that this polynomial was zero too often if the set was too small. In addition to resolving a long-studied problem in combinatorial geometry, this method also led to new constructions of "randomness extractors'. In this talk I will describe algebraic methods to improve the analysis of Dvir, by using polynomials that vanish with "high multiplicity' on every point on the given set. This method, based on prior work with Guruswami (1998), ends up yielding extremely tight (to within a factor of 2) bounds on the size of Kakeya sets; and, in combination with a host of other techniques, state-of-the-art "extractors" (algorithms that purify randomness). In this talk I will describe the (simple) idea behind the method of multiplicities and some of the applications. Based on joint works with Shubhangi Saraf (Analysis & PDE, 2009); and with Zeev Dvir, Swastik Kopparty, and Shubhangi Saraf (FOCS 2009).

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IP6
Configurations in Large t-connected Graphs

I will discuss a technique that allows us to establish the existence of certain configurations in large t-connected graphs, even though such configurations need not exist in small graphs. Two configurations of interest are complete minors and disjoint paths connecting prescribed pairs of vertices. We prove that for every integer t there exists an integer N such that every t-connected graph on at least N vertices with no minor isomorphic to the complete graph on t vertices has a set of at most t-5 vertices whose deletion makes the graph planar. This is best possible, except for the value of N. We also prove that the k Disjoint Paths Problem is feasible in every sufficiently big (2k+3)-connected graph. This is joint work with Sergey Norin.

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IP7
Hypergraphs with Low Dimension

Any hypergraph can be viewed as an object with geometric properties, by considering a geometric realisation of its associated abstract simplicial complex. It is well-known that any k-uniform hypergraph has such a realisation in $(2k-1)$-dimensional real space. We focus in particular on k-uniform hypergraphs that have a geometric realisation in k-dimensional space (so when $k = 2$ this is the class of planar graphs). We consider some properties of planar graphs that naturally extend to this class of "low-dimensional' hypergraphs.

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IP8
A Survey of Alternating Permutations

A permutation $a_1a_2 \cdots a_n$ of $1, 2, \ldots, n$ is *alternating* if $a_1 > a_2 < a_3 > a_4 < a_5 > \cdots$. If E_n is the number of alternating permutations of $1, 2, \ldots, n$, then

$$\sum_{n\geq 0} E_n \frac{x^n}{n!} = \sec x + \tan x.$$

We will discuss several aspects of the theory of alternating permutations. Some occurences of the numbers E_n, such as counting orbits of group actions and volumes of polytopes, will be surveyed. The behavior of the length of the longest alternating subsequence of a random permutation will be analyzed, in analogy to the length of the longest increasing subsequence. We will also explain how various classes of alternating permutations, such as those that are also fixed-point free involutions, can by counted using umbral techniques arising from a certain representation of the symmetric group S_n whose dimension is E_n.

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CP1
A Solution to Alspach's Problem for Complete Graphs of Large Odd Order

In 1981 Alspach posed the problem of proving that a complete graph of odd order n can be decomposed into edge-disjoint cycles of specified lengths $m_1, m_2, \ldots, m_t$ whenever the obvious necessary conditions that $3 \leq m_1, m_2, \ldots, m_t \leq n$ and $m_1 + m_2 + \cdots + m_t = \binom{n}{2}$ are satisfied. In this talk I will give a brief outline of a solution to Alspach's problem for sufficiently large odd values of n.

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CP1
When Every k-Cycle Has at Least $f(k)$ Chords

Chordal graphs can be characterized by every k-cycle having at least $k - 3$ chords. Similarly, requiring $\geq 2\lfloor \frac{k-3}{2} \rfloor$ chords characterizes the house-hole-domino-free graphs, and requiring $\geq 2k - 7$ chords characterizes graphs whose blocks are trivially perfect. Moreover, these three functions $f(k)$ are optimum for their graph classes—there are always graphs in each class that have k-cycles with exactly $f(k)$ chords. The functions $3\lfloor \frac{k-3}{3} \rfloor$ and $3k - 11$ characterize similar graph classes without being optimum.

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CP1
4-Cycle Systems of K_n with An Almost 2-Regular Leave

An almost 2-regular leave of K_n is a subgraph of K_n in which each vertex except one has degree two; the exceptional vertex has arbitrary degree. In this talk, we will provide the necessary and sufficient conditions for the existence of 4-cycle systems of K_n with an almost 2-regular leave. The solution to this problem has applications in neighbor designs used by serology researchers.

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CP1
Approaching Kelly's Conjecture

A Hamilton decomposition of a digraph G is a set of edge-disjoint Hamilton cycles which together cover all the edges of G. A conjecture of Kelly from 1968 states that every regular tournament has a Hamilton decomposition. We recently proved the following approximate version of Kelly's conjecture: Every regular tournament on n vertices contains $(1/2 - o(1))n$ edge-disjoint Hamilton cycles. I will discuss some of our techniques as well as some related open problems.

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CP2
Packing of Degree Sequences

We consider the question of when graphic sequences can be simultaneously realized by edge-disjoint graphs on the same vertex set. Results will be presented in both the bipartite and non-bipartite cases.

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CP2
The Embedded Graphs of a Knot and the Partial Duals of a Plane Graph

Recently O. Dasbach et. al. introduced a way to construct an embedded graph from a knot. Two fundamental questions arise from this construction: "which embedded graphs represent knots?" and "how are knots presented by the same embedded graph related to each other?". In this talk I will answer both of these questions through the use of a characterization of the partial duals of a plane graph in terms of separability.

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CP2
Progress on Hendry's Tables of Ramsey Numbers

In 1989, George R. T. Hendry presented a table of two-color graph Ramsey numbers $R(G, H)$ for all pairs of graphs G and H having five vertices, except seven cases: $R(K_5 - K_{1,3}, K_5) = R(K_4, K_5)$, $R(W_5, K_5 - e)$, $R(B_3, K_5)$, $R(W_5, K_5)$, $R(K_5 - P_3, K_5)$, $R(K_5 - e, K_5)$ and $R(K_5, K_5)$. The values $R(K_4, K_5) = 25$ and $R(W_5, K_5 - e) = 17$ are known since 1995. In this talk we overview the other two solved cases $R(B_3, K_5) = 20$ and $R(W_5, K_5) = 27$, where $B_3 = K_2 + \overline{K}_3$ and $W_5 = K_1 + C_4$, and present the progress (or lack of it) on the remaining three open cases.

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CP2
How to Draw a Tait-Colored Graph

Suppose G is a cubic graph with a Tait-coloring. We wish to draw G in the plane in such a way that (a) every edge is represented by a line segment, (b) all of the lines supporting the segments sharing a common color are concurrent, and (c) every supporting line has exactly two vertices. Using a seemingly unrelated result about 3-connected Tait-colored graphs, we shall see a sufficient (and possibly necessary) condition for when G has such a drawing.

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CP3
Mobius Inversion for Functions in Several Variables and Combinatorial Identities Involving Mertens and Mobius Functions

Dirichlet's convolution and Möbius inversion can be extended to arithmetical multivariable functions in many ways. We mention two examples. If α is an arithmetical function in one variable and F and G be arithmetical function of k variables, then we define two convolutions $\alpha \bullet F$ and $\alpha \diamond F$:

$$(\alpha \bullet F)(m, n_1, n_2, \ldots, n_{k-1}) = \sum_{d|m} \alpha(d) F\left(\frac{m}{d}, \left[\frac{n_1}{d}\right], \left[\frac{n_2}{d}\right], \ldots, \left[\frac{n_{k-1}}{d}\right]\right),$$

$$(\alpha \diamond F)(n_1, n_2, \ldots, n_k) = \sum_{d|(n_1, n_2, \ldots, n_k)} \alpha(d) F\left(\frac{n_1}{d}, \frac{n_2}{d}, \ldots, \frac{n_k}{d}\right).$$

For simplicity we let

$$\overline{n}_k = (n_1, n_2, \ldots, n_k) \text{ and } \left\lfloor \frac{n}{d} \right\rfloor_k = (\left\lfloor \frac{n_1}{d} \right\rfloor, \ldots, \left\lfloor \frac{n_k}{d} \right\rfloor).$$

Theorem. Let α be arithmetical having an inverse α^{-1} and let F and G are arithmetical of k variables. Then (a)

$$G(m, \overline{n}_{k-1}) = \sum_{d|m} \alpha(d) F\left(\frac{m}{d}, \left\lfloor \frac{n}{d} \right\rfloor_{k-1}\right) \Leftrightarrow F(m, \overline{n}_{k-1}) = \sum_{d|m} \alpha^{-1}(d) G\left(\frac{m}{d}\right.$$

(b)

$$G(\overline{n}_k) = \sum_{d|(n_1, n_2, \ldots, n_k)} \alpha(d) F\left(\frac{n}{d}\right)_k \Leftrightarrow F(\overline{n}_k) = \sum_{d|(n_1, n_2, \ldots, n_k)} \alpha^{-1}(d) G\left(\frac{n}{d}\right)$$

As applications we will use these extensions to count for any nonempty finite set of integers the number of its subsets which are relatively prime to a fixed positive integer and we count the number of such subsets having some fixed cardinality. Other applications are combinatorial identities involing Mertens and Mobius functions

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CP3
Effect of Seasonal Forces and Cross-Immunity on the Transmission Dynamics of Two Strains of Dengue

A deterministic model for the transmission dynamics of two strains of dengue disease is presented. The model, consisting of mutually-exclusive epidemiologi- cal compartments representing the human and vector dynamics, has a locally- asymptotically stable, disease-free equilibrium whenever the maximum of the associated reproduction numbers of the two strains is less than unity. The model can have innitely many co-existence equilibria if infection with one strain confers complete cross-immunity against the other strain and the associated reproduc- tion number of each strain exceeds unity. On the other hand, if infection with one strain confers partial immunity against the other strain, disease elimination, competitive exclusion or co-existence of the two strains can occur. The eect of seasonality on dengue transmission dynamics is explored using numerical simu- lations, where it is shown that the oscillation pattern diers between the strains, depending on the degree of the cross-immunity between the strains.

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CP3
Limit Theorems on Weakly Logarithmic Random Assemblies

We are concerned with the asymptotic value distribution problems for additive mappings defined on the random decomposable structures called assemblies. Extending the known approximations of the component structure vector by independent random variables in the total variation metrics to weakly logarithmic classes, we seek sufficient and at the same time necessary convergence conditions when the sizes increase. The one-dimensional, functional, and strong convergence will be discussed.

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CP3
The Distribution of the δ-Transformation for All Derangements of Order n with a Single Cycle

We find a general formula for this distribution. The algorithm was obtained by studying patterns in the unique outputs, obtained from the Burrows-Wheeler Transform for all possible permutations of order n. We start with an initial distribution and then subtract appropriate elements by making connections with indices in appropriately constructed matrices. We also find some interesting rules and patterns related to these derangements.

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CP4
Perfect Matchings in Grid Graphs after Vertex Deletions

We consider the d-dimensional grid graph $G = G_m^d$ on vertices $\{1, 2, \ldots, m\}^d$ (a subset of $\mathbf{Z}^d$) where two vertices are joined if and only if their coordinates differ in one place and have a difference of just 1. The graph is bipartite and the m^d vertices have bipartition W and B (sets W, B can be determined by the parity of their sum of coordinates). We show that there are constants a_d, b_d so that for every even m, if we choose subsets $B' \subseteq B$ and $W' \subseteq W$ in the d-dimensional grid graph G which satisfy three conditions (i) $|B'| = |W'|$, (ii) for any $x, y \in B'$ $d_G(x, y) \geq a_d m^{1/d} + b_d$ and (iii) for any $x, y \in W'$ $d_G(x, y) \geq a_d m^{1/d} + b_d$ then G with the vertices $B' \cup W'$ deleted has a perfect matching. The factor $m^{1/d}$ is best possible.

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CP4
Minimum Degree Threshold for Bipartite Graph Tiling

Graph tiling problems involve finding many vertex disjoint copies of H in a larger graph G. We answer a question of Zhao [*SIAM J. Disc. Math.* **23** vol.2, (2009), 888-900] that determines the minimum degree threshold for a bipartite graph G to contain an H-factor (a perfect tiling of G with H) for any bipartite graph H. We also show that this threshold is best possible up to a constant depending only on H. This result can be viewed as an analog to Kuhn and Osthus' result [*Combinatorica* **29** (2009), 65-107] for bipartite graphs.

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CP4
Rainbow Matchings in Edge-Colored Graphs

The *color degree* of a vertex v in an edge-colored graph is the number of distinct colors appearing on edges incident to v. Wang and Li conjectured that for $k \geq 4$, edge-colored graphs with minimum color degree at least k contain rainbow matchings of size at least $\lceil k/2 \rceil$. We guarantee rainbow matchings of size $\lfloor k/2 \rfloor$ and prove the conjecture for triangle-free graphs and properly edge-colored graphs whose complements have non-leaf vertices.

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CP4
K_6-Minors in Triangulations on Surfaces

If $n \leq 5$, graphs with no K_n-minor have already been characterized. (In particular, the case of $n = 5$ was solved by Wagner.) However, it seems to be difficult to characterize graphs with no K_6-minor, in general. For the projective plane and the torus, we characterize triangulations with no K_6-minor by a unique forbidden subgraph. In our talk, we shall characterize triangulations with no K_6-minor for surfaces with low genus.

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CP4

Edge-Connectivity, Eigenvalues, and Matchings in Regular Graphs

The matching number of a graph is the maximum size of a matching in it. We previously characterized the graphs having the smallest maximum number among connected $(2k+1)$-regular graphs with n vertices; the extremal graphs have cut-edges. In this talk, we prove a lower bound for the maximum matching in a t-edge-connected r-regular graph with n vertices, for $t \geq 2$ and $r \geq 4$; various special cases were obtained earlier. We also characterize the graphs achieving equality. We also study the relationship between eigenvalues and matchings in t-edge-connected r-regular graphs. We give a condition on anappropriate eigenvalue that guarantees a lower bound for the matching number in a t-edge-connected r-regular graph; this generalizes a recent result of Cioaba, Gregory, and Haemers.

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CP5

Dynamic Forests and Load Balancing in Wireless Networks

We define a dynamic forest in a DAG to be a random forest generated by independently choosing a parent from the out-neighborhood of each non-sink node with respect to a given probability distribution. We present results and algorithms for solving the bi-criteria optimization problem of balancing the load on the nodes for longer lifetime and the load on the edges incident with each node for greater reliability. Our results have applications to wireless networks.

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CP5

Markovian Network Interdiction and the Four Color Theorem

Applications such as supply chains management, traffic monitoring and disease control give rise a discrete optimization problem termed The Unreactive Markovian Evader Interdiction Problem (UME). UME asks to optimally place sensors on a network to detect Markovian motion by one or more "evaders". We prove that the problem is NP-hard with just 2 evaders using a connection to coloring of planar graphs. The result suggests that approximation algorithms are needed even in applications where the number of evaders is small.

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CP5

A Multi-Hub Theory for Spectral-Based System Design

There are a variety of systems whose properties are governed by the leading eigenvectors of the underlying system matrix. If the set of dominant eigenvalues are clearly separated from the next largest eigenvalues, we can characterize the system properties. We will describe approach which can assure clear separation in leading eigenvalues by imposing a proper structure of the underlying matrix. Specifically, we provide bounds on eigenvalues for hierarchical system connection structure. Based on these results, we can design hierarchical systems with assured clustering behavior or absence of it.

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CP5

The Coloring Methods and the Rearrangeablility of Banyan-Type Networks

The Banyan-type networks are built by basic 2?2 directional couplers with the network structure topology derived from a horizontal expansion and vertical stacking of 2?2 Banyan networks. Some necessary and sufficient conditions of Banyan-type networks which are rearrangeably nonblocking that haves been proposed for optical interconnection network fabrics, where these rearrangeably nonblocking conditions are well-supported assuming that all the connections are not allowed to have any crosstalk. In this talk, we use the coloring methods to study the necessary and sufficient conditions for Banyan-type networks, which are rearrangeable nonblocking by considering all possible degrees of crosstalk constraints.

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CP6

Aperiodic Sequences and Self-Stabilizing Algorithms

Self-stabilizing algorithms represent an extension of distributed algorithms in which nodes of the network have neither coordination, synchronization, nor initialization. Recently we provided a novel algorithm for determining the size of a unidirectional ring where all nodes except one use constant space. This algorithm exploits a token-circulation idea due to Afek and Brown and uses the concept of aperiodic sequences. In this talk we review the algorithm and discuss generating aperiodic sequences using self-stabilization.

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CP6

Some Contributions in Biform Games

Brandemburger and Stuart (2006) have introduced the biform game(BG). the mixed extension of BG, needs cores comparison. The convex combination of non empty cores is analyzed. We mentioned results obtained by Zhao (2000) and Cesco (2010). Cesco studies when the core is a point. The unidimensional core of a (0,1)-reduction game is located in the boundary. New dominations in the sense of Marchi and Auriol (2010) are presented.

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CP6

A Measure of the Connection Strengths Between Graph Vertices with Applications

We present a simple iterative strategy for measuring the connection strength between a pair of vertices in a graph. The method is attractive in that it has a linear complexity and can be easily parallelized. Based on an analysis of the convergence property, we propose a mutually reinforcing model to explain the intuition behind the strategy. The practical effectiveness of this measure is demonstrated through several discrete optimization problems on graphs and hypergraphs.

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CP6

A Realistic Approach to Space-Time Performance of Computational Algorithms.

Computational complexity is widely researched in Theoretical Computer Science. However, only a few of them have treated complexity as applied to the real-life computation. Time and space complexities jointly depict the overall computational scenario. Without the treatment of either one of these, the analysis is incomplete, and the model may not depict the actual computation. Using a realistic approach, this paper has treated both of these complexities due to a wide variety of algorithmic data structures arising frequently in practice.

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CP7

A Note on Antimagic Labelings of Graphs

In this talk, we will discuss the conjecture proposed by M. Miller and M. Bača in 2000. It said that the generalized Petersen graphs $P(n,k)$ are $(\frac{5n+5}{2},2)$-antimagic for odd n, $n \geq 5$ and $2 \leq k \leq \frac{n-1}{2}$. We will show that it is wrong when $n = 5$.

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CP7

The Graph Induced by All Vertices in Some Critical Independent Set

An independent set I_c of a graph G is a *critical independent set* if $|I_c| - |N(I_c)| \geq |J| - |N(J)|$, for any independent set J. Critical independent sets are of interest for both computational and theoretical reasons. It will be shown that the graph induced on the set H of all vertices in some critical independent set of G is a König-Egerváry graph whose components are either isolated vertices or which have perfect matchings. Furthermore, if I_0 is the set of isolated vertices in $G[H]$, then $\alpha(G[H]) = |I_0| + \frac{1}{2}|H \setminus I_0|$.

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CP7

Bounds on Steiner Trees in the Hypercube

Let S be a set of vertices in the n-dimensional hypercube Q_n, and let $L(S)$ be the minimum number of edges in any connected subgraph H of Q_n containing S. We obtain the the following results by probabilistic methods. (1) If S is of size k, then $L(S) \leq \frac{1}{3}(k+1+ln(k-1))n$. (2) We show the above bound is nearly best possible for a certain range in k as follows. Let $\epsilon > 0$ be a fixed small real number, and let n be sufficiently large as a function of ϵ. Further let k lie in the range $K_1 \leq k \leq K_2 c^n$, where K_1, K_2, and c constants which depend only on ϵ, with $1 < c < 2$. Then there exist sets S in Q_n of size k such that $L(S) \geq (\frac{1}{3} - \epsilon)kn$.

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CP7

An Approximate Version of Sumner's Universal Tournament Conjecture

Sumner's Universal Tournament Conjecture, first posed in 1971, states that any tournament on $2n-2$ vertices contains any directed tree on n vertices. In this talk, I will explain how a randomized embedding algorithm can be used to prove an approximate version of this conjecture, and also a stronger result for trees of bounded maximum degree. I will also outline progress towards a proof of the conjecture for large n.

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CP7

Every Longest Hamiltonian Path in Odd N-Gons

This presentation concerns the resolution of the $\lfloor \frac{n}{2} \rfloor$ different Longest Euclidean Hamiltonian path problems on the vertices of an odd regular polygon. Firstly, we show the lengths of every longest Euclidean Hamiltonian path problem. Secondly, we determine the composition of the directed sides that should accomplish those longest traveled lengths. Finally, we single out the Euclidean Hamiltonian paths that solve every problem. This paper is developed with our methodology, which has been proposed in "*Finding Every Longest Hamiltonian Path on a Regular Polygon*' and already submitted to *Discrete Mathematics*.

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CP8

Degree Sequences, Vertex Substitutions, and Matrogenic Graphs

Given graphs G and H and a vertex v of H, *substituting* G *for* v is done by deleting v and making each vertex of G adjacent to all neighbors of v in H. The *substitution closure* of a graph class $\mathcal{C}$ is the smallest class that contains $\mathcal{C}$ and is closed under substitutions. Motivated by questions on degree sequences, we characterize graphs in the substitution closures of the split graphs and the matrogenic graphs.

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CP8

Identification of Universal Vertex in Threshold Component for Strict 2-Threshold Graphs

An efficent algorithm to identify universal vertex for each of the two threshold components for strict 2-threshold (S2T) graph is proposed. S2T graph is a prominent sub-class of a class of perfect graph named 2-threshold graph, which has wide applications including synchronization of processes. Previous method assumes vertex of maximum degree is one of the said universal vertices and applies recognition algorithm for threshold to conduct further checking. In this paper, an efficient method is proposed to achieve the same purpose simply by degrees of two vertices. The time consumed compares favorably to previous method.

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CP8

Finding a Sun in Building-Free Graphs

A *sun* is a graph with a Hamiltonian cycle $(x_1, y_1, \cdots, x_n, y_n)$, $n \geq 3$, where each x_i has degree two and the y_i vertices form a clique. Deciding whether an arbitrary graph contains a sun is NP-complete, while for some graph classes (e.g. chordal, hhd-free) the problem is polynomial time. We give a polynomial-time algorithm to test for suns in *building-free* graphs. Building-free graphs generalize Meyniel graphs (and hence, hhd-free, i-triangulated, and parity graphs).

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CP8

Elimination Orderings of Graphs of Bounded Asteroidal Number

The asteroidal number of a graph is the size of a largest subset of vertices such that for no vertex in the set, its closed neighbourhood disconnects the remaining vertices of the set. We characterize graphs of bounded asteroidal number by means of a vertex elimination ordering. Similar characterizations are known for chordal, interval, cocomparability, and path-orderable graphs, last three being, in fact, proper subclasses of AT-free graphs (asteroidal number two).

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CP9

On Enumeration of Simple Polytopes

Two simple polytopes are said to be distinct if their face posets are non-isomorphic. We consider the problem of enumerating distinct n-facet simple polytopes in R^d, denoted (n, d)-polytopes. Let the number of distinct (n, d)-polytopes be $\#(n, d)$. In this talk, we present a new algorithm to generate all (n, d) simple polytopes in time polynomial in $\#(n, d)$. The algorithm operates by computing the effect of a hyperplane sweep on the face lattice of a sequence of polytopes. Further, we present new bounds on the value of $\#(n, d)$.

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CP9

Polytope Numbers

Polytope numbers for a polytope are a sequence of nonnegative integers which are defined by the facial information of a polytope. This is a higher dimensional generalization of polygonal number. It is well known that every polygon can be decomposed into triangles. A higher dimensional analogue of this fact states that every polytope has a triangulation, namely, it can be decomposed into simplices. Thus it may be possible to represent polytope numbers as sums of simplex numbers, which gives another way of calculating polytope numbers. In this talk, we define polytope numbers and calculate polytope numbers for several polytopes, and we introduce decomposition theorem, which is a way of representing polytope numbers as sums of simplex numbers. Joint work with Prof. Hyun Kwang Kim,

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CP9

The Cunningham-Geelen Algorithm in Practice: Branch-Decompositions and Integer Programs

Consider the integer program $\max(c^T x : Ax = b, x >= 0,)$ where A is non-negative and the column-matroid of A (denoted by M(A)) has constant branch width. Cunningham and Geelen introduce a pseudo-polynomial time algorithm for solving this integer program that takes a branch decomposition T of M(A) as input. We describe a heuristic for finding T and report on computation results of a C++ implementation of this algorithm, where the input branch decomposition T is produced by this heuristic.

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CP9

Dominating Circuits in Matroids

In 1971, Nash-Williams proved that if G is a simple 2-connected graph on n vertices having minimum degree $\delta_G \geq \frac{1}{3}(n + 2)$, then any longest cycle C in G is also edge-domininating; that is, each edge of G has at least one end-vertex belonging to C. We say that a circuit C in a matroid M is dominating if each component of M/C has rank at most one. In this talk, we shall describe an analogous theorem for regular matroids: we show that if each cocircuit in a simple connected regular matroid M has at size at least $\frac{1}{3}r(M) + 1$, then any longest circuit is dominating.

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CP9

On the Convexity of the Tutte Polynomial of a Paving Matroid Along Line Segments

We prove that the Tutte polynomial of a coloopless paving matroid is convex along the line segments $x + y = p$ for $p \geq 0$ and $0 \leq y \leq p$. Every coloopless paving matroids is in the class of matroids which contain two disjoint bases or whose ground set is the union of two bases of M^*. For this latter class we give a proof that $T_M(a, a) \leq \max\{T_M(2a, 0), T_M(0, 2a)\}$ for $a \geq 2$. We conjecture that $T_M(1, 1) \leq \max\{T_M(2, 0), T_M(0, 2)\}$ for the same class of matroids. We also prove this conjecture for some families of graphs and matroids.

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CP10

On Enumerating Diverse Feasible Solutions to a Combinatorial Optimization Problem

This talk summarizes efforts at the National Renewable Energy Laboratory to enumerate diverse building designs that satisfy an energy goal, and are ranked by cost. The mathematical setting is optimization over discrete variables, each possible combination of which represents a valid design that may or may not be feasible according to a nonlinear function. The origin acts as a baseline value, and diversity is obtained by partitioning the decision space into functional categories.

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CP10

The Minimum Cost Flow Problem in Dynamic Multi Generative Network Flows

This paper consists in constructing and modeling Dynamic Multi Generative Network Flows in which the flow commodities is dynamically generated at source nodes and dynamically consumed at sink nodes. It is assumed that the source nodes produce the flow commodities according to k time generative functions and the sink nodes absorb the flow commodities according to k time consumption functions. The minimum cost dynamic flow problem in such networks that extend the classical optimal flow problems on static networks, for a pre-specified time horizon T is defined and mathematically formulated. Moreover, it is showed that the dynamic problem on these networks can be formulated as a linear program whose special structure permits efficient computations of its solution and can be solved by one minimum cost static flow computation on an auxiliary time-commodity expanded network. By using flow decomposition theorem, we elaborate a different model of the problem to reduce its complexity. We consider the problem in the general case when the cost and capacity functions depend on time and commodity.

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CP10

Using Markov Chains Properties to Analyze the Effectiveness of Local Search Algorithms for Hard Discrete Optimization Problems

The performance of local search algorithms (guided by the best-to-date solution at each iteration) in visiting suboptimal solutions for hard discrete optimization problems is explored. The β-acceptable solution concept is used to capture how effectively an algorithm has performed to date and how effectively an algorithm can be expected to perform in the future in visiting suboptimal solutions. Markov chain state pooling is introduced and used to obtain an estimator for the expected number of iterations to visit a β-acceptable solution. Convergence results for this estimator are provided. Computational experiments with the Lin-Kernighan-Helsgaun algorithm applied to medium and large traveling salesman problem instances taken from TSPLIB (all with known optimal solutions) are reported to illustrate the application of this estimator.

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CP10

A Lower Bounding Scheme for a Maximum Dispersion Territory Design Problem

We present a lower bounding scheme for a territory desig problem that arises in the recollection of waste electric and electronic equipment. The problem consists of assigning recollection points to companies so as to minimize company monopoly in specific region. Our proposed scheme is used for measuring the quality of some heuristics for this NP-hard problem.

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CP10

Territory Design with a Routing Constraint by Iterated Greedy Local Search

An iterated greedy local search heuristic for a commercial territory design optimization problem is presented. The problem consists on finding a partition of city blocks so as to minimize territory compactness subject to node activity balancing, territory conectivity, and a routing budget constraint. The empirical results show the effectiveness of the proposed approach.

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CP11

$\mathbf{Z}_4$ Linear Kerdock Codes Are Relative Difference Sets

In this talk, we will demonstrate that $\mathbf{Z}_4$ linear Kerdock codes are equivalent to abelian $(2^m, 2^m, 2^m, 1)$- relative dif-

ference sets in Galois rings.

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CP11

On The Existence Of Perfect Quartenary Codes*

In this work, we investigate parameters of perfect quaternary codes with respect to the Lee metric. In order to gain some insight, we establish a binomial formula that gives the number of codewords of a particular Lee weight. Further, by making use of the fact that the balls centered at codewords of a t error correcting perfect code must intersect at only zero codeword, we are able to exlude many parameters. Here we only present some inital results of an ongoing research problem. * This research is supported by TUBITAK-Grant No:109T328.

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CP11

New Bounds for the Minimum Density of An r-Identifying Code in Some Infinite Grids

An r-identifying code on a graph G is a set $C \subset V(G)$ such that for every vertex in $V(G)$, the intersection of the radius-r closed neighborhood with C is nonempty and unique. On a finite graph, the density of a code is $|C|/|V(G)|$, which naturally extends to a definition of density in certain infinite graphs which are locally finite. We present improved bounds for the minimum density of a code on the infinite hexagonal and square grids.

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CP11

The Covering Problem for Galois Rings with Respect to the RT-Metric

One of the important problems in Coding Theory is the covering problem which is related to the optimal error correcting of the code. Also this problem is related to the packing problem in finite (or infinite) structures. Lately codes over Galois rings and newly defined RT metric independently has been studied. In this work, the cardinality of the minimal R-covers of Galois rings with respect to the RT-metric is established. By generalizing the result obtained by Nakaoko and Santos (2009), the minimal cardinalities of zero-short coverings of Galois rings are calculated. The connection between R-short coverings of Galois rings with respect to the RT metric and the zero-short coverings of these rings are demonstrated and with the help of this connection, the problem of finding the minimal cardinalities of R-short coverings of Galois finite rings is solved.

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CP11

The MacWilliams Theorem for Four-Dimensional Modulo Metric

In this paper,the MacWilliams theorem is stated for codes over finite field with four- dimensional modulo metric

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CP12

Counting Bordered Partial Words by Critical Positions

The concepts of primitivity and borderedness are highly connected in areas including combinatorics on words, coding theory, formal languages and text algorithms. A primitive word is a sequence that cannot be written as a power of another sequence, while a bordered word is a sequence such that at least one of its proper prefixes is one of its suffixes. The numbers of primitive and bordered words of a fixed length over an alphabet of a fixed size are well known, the number of primitive words being related to the Möbius function. Here we give formulas for the number of bordered *partial words* (partial words are sequences over a finite alphabet that may contain some undefined positions called "holes"). When dealing with bordered partial words, two types of borders are identified: *simple* and *overlapping*. A partial word is called unbordered if it does not have any border. In the case of words without holes, all borders are simple. Our problem is made extremely more diffiult by the failure of that combinatorial property. For the finite alphabet $\{a, b, c\}$, the partial word $a\diamond\diamond b$ has both a simple border ab and a nonsimple border aab, while the partial word $a\diamond bc$ is unbordered (the $\diamond$ symbol represents an undefined position or a hole, and matches every character of the alphabet). Our approach is based on the notion of critical positions that once changed into holes create borders.

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CP12

Cyclically t-complementary Uniform Hypergraphs

Consider a partition of the set of all k-element subsets of an n-element set V into t parts, such that there is a permutation of V which permutes the t parts cyclically. Such a permutation is called a (t, k)-*complementing permutation*, and each part in the partition is called a *cyclically t-complementary k-hypergraph*. When $t = k = 2$ these are self-complementary graphs, which are well studied due to their connection to the graph isomorphism problem. We give necessary and sufficient conditions on the order of cyclically t-complementary k-hypergraphs by characterizing their (t, k)-complementing permutations.

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CP12

Computing Periods in Partial Words

Computing periods in *words*, or finite sequences of symbols from a finite alphabet, has important applications in several areas including data compression, coding, computational biology, string searching and pattern matching algorithms. We give an extension of Fine and Wilf's well known periodicity result in the context of *partial words*, or sequences that may have undefined positions or holes. Here any word with h holes and having periods $p_1, \ldots, p_m$ and length at least the so-denoted $L_h(p_1, \ldots, p_m)$ has also $\gcd(p_1, \ldots, p_m)$ as a period. We investigate optimal words for the bound $L_h(p_1, \ldots, p_m)$, that is, partial words u with h holes of length $L_h(p_1, \ldots, p_m) - 1$ such that $p_1, \ldots, p_m$ are periods of u but $\gcd(p_1, \ldots, p_m)$ is not a period of u. We give closed formulas for $L_h(p_1, \ldots, p_m)$ in a number of cases. Our approach is based on connectivity in graphs associated with sets of periods. World Wide Web server interfaces have been established at www.uncg.edu/cmp/research/finewilf4 and /finewilf5 for automated use of programs which given a number of holes and a period set, compute the optimal bound and an optimal word for that bound.

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CP12

A Generalization of Larman-Rogers-Seidel's Theorem

Let X be an s-distance set in the Euclidean space $\mathbf{R}^d$, and $A(X) = \{\alpha_1, \alpha_2, \ldots, \alpha_s\}$ be the set of Euclidean distances between two distinct elements of X. For $s = 2$, Larman-Rogers-Seidel proved that if $|X| \geq 2d+4$, then there exists an integer k such that ${\alpha_1}^2/{\alpha_2}^2 = (k-1)/k$. In this talk, for any s, we give a generalization of the theorem due to Larman-Rogers-Seidel.

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CP12

The Total Weak Discrepancy of a Partially Ordered Set

We consider the total (fractional) weak discrepancy of a partially-ordered set and compare it to our earlier results for weak and fractional weak discrepancy. We prove that, unlike the earlier case, the total fractional weak discrepancy is always an integer. In the proof, we express the problem as a linear program and solve it using the dual, which is a circulation problem with side constraints on a directed graph.

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CP13

Distinguishing and Distinguishing Chromatic Numbers

The distinguishing number of a graph was first defined by Mike Albertson and the presenter in 1996, and the distinguishing chromatic number was first defined by the presenter and Ann Trenk in 2006. This talk will compare and contrast known results about each parameter from the point of view of how the automorphism group of a graph affects its distinguishing and distinguishing chromatic numbers, and discuss these numbers for particular families of graphs.

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CP13

Harmonious Colorings of Digraphs

Let D be a directed graph with n vertices and m edges. A function $f : V(D) \to \{1, 2, 3, ...k\}$ where $k \leq n$ is said to be *harmonious coloring* of D if for any two edges xy and uv of D, the ordered pair $(f(x), f(y)) \neq (f(u), f(v))$. If the pair (i, i) is not assigned, then f is said to be a *proper harmonious coloring* of D. The minimum k is called the *proper harmonious coloring number* of D. We investigate the proper harmonious coloring number of graphs such as unidirectional paths, unicycles, inspoken (outspoken) wheels, n-ary trees of different levels, union of unidirectional paths, alternating paths and alternating cycles etc.

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CP13
Chromaticity of a Family of k-Bridge Graphs

Let $P(G, \lambda)$ denote the chromatic polynomial of a graph G. Two graphs G and H are chromatically equivalent, written $G \sim H$, if $P(G, \lambda) = P(H, \lambda)$. A graph G is chromatically unique written $\chi-$unique, if for any graph H, $G \sim H$ implies that G is isomorphic with H. In this paper we prove the chromatic uniqueness of a new family of k-bridge graphs.

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CP13
5-Coloring Graphs with 4 Crossings

We disprove a conjecture of Oporowski and Zhao stating that every graph with crossing number at most 5 and clique number at most 5 is 5-colorable. However, we show that every graph with crossing number at most 4 and clique number at most 5 is 5-colorable.

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CP13
Acyclic List Edge Coloring of Graphs

A proper edge coloring of a graph is said to be acyclic if any cycle is colored with at least three colors. An edge-list L of a graph G is a mapping that assigns a finite set of positive integers to each edge of G. An acyclic edge coloring ϕ of G such that $\phi(e) \in L(e)$ for any edge e is called an acyclic L-edge coloring of G. A graph G is said to be acyclically k-edge choosable if it has an acyclic L-edge coloring for any edge-list L that satisfies $|L(e)| \geq k$ for each edge e. The acyclic list chromatic index is the least integer k such that G is acyclically k-edge choosable. We develop techniques to extend acyclic list edge colorability and apply them to obtain bounds for the acyclic list chromatic indexes of outerplanar graphs, subcubic graphs, and subdivisions of Halin graphs.

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CP14
Magic Sum Spectra of Group Magic Graphs

For a positive integer $k \geq 2$, let $Z_k = (Z_k, +, 0)$ be the additive abelian group of integer congruences modulo k with identity 0. We call a finite simple graph $G = (V(G), E(G))$ to be Z_k-magic if it admits an edge labeling ranging in $Z_k \backslash \{0\}$ such that the induced vertex sum (sum of all incident edge labels at a vertex) is constant, and such constant is called a magic sum index. For each integer k, we define $I_k(G)$ as the set of all magic sum indices r such that G is Z_k-magic with an index r. We call $I_k(G)$ the **magic sum spectrum** of G with respect to Z_k. In this talk, we present the properties of the magic sum spectra of a graph G. In particular we show that, for a regular graph G admitting a 1-factor, the magic sum spectrum $I_k(G)$ is full Z_k, for each $k \geq 3$. We also give examples of regular graphs without 1-factor whose magic sum spectrum is not full Z_k for some $k \geq 3$. We prove that the magic sum spectra with respect to Z_k of complete bipartite graphs are isomorphic to the additive cyclic subgroups of Z_k, for each $k \geq 3$. Among others, the magic sum spectra of Cartesian product and lexicographic product of graphs are presented, and the magic sum spectra of fans, wheels, and circulant graphs are completely determined. Some open problems will be mentioned in the concluding remarks.

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CP14
The Spectrum of 2-Idempotent 3-Quasigroups with Conjugate Invariant Subgroups

A ternary quasigroup (or 3-quasigroup) is a pair (N, q) where N is an n-set and $q(x, y, z)$ is a ternary operation on N with unique solvability. A 3-quasigroup is called 2-idempotent if it satisfies the generalized idempotent law: $q(x, x, y) = q(x, y, x) = q(y, x, x) = y$. A conjugation of a 3-quasigroup, considered as an $\mathrm{OA}(3, 4, n)$, (N, B), is a permutation of the coordinate positions applied to the 4-tuples of B. The subgroup of conjugations under which (N, B) is invariant is called the conjugate invariant subgroup of (N, B). Recently, we determined the existence of 2-idempotent 3-quasigroups of order n, $n \equiv 7$ or 11 (mod 12) and $n \geq 11$, with conjugate invariant subgroup consisting of a single cycle of length three. This result completely determined the spectrum of 2-idempotent 3-quasigroups with conjugate invariant subgroups.

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CP15

On the Upper Bound of the Modulus of Subdominant Eigenvalue of Stochastic Matrix.

The subdominant eigenvalues of the transition probability matrix of a Markov chain are determining factor in the speed of transition of the chain to a stationary state. In this talk, we introduce the notion of the scrambling index of a directed graph, and discuss some of its properties. We then present an upper bound on the scrambling index of primitive stochastic matrix T in terms of Boolean rank $b(T)$ and characterize all the primitive matrices that can achieve this upper bound. Furthermore by using the scrambling index of the directed graph of a stochastic matrix, we give an attainable upper bound on the modulus of subdominant eigenvelue of T.

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CP15

Weak Sense of Direction Labelings and Graph Embeddings

In distributive computing, when the edge-labeling of a graph has a *sense of direction*, the communication complexity of many distributed problems significantly improves. We consider a weaker version of this property called *weak sense of direction* (WSD). Cayley graphs play a central role in WSD-labelings. They are exactly the regular graphs that have minimal symmetric WSD-labelings. We present new results on WSD-labelings that extend the connections of Cayley graphs and WSD-labelings to nonregular directed graphs.

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CP15

Riemann-Roch for Sub-Lattices of the Root Lattice A_n

Recently, Baker and Norine (*Advances in Mathematics*, 215(**2**): 766-788, 2007) found new analogies between graphs and Riemann surfaces by developing a Riemann-Roch machinery on a finite graph G. We develop a general Riemann-Roch Theory for sub-lattices of the root lattice A_n by following the work of Baker and Norine, and establish connections between the Riemann-Roch theory and the Voronoi diagrams of lattices under certain simplicial distance functions. In this way, we rediscover the work of Baker and Norine from a geometric point of view and generalise their results to other sub-lattices of A_n. In particular, we provide a geometric approach for the study of the Laplacian of graphs. Applications to the classification of lattices are discussed.

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CP15

The Tammes and Related Problems

The Tammes problem asks to find maximal radius of N equal size nonoverlapping spherical caps in the unit 2-sphere. In this talk we are going to discuss a computer based solution of the Tammes problem for N=13 as well as for several greater N. This is a join work with Alexey Tarasov.

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CP15

Planar Reachability in Log-Space Complexity Classes

Log-space computation is a central tool in complexity theory. The requirement of using $O(\log n)$ space gives rise to local algorithms. Deciding reachability in different classes of graphs gives complete problems for different log-space classes, such as the extremes of reachability in undirected graphs is L-complete while reachability in directed graphs is NL-complete. Separating these classes is the space-bounded equivalent of the P=NP question. The complexity of directed planar graphs is currently unknown. This talk presents recent developments in the reachability problem for several classes of planar graphs.

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CP16

Reflexive Injective Oriented Colourings

We study oriented colourings of directed graphs which satisfy the local injectivity property that no two in-neighbours of any vertex are assigned the same colour, but in which adjacent vertices need not be assigned different colours. We shall discuss complexity, obstructions, bounds, and related homomorphism problems.

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CP16
On the Edit Distance of Forb($K_{2,t}$)

The edit distance from a graph G to a hereditary property $\mathcal{H}$ is the minimum number of edge-additions/deletions required to transform G into a member of $\mathcal{H}$. The maximum of this quantity, over all density-p, n-vertex graphs, normalized by dividing by $\binom{n}{2}$ and letting $n \to \infty$, is the *edit distance function*. We will give bounds on its value for hereditary properties of the form $\mathcal{H} = \text{Forb}(\mathcal{K}_{\in,\sqcup})$, computing it exactly in the case $t = 3$.

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CP16
L(2,1)-Labeling of Unigraphs

An L(2,1)-labeling for a graph G consists of assigning nonnegative integers, 0s, to the nodes of G so that adjacent nodes get values at least two apart and nodes at distance two get different values. Minimize s is an NP-complete problem. Here is conjectured that this problem remains NP-complete also for unigraphs, i.e. graphs uniquely determined by their own degree sequence up to isomorphism, and a linear time algorithm for L(2,1)-labeling unigraphs is designed.

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CP16
Weighted Well-Covered Graphs Without Cycles of Lengths 4, 6 and 7

Let w be a linear set function defined on the vertices of a graph G. The graph G is *w-well-covered* if all its maximal independent sets have the same weight. Recognizing w-well-covered graphs is known to be **co-NP**-complete. We prove that the vector space of weight functions under which an input graph is w-well-covered can be found in polynomial time, if the input graph does not contain cycles of lengths 4, 6 and 7.

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CP17
On the Mixing Time of Geometric Threshold Graphs

We study the mixing time of random graphs generated by the geographical threshold graph (GTG) model, a generalization of random geometric graphs (RGG). In a GTG, nodes are distributed in a Euclidean space, and edges are assigned according to a threshold function involving the distance between nodes as well as randomly chosen node weights. If the weight distribution function decays with $\Pr[W \geq x] = O(x^{-d-\nu})$ for an arbitrarily small constant $\nu > 0$ then the mixing time of GTG is $O(n^{2/d}(\log n)^{(d-2)/d})$. This matches the known mixing bounds for RGG.

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CP17
The Typical Structure of H-Colourings of Regular Bipartite Graphs

For a graph H (perhaps with loops), an *H-colouring* of a simple graph G is a function from the vertices of G to the vertices of H which maps adjacent vertices to adjacent vertices. With suitable choices of H, H-colourings can encode, for example, weighted independent sets and proper colourings of G. H-colourings are also referred to as *graph homomorphisms*. We address the following question: in a typical (uniformly chosen) H-colouring of a regular bipartite graph G, what proportion of the vertices of G get mapped to each vertex of H? For a very large class of graphs H, we can give a quite precise answer to this question. For example, we can say that in almost all proper $2k$-colourings of a regular bipartite graph on N vertices, each colour will appear very close to $N/2k$ times. The approach is through entropy, and extends work of J. Kahn from 2001 (who considered the size of randomly chosen independent sets of a regular bipartite graph).

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CP17
A Counterexample to the Alon-Saks-Seymour Conjecture and Related Problems

Consider a graph obtained by taking an edge disjoint union of k complete bipartite graphs, Alon, Saks, and Seymour conjectured that such graphs have chromatic number at most k+1. This well known conjecture remained open for almost twenty years. In this talk, we will show a counterexample to this conjecture. This construction will also lead to some related results in combinatorial geometry and communication complexity. In particular, it implies a nontrivial lower bound of the non-deterministic communication complexity of the "clique versus independent set' problem. Joint work with Benny Sudakov.

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CP17

Resilient Pancyclicity of Random Graphs

A graph is called pancyclic if it contains cycles of all lengths. A classical theorem of Bondy states that every n-vertex graph G with $\delta(G) > n/2$ is pancyclic. In this talk, we discuss extensions of this and another pancyclicity result to random graphs. In particular, our results show that random graphs remain pancyclic even after deletion of constant proportion of edges incident to every vertex.

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CP17

Analysis of Scale-Free Network Models Based on k-Trees

We introduce various growth-models for the combinatorial family of k-trees (introduced by Beineke & Pippert, 1969), which all lead to an asymptotic power-law degree distribution. Based on two descriptions of k-trees, firstly via a bottom-up approach due to the growth process, and secondly via a top-down approach due to a combinatorial decomposition, we are able to give a quite precise analysis of these network models leading to exact and asymptotic results of various parameters, as node degrees, distance parameters, number of descendants, and the clustering coefficient.

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CP18

On Dobrynin-Gutman Conjecture

Let G be a connected graph and $\eta(G) = Sz(G) - W(G)$, where $W(G)$ denotes the Wiener index and $Sz(G)$ denotes the Szeged index of G. A well-known result of Klavžar, Rajapakse and Gutman states that $\eta(G) \geq 0$ and by a result of Dobrynin and Gutman $\eta(G) = 0$ if and only if each block of G is complete. In this paper an edge-path matrix for the graph G is presented by which it is possible to present a new characterization for the graphs in which the Wiener and Szeged are the same. It is also shown that $\eta(G) \neq 1, 3$ and a classification of all graphs with $\eta(G) = 2, 4, 5$ are presented. Finally, it is proved that for a given positive integer $k, k \neq 1, 3$, there exists a graph G with $\eta(G) = k$.

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CP18

Cospectral Graphs for the Normalized Laplacian

Two graphs are cospectral with respect to some matrix associated with the graph if the two matrices have the same eigenvalues. We will focus on the problem of cospectral graphs for the normalized Laplacian, and in particular give the first construction of an infinite family of non-bipartite non-regular graphs which are cospectral with respect to the normalized Laplacian.

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CP18

Construction of Maximal-Determinant Binary Matrices

Hadamard matrices have maximal determinant among matrices with elements -1 and 1, but cannot exist when the size n is not divisible by 4. I describe matrices with large or maximal determinant when $n \not\equiv 0 \pmod 4$. When $n \equiv 1 \pmod 4$ an $(n-1) \times (n-1)$ Hadamard matrix with suitable properties is used. When $n \equiv 2$ or $3 \pmod 4$, a pair of binary sequences whose autocorrelation functions have sharply-peaked sum is needed. Brent, Osborn, Zimmerman, and I have proved maximality of some of these determinants.

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CP18

Matrix Interdiction Problem

In the matrix interdiction problem, a real-valued matrix is given, and a row value is defined at each row as the maximum value of the row elements. The objective is to remove k columns such that the sum of row values over all rows is minimized. This combinatorial problem is closely related to bipartite network interdiction problem which can be applied to prioritize the border checkpoints in order to minimize the probability that an adversary can successfully cross the border. After introducing the matrix interdiction problem, we will prove the problem is NP-hard, and even NP-hard to approximate with any sub-linear (in n) factor. We also present an algorithm for this problem that achieves a factor of $(n-k)$ approximation.

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MS1

Large Cliques and Stable Sets Excluding Paths and Antipaths

For every fixed graph H, if a graph G does not contian H as a minor, then one can say a lot about the structure and properties of H. Unfortunately, results of that kind do not seem to be true if we replace the minor containment by induced subgraph containment. One of the few conjectures about general behavior of graphs with certian induced subgraphs forbidden is the Erdos Hajnal Conjecture. It states that for every fixed graph H there exists a constant $\delta(H)$, such that if a graph G has no iduced subgraph isomorphic to H, then G contains a big clique or a big stable set of size $|V(G)|^{\delta(H)}$. The Erdos Hajnal Conjecture is known to be true for graphs H on at most four vertices, but there are some five-vertex graphs for which the conjecture is still open. One of such graphs is a path of length four (edges). We prove that if a graph G does not contain as induced subgraphs a path of length four or the complement of a path of length five, then G contains a clique or a stable set of size $|V(G)|^{\frac{1}{6}}$.

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MS1

Edge List Colouring Class II Plane Graphs with Few Long Lists

Given an integer-valued edge weighting $w : E(G) \to N$, we say that G is *w-edge-choosable* if, for every list assignment $L : E(G) \to 2^N$ satisfying $|L(e)| \geq w(e)$, there exists a proper edge coloring c for which $c(e) \in L(e)$ for every edge e. We show how to use the Combinatorial Nullstellensatz to prove choosability results for regular graphs which are not 1-factorable. For example, every planar cubic graph G is w-edge-choosable, for some $w : E(G) \to \{1, 2, 3, 4\}$ where the number of edges e with $w(e) = 4$ is linear in the number of cut-edges in G.

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MS1

Fractional Total Colourings of Graphs of High Girth

In 1993, Kilakos and Reed proved that the fractional total chromatic number of a d-regular graph is between $d+1$ and $d+2$. Reed recently conjectured that for fixed d and ϵ, a graph of sufficiently high girth and maximum degree d has fractional total chromatic number at most $d+1+\epsilon$. We prove a stronger result of this type for $d \in \{3, 4, 6, 8, \ldots\}$, i.e. that a graph of sufficiently high girth (depending on d) has fractional total chromatic number exactly $d+1$. We prove this conjecture using the approach of l-path decompositions and a randomized method for choosing total stable sets of G.

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MS1

The Last Fraction of a Fractional Conjecture and Open Problems

A total coloring of a graph is composed of a (proper) vertex coloring and a (proper) edge coloring with the additional constraint that vertices and edges that are incident are assigned different colors. Fractional total colorings are the linear relaxation of total colorings. Reed conjectured that for fixed Δ and ϵ, a graph of maximum degree Δ and sufficiently high girth has fractional total chromatic number at most $\Delta + 1 + \epsilon$. Kaiser, King and Král' proved that for $\Delta = 3$ and $\Delta \in \{4, 6, 8, \ldots\}$, every graph of maximum degree Δ and sufficiently high girth has fractional total chromatic number *exactly* $\Delta + 1$. With F. Kardoš and D. Král', we proved the conjecture for the remaining cases. Our proof relies on first establishing the result for cyclically Δ-edge-connected graphs (using a suitable partition of the edges) and then dealing with the general case by induction on the number of edges (using a tree-recoloring lemma). I will give a sketch of the proof and a part of the talk will be devoted to open problems.

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MS2

Filtered Hopf Algebras

We present a theory of non-homogeneous quasi-symmetric invariants of combinatorial Hopf algebras. It extends previous results by the author with Bergeron and Sottile and is motivated by Stanley's theory of P-kernels (which becomes a special case) and work of Billera and Brenti on Kazhdan-Lusztig polynomials.

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MS2

Hopf Algebras, g-polynomials and Kazhdan-Lusztig Polynomials

We apply the newly developed theory of non-homogeneous quasi-symmetric invariants of combinatorial Hopf algebras to the special cases of g-polynomials of regular CW-spheres and Kazhdan-Lusztig polynomials of Bruhat intervals as well as some extensions of these.

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MS2

New Hopf Algebra Structures on Compositions.

Compositions, or bijectively boolean subsets, form the graded basis for the very important combinatorial Hopf algebra of quasisymmetric functions. Now, via a description of the simplices as cellular projections of associahedra, we introduce a new graded algebra with the n^{th} component of its basis the vertices of the standard $(n-1)$-simplex. We extend this new algebra to a new graded Hopf algebra based upon the full face posets of simplices: the boolean posets. Next, from a description of the cubes as projections of the multiplihedra, comes another new Hopf algebra based upon the compositions illustrated as painted trees. Mysteriously, it appears that our two new algebras are in fact dual to each other.

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MS2

Lagrange's Theorem: from Groups to Hopf Monoids in Species

Recall that if $K \subseteq H$ are finite groups, then $|K|$ divides $|H|$. The literature contains several Hopf variations on this theme. We recount a few, then introduce our own: if $K \subseteq H$ are Hopf monoids in species, then H is free over K. We apply our theorem to enumeration questions in combinatorial Hopf algebras.

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MS2

The Hopf Algebra of Strict Multiset Compositions and Structure Transfer

We explore the structure of the cocommutative Hopf algebra freely generated (as an algebra) by the coalgebra of finite subsets of natural numbers. We determine explicit formulas for its primitive elements and its antipode. We also develop machinery to transfer this structure to several combinatorial Hopf algebras appearing in the literature, including the Bergeron-Reutenauer-Rosas-Zabrocki Hopf algebra of symmetric functions in noncommuting variables.

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MS3

Polynomial Littlewood-Offord Type Theorems

In their studies of the roots of random polynomials Littlewood and Offord came across a question which can be worded probabilstically as follows: $If a_1, a_2, ..., a_n$ are fixed nonzero constants, and $x_1, x_2, ..., x_n$ are independently set equal to 1 or -1 with equal probability, what is the maximum concentration of the "random walk" function $a_1x_1 + a_2x_2 + ... + a_nx_n$ on any given value? Motivated by a question regarding the singularity probability of random symmetric matrices (whose determinant is a quadratic form in the entries of any particular row or column of the matrix), we consider an analogue of this question where the random walk is replaced by a polynomial function of the inputs.

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MS3

Sum-product Phenomenon and Expanders - Part I of II

We present a new approach to establishing expansion and spectral gap bounds based on using tools from arithmetic combinatorics, in particular sum-product estimates (joint work with Jean Bourgain)

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MS3

Sum-product Phenomena and Expanders - Part II of II

We present a new approach to establishing expansion and spectral gap bounds based on using tools from arithmetic combinatorics, in particular sum-product estimates (joint work with Jean Bourgain)

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MS3

Automated Bounds for Some Problems in Extremal Additive Combinatorics

I will show that how an automated approach can be used to improve some previously known bounds for problems in extremal additive Combinatorics.

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MS3

Finite Point Configurations in Discrete, Continuous and Arithmetic Settings

We shall discuss the general problem of finding congruent copies of finite point configurations inside sufficiently large subsets of vector spaces and connections between discrete, continuous and arithmetic phenomena that arise in the process.

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MS4

A Construction of Infinite Sets of Intertwines for Pairs of Matroids

Intertwines arise naturally when considering the excluded minors of a union of minor-closed classes. An intertwine of a pair of matroids is a matroid such that it, but none of its proper minors, has minors that are isomorphic to each matroid in the pair. Intertwines can be defined likewise for graphs. From the graph minors theorem of Robertson and Seymour (specifically, that graphs are well-quasi-ordered under minors), it follows that any pair of graphs has only finitely many intertwines. In contrast, addressing a problem first posed by Tom Brylawski, Dirk Vertigan showed that certain pairs of matroids have infinitely many intertwines. We will approach the construction of intertwines from a new perspective, namely, that of cyclic flats and their ranks; this leads to an expanded range of results as well as new open problems.

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MS4

Fragility in Matroids

For a matroid M with a minor N, we say that M is N-fragile if, for every element e in the ground set of M, either $M\backslash e$ or M/e does not contain N as a minor. Understanding the structure of N-fragile matroids is necessary for thinking about Rota's conjecture. In this talk, we present a characterization of the binary, Fano-fragile matroids.

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MS4

Linear Rank Inequalities on Five or More Variables

Ranks of subspaces of vector spaces satisfy all linear inequalities satisfied by entropies (including the standard Shannon or polymatroid inequalities) and an additional inequality due to Ingleton; such additional inequalities are a useful way to prove the nonrepresentability of matroids. It is known that the Shannon and Ingleton inequalities generate all such linear rank inequalities on up to four variables, but it had been an open question whether additional inequalities hold for the case of five or more variables. Here we present a list of 24 inequalities which, together with the Shannon and Ingleton inequalities, generate all linear rank inequalities on five variables. (This is proved by showing that all of the extreme rays of the polytopal cone bounded by these inequalities are given by representable polymatroids.) We also present a partial list of linear rank inequalities on six variables (numbering several hundred at this point) and general results which produce such inequalities on an arbitrary number of variables; we prove that there are essentially new inequalities at each number of variables beyond four (a result also proved recently by Kinser).

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MS4

Constructing all Triangle-free 3-connected Matroids

Tutte's Wheel Theorem guaranties that any simple 3-connected graph is obtained from an appropriated wheel by adding edges or splitting vertices. This result is equivalent to the following: if G is a simple 3-connected graph non-isomorphic to a wheel, then G has an edge e such that $G\backslash e$ or G/e is a simple 3-connected graph. Kriesell obtained a similar result for the class of simple triangle-free 3-connected graph. Instead of two basic reductions, that is, an edge contraction or deletion, one need to apply six small operations to reduce a simple triangle-free 3-connected graph, without leaving this class in any step, to a graph isomorphic to $K_{3,3}$ or to a double-wheel. Tutte extended his result to 3-connected matroids in a fundamental paper in Matroid Theory. We are able to extend Kriesell's theorem to triangle-free 3-connected matroids. We present this result in this talk.

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MS4

Is the Missing Axiom of Matroid Theory Lost Forever?

In Whitney's seminal paper on matroids, he says that "the fundamental question of completely characterizing systems which represent matrices is left unsolved". Given that his example of a non-matrix matroid is the Fano plane, it seems clear that Whitney was effectively referring to a characterization of real-representable matroids. In 1978, Vámos addressed this question in a paper entitled "The missing axiom of matroid theory is lost forever" giving the clear impression that Whitney's problem is hopeless. But it turns out that the situation is far from being as clear as the title of Vámos' paper suggests. I propose to discuss this issue as well as discussing some recent results on matroid representation over infinite fields.

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MS5

Circumferences of k-Connected Graphs Involving Independence Numbers

Let G be a k-connected graph of order n, $\alpha := \alpha(G)$ the independence number of G, and $c(G)$ the circumference of G. Chvátal and Erdős proved that if $\alpha \leq k$ then G is hamiltonian. For $\alpha \geq k \geq 2$, Fouquet and Jolivet in 1978 made the conjecture that $c(G) \geq \frac{k(n+\alpha-k)}{\alpha}$. Fournier proved that the conjecture is true for $\alpha \leq k+2$ or $k=2$ in two different papers. Manoussakis recently proved that the conjecture is true for $k=3$. We will show that if G is a k-connected graph, $k \geq 4$, of order n and independence number $\alpha \geq k$, then $c(G) \geq \frac{k(n+\alpha-k)}{\alpha} - \frac{(k-3)(k-4)}{2}$. Consequently, the Fouquet-Jolivet Conjecture holds for $k=4$. In addition, we confirm the conjecture for $\alpha = k+3$. Inspired by a result of Kouider, we conjecture that, for every graph G and any two distinct vertices u and v, there is a u–v path P such that $\alpha(G-V(P)) \leq \alpha(G)-1$ unless $V(G)$ have a partition $V_1 \cup V_2$ satisfying $(G) = (G[V_1]) + (G[V_2])$. In this paper, we obtain a partial result regarding this conjecture. Let G be a k-connected graph and $k \geq 2$. In study the intersection of longest cycles, J. Chen et al conjectured that, for any two cycles C_1 and C_2 of G, there are two cycles D_1 and D_1 such that $V(D_1) \cup V(D_2) \supseteq V(C_1) \cup V(C_2)$ and $(D_1) \cap V(D_2)| \geq k$. We show that the combination of the above two conjectures implies the Fiuquet-Jolivet Conjecture.

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MS5

Disjoint Cycles and Dicycles in Digraphs

We study the following problem: Given a digraph D, decide if there is a cycle B in D and a cycle C in its underlying undirected graph such that $V(B) \cap V(C) = \emptyset$. Whereas the problem is $\mathcal{NP}$-complete if, as an additional part of the input, a vertex x is prescribed to be contained in C, one can decide the existence of B, C in polynomial time under the (mild) additional assumption that D is strongly connected.

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MS5

2-connected Subgraphs After Deleting Many Disjoint Paths

Motivated by the well-known conjecture by Lovász on the connectivity after the path removal, we study the following problem: There exists a function $f = f(k,l)$ such that the following holds. For every $f(k,l)$-connected graph G and two distinct vertices s and t in G, there are k internally disjoint paths $P_1, \ldots, P_k$ with endpoints s and t such that $G - \bigcup_{i=1}^{k} V(P_i)$ is l-connected. When $k=1$, this problem corresponds to Lovász conjecture, and it is open for all the cases $l \geq 3$. We show that $f(k,1) = 2k+1$ and $f(k,2) \leq 3k+2$. The connectivity "$2k+1$" for $f(k,1)$ is best possible. Thus our result generalizes the result by Tutte for the case $k=1$ and $l=1$ (the first settled case of Lovász conjecture), and the result by Chen, Gould and Yu, Kriesell, Kawarabayashi, Lee, and Yu, independently, for the case $k=1$ and $l=2$ (the second settled case of Lovász conjecture). When $l=1$, our result also improves the connectivity bound "$22k+2$" given by Chen, Gould and Yu. This is the joint work with K. Kawarabayashi.

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MS5

Color-Critical Graphs Have Logarithmic Circumference

A graph G is k-critical if every proper subgraph of G is $(k-1)$-colorable, but the graph G itself is not. We prove that every k-critical graph on n vertices has a cycle of length at least $\log n/(100 \log k)$, improving a bound of Alon, Krivelevich and Seymour from 2000. Examples of Gallai from 1963 show that the bound cannot be improved to exceed $2(k-1)\log n/\log(k-2)$. We thus settle the problem of bounding the minimal circumference of k-critical graphs, raised by Dirac in 1952 and Kelly and Kelly in 1954.

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MS5

A Shorter Proof of the Unique Linkage Theorem

Let G be a graph and $P_1, \ldots, P_k$ disjoint paths in G such that $\bigcup_1^k V(P_i) = V(G)$. The unique linkage theorem of Robertson and Seymour states that either there exist disjoint paths $P'_1, \ldots, P'_k$ such that P_i and P'_i have the same endpoints for $1 \leq i \leq k$ and $\bigcup_1^k V(P'_i)$ is a proper subset of $V(G)$, or, alternatively, the tree width of G is bounded by a function of k. The unique linkage theorem is a major tool in the proof of the polynomial running time of Robertson and Seymour's algorithm for the k disjoint paths problem. The original proof of Robertson and Seymour of the unique linkage theorem is quite difficult and uses the structure theorem for graphs excluding a clique minor. I will describe a new and simpler proof that avoids many of these difficulties; specifically, the proof does not rely on the excluded minor structure theorem of Robertson and Seymour.

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MS6

The cd-index of Bruhat and Balanced Graphs

The **cd**-index is a noncommutative polynomial which compactly encodes the flag vector data of an Eulerian poset. There are two major classes of Eulerian poset: face lattices of convex polytopes (and more generally face posets of regular spherical CW-complexes) and intervals of the strong Bruhat order of Coxeter groups. Billera and Brenti introduced the notion of the complete **cd**-index of a Bruhat interval which encodes more information that than the classical **cd**-index of the interval. Motivated by their work, we extend the notion of Bruhat graphs to balanced labeled graphs and prove the existence of the **cd**-index. We end with a discussion about open problems including nonnegativity questions. This is joint work-in-progress with Margaret Readdy.

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MS6

Topological Methods for Cellular Resolutions

A cellular resolution of an ideal is a resolution where all the maps are boundary maps of a supporting cellular complex. Whenever new types of resolutions of monomial ideals are found, it is also common to look for cellular complexes supporting them. In a joint work with Anton Dochtermann, we have tried to understand from a topological perspective how to construct explicit supporting complexes and describe the maps between them. For example, we generalize and explain resolutions studied by Corso, Froberg, Nagel, and Reiner.

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MS6

Combinatorics and Topology of Face Posets

This talk will give an overview on results about face posets of simplicial complexes and closure posets of regular CW complexes, including recent work using a mixture of combinatorics of face posets together with codimension one topology to study which stratified spaces are regular CW complexes.

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MS6

A Survey of f-vectors since Bjorner's 2005 NSF-CBMS San Francisco Lecture Series, "Algebraic and Topological Combinatorics of Ordered Sets" - Part II of II

In 2005, Bjorner gave a lecture series at an NSF-CBMS regional conference in San Francisco titled, "Algebraic and Topological Combinatorics of Ordered Sets." This is part II of a two-part survey covering advances in face enumeration since then.

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MS6

A Survey of f-vectors since Bjorner's 2005 NSF-CBMS San Francisco Lecture Series, "Algebraic and Topological Combinatorics of Ordered Sets" - Part I of II

In 2005, Bjorner gave a lecture series at an NSF-CBMS regional conference in San Francisco titled, "Algebraic and Topological Combinatorics of Ordered Sets." This is part I of a two-part survey covering advances in face enumeration since then.

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MS7

Inverse Littlewood-Offord Theory

Let $V = \{v_1, .., v_n\}$ be a multiset of n real numbers. Let η_i be i.i.d. Bernoulli random variables. The concentration probability $P(V)$ of V is defined as $P(V) := sup_v P(\eta_1 v_1 + .. + \eta_n v_n = v)$. A classical result of Littlewood-Offord and Erdos from the 1940s asserts that if the v_i are non-zero, then the concentration probability of V is $O(n^{-1/2})$. In the reverse direction, Tao and Vu proved that any set of large concentration probability must have structure. In this talk, we will provide a general approach that gives an almost best possible characterization for all such V. This allows us to recover several previous forward Littlewood-Offord results, including a significant result of Stanley from the 1980s on the optimal value of $P(V)$ when v_i are distinct. (Joint with Van Vu, Rutgers University)

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MS7
A Sharp Estimate for the Square Dependence Problem

Motivated by applications to fast integer factoring algorithms, Pomerance had raised the so-called *square dependence problem* in 1994: *Select integers* $a_1, a_2, \ldots,$ *at random from the interval* $[1, x]$*, until some (non-empty) subsequence has product equal to a square. Find a tight estimate for the expected stopping time of this process.* Using an idea of Schroeppel (1985), Pomerance showed that, with probability $1 - o(1)$, the square dependence occurs after at least $J_0^{1-o(1)}$ integers have been selected, but no more than J_0, for an appropriate explicitly determined $J_0 = J_0(x)$. In joint work with Croot, Granville and Pemantle, we determine this expected stopping time up to a small *constant factor*, tightening Pomerance's interval to

$$[(\pi/4)(e^{-\gamma} - o(1))J_0,\ (e^{-\gamma} + o(1))J_0],$$

where $\gamma = 0.577...$ is the Euler-Mascheroni constant.

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MS7
Structural Approach to Problems to Combinatorial Number Theory - Part I of II

We give a brief survey on an emerging approach for solving problems in combinatorial number theory. The core of this approach are structural (or inverse, or rigidity) theorems, which characterize sets with certain additive properties. Examples will include: (1) Olson-type subset sums problem in Z_p. (2) Erdos-Ginzburg-Ziv, Caychy-Davenport, and Erdos-Heilbronn. (3) Erdos-Folkman conjecture on complete sequences (4) Erdos square-free conjecture.

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MS7
Structural Approach to Problems to Combinatorial Number Theory - Part II of II

We give a brief survey on an emerging approach for solving problems in combinatorial number theory. The core of this approach are structural (or inverse, or rigidity) theorems, which characterize sets with certain additive properties. Examples will include: (1) Olson-type subset sums problem in Z_p. (2) Erdos-Ginzburg-Ziv, Caychy-Davenport, and Erdos-Heilbronn. (3) Erdos-Folkman conjecture on complete sequences (4) Erdos square-free conjecture.

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MS7
The Inverse Erdős-Helibronn Problem

The Erdős-Heilbronn conjecture (proved by Dias da Silva and Hamidoune in 1994) asserts that if A is a subset of $\mathbf{Z}/p\mathbf{Z}$, the cyclic group of the integers modulo a prime p, then $A \widehat{+} A$, the set of all sums of distinct elements, has cardinality at least $\min\{2|A| - 3, p\}$. The bound is sharp when A is an arithmetic progression. A natural question to ask is whether, conversely, $A \widehat{+} A$ being small implies that A is close to an arithmetic progression. In this talk, we will discuss some recent progress towards answering this question. Joint work with Van Vu.

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MS8
Developments in Nash Equilibrium Computation

According to Aumann, zero-sum games are "one of the few areas in game theory, and indeed in the social sciences, where a fairly sharp, unique prediction is made". We provide a generalization of the minmax theorem to *multi-player games*. The games we consider are zero-sum polymatrix—that is, every pair of players plays a (potentially different) two-player game, and every outcome of the global interaction has zero sum of all players' payoffs. Our generalization of the minmax theorem to this setting implies convexity of equilibria, polynomial-time tractability, and convergence of no-regret learning algorithms to equilibria. We show that our class of games is essentially the broadest class of multiplayer zero-sum games to which we can hope to push tractability results. And what about extending our results beyond zero-sum games? Previous work has established that computing exact Nash equilibria is computationally intractable, and research on approximation algorithms has made no progress beyond finite values of approximation. Nevertheless, inapproximability results have been evading current techniques. We provide the first inapproximability result for Nash equilibria in two-player games, for constant values of relative approximation.

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MS8
Computational Mechanism Analysis: Towards a "CPLEX for Mechanisms"

Many mechanisms become important "in the wild" despite a lack of theoretical arguments in their favor, chiefly because their complexity precludes analysis by existing techniques. This talk advocates the creation of computational tools for describing and empirically analyzing such mechanisms. This agenda raises a host of new theoretical problems: identifying representations that compactly represent interesting classes of games; determining encodings of mechanisms of interest into these representations; and deriving efficient procedures for computing solution concepts of interest given these encodings. Recently, we have begun to take steps to make this agenda concrete. Specifically, I will describe "Action Graph Games", a compact encoding for perfect-information games in which agents' payoffs exhibit context-free independencies. I will show how this representation can be used to encode sponsored search mechanisms, and will characterize resulting equilibrium behavior both in terms of social welfare and revenue. I will also outline some recent extensions of our representation to encompass Bayesian games.

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MS8

Game Theory with Costly Computation

We develop a general game-theoretic framework for reasoning about strategic agents performing possibly costly computation. In this framework, many traditional game-theoretic results (such as the existence of a Nash equilibrium) no longer hold. Nevertheless, we can use the framework to provide psychologically appealing explanations to observed behavior in well-studied games (such as finitely repeated prisoner's dilemma and rock-paper-scissors). Furthermore, we provide natural conditions on games sufficient to guarantee that equilibria exist. As an application of this framework, we develop a definition of protocol security relying on game-theoretic notions of implementation. We show that a natural special case of this this definition is equivalent to a variant of the traditional cryptographic definition of protocol security; this result shows that, when taking computation into account, the two approaches used for dealing with "deviating" players in two different communities—Nash equilibrium in game theory and zero-knowledge "simulation" in cryptography—are intimately related. Joint work with Joseph Halpern

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MS8

Intrinsic Robustness of the Price of Anarchy

The price of anarchy is a measure of the inefficiency of decentralized behavior that has been successfully analyzed in many systems. It is defined as the worst-case ratio between the welfare of an equilibrium and that of an optimal solution. Seemingly, a bound on the price of anarchy is meaningful only if players successfully reach an equilibrium. Our main result is that for most of the classes of games in which the price of anarchy has been studied, results are "intrinsically robust" in the following sense: a bound on the worst-case price of anarchy for equilibria *necessarily* implies the exact same worst-case bound for a much larger set of outcomes, such as the possible sequences generated by no-regret learners. We also describe recent applications to the analysis of Bayes-Nash equilibria in (non-truthful) mechanisms.

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MS8

Two Dimensional Matching Markets

We study heterogeneous matching or marriage markets where the payoff of the individuals involved in a matching is determined by the type of their mutual partner. Previously, models with one-dimensional type are considered. These models lead to complete homophily in the emerging equilibrium: individuals tend to match with the people of their own type (or attractiveness). Moreover, in the presence of search frictions in such markets, we will observe block segregation. We show that the block segregation (and homophily in general) is an artifact of the assumption that the types are one-dimensional. We investigate such markets in a more natural setting where the individual types can have multiple dimensions (in our model, two) and each individual cares about a certain dimension of his or her partners type. We characterize the equilibrium in such markets (in both frictional and frictionless instances) and show that a combination of homophily and mixing appears in the equilibrium. Our result explains the mixing observed in both experimental results and real-world studies. Joint work with Daron Acemoglu, Arash Asadpour, Christian Borgs, and Jennifer Chayes

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MS9

Linear Extension Diameter and Random Posets

The linear extension diameter of a poset is the maximum distance between two linear extensions of the poset, where distance is counted as the number of pairs of elements in opposite order. We shall discuss some recent results on this topic. We shall focus on the use of random partial orders to obtain upper bounds on the linear extension diameter for posets in which most pairs are incomparable.

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MS9

On the Size of Maximal Chains and the Number of Pairwise Disjoint Maximal Antichains

Fix integers n and k with $n \geq k \geq 3$. We prove that if P is a finite poset and $n \leq |C| \leq n + (n-k)/(k-2)$ for every maximal chain in P, then P must contain k pairwise disjoint maximal antichains. We construct examples showing that these inequalities are tight. The result has a dual version, the subject of work by Howard and Trotter.

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MS9

Families of Maximal Chains

Fix integers n and k with $n \geq k \geq 3$. Duffus and Sands proved that if P is a finite poset and $n \leq |C| \leq n + (n-k)/(k-2)$ for every maximal chain in P, then P must contain k pairwise disjoint maximal antichains. They also constructed a family of examples to show that these inequalities are tight. These examples are 2-dimensional which suggests that the dual statement may also hold. In this paper, we show that this is correct. Specifically, we show that if P is a finite poset and $n \leq |A| \leq n+(n-k)/(k-2)$ for every maximal antichain in P, then P has k pairwise disjoint maximal chains. Our argument actually proves a somewhat stronger result, and we are able to show that an analogous result holds for antichains.

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MS9
Lattices and Polytopes from Graphs

Abstract not available at time of publication.

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MS9
Chains in Normalized Matching Posets

Given a poset P with n elements and a partition μ of the integer n, can we find a partition of P into chains such that the sizes of the chains are given by the non-zero parts of μ? In the case when P is a normalized matching (aka LYM) poset, combining a number of 25 to 35 year old conjectures by Griggs, Füredi, and others, we conjecture that the answer is yes if and only if μ is majorized (or dominated) by the partition of n coming from a nested chain decomposition of P. In this talk, we will survey the evidence for this conjecture.

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MS10
Flows in Oriented Matroids

Extensions of flow number to matroids via definitions of the circular flow number of a graph, $\phi_c(G)$, are known to work for certain classes for example orientation classes of orientable matroids and $\sqrt[6]{1}$-matroids. Dually, we obtain notions of circular chromatic number for the same classes. We will mention some results on this topic and discuss the idea of *Eulerian matroid* thus obtained, as time allows.

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MS10
Overview of Flows in Graphs and Matroids

As an approach to studying the chromatic number, Tutte introduced the notion of (group-valued) flows in graphs. In the past 50 years, flows in graphs has been connected to a wide variety of graph problems involving cycles, spanning trees, orientations, embeddings, edge colorings and graph polynomials. More recently, the notion of flows has been extended to various classes of matroids, such as binary, ternary, orientable and sixth-root-of-unity matroids. I will give an overview of this subject, emphasizing what I consider to be the important questions, and touching on topics to be presented by the other speakers of this minisymposium.

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MS10
Representations of Even Cut Matroids.

Even cut matroids are a minor closed class of matroids that are represented by grafts. A difficulty when dealing with even cut matroids arises from the fact that the same even cut matroid may be represented by grafts which are not related by simple operations. We define equivalence classes on the set of representations of even cut matroids and we study how equivalence classes behave under a single element extension or co-extension. The goal is to show that the set of representations of any even cut matroid can be covered by a costant number of equivalence classes.

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MS10
Thin Trees, Nowhere-zero Flows, and the Asymmentric Traveling Salesman Problem

I will talk about recent results on designing approximation algorithms for the Asymmetric Traveling Salesman Problem (ATSP). Our approach is based on constructing a "thin' spanning tree from the solution of a classical linear programming relaxation of the problem and augmenting the tree to an Eulerian subgraph. I will talk about Goddyn's conjecture on the existence of such trees and its relationship to nowhere-zero flows.

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MS10
The Lattice of Integer Flows of a Regular Matroid

Abstract not available at time of publication.

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MS11
A Solution to Havel's Problem

In 70's, Havel posed the following problem: does there exist a constant C such that every planar graph in that the distance between any two triangles is at least C is 3-colorable?

We answer this question in affirmative.

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MS11
Doubly Critical Graphs

A graph G is *doubly critical* if the removal of any pair of adjacent vertices yields a graph whose chromatic number is two less than that of G. A long-standing conjecture of Lovász states that the only connected doubly critical graphs are the complete graphs. We will give an overview of results and problems related to this conjecture and discuss some recent developments.

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MS11
Maximum Number of q-colorings

We consider an old problem of Linial and Wilf to determine the structure of graphs which allow the maximum number of q-colorings among graphs with n vertices and m edges. We prove that if n is large compared to q, $m = n^2/4$ and q is even, then the maximum is achieved by a complete balanced bipartite graph. This partially confirms a conjecture of Lazebnik. Our proof builds on methods of Loh, Pikhurko and Sudakov, which reduce the problem to a quadratic program.

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MS11
Fano Colorings of Cubic Graphs and a Conjecture of Fan and Raspaud

A Fano coloring is a coloring of the edges of a cubic graph by points of the Fano plane such that the colors around every vertex form a line. Macajova and the speaker proved (2005) that six lines suffice to color every bridgeless cubic graph, and conjectured that four lines would do. We show that this conjecture is true for cubic graphs with a 2-factor having exactly two odd circuits.

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MS11
Color-critical Graphs on Surfaces

A fundamental question in topological graph theory is as follows: Given a surface Σ and an integer $t \geq 0$, which graphs drawn in Σ are t-colorable? We say that a graph is $(t+1)$-*critical* if it is not t-colorable, but every proper subgraph is. In 1993, Carsten Thomassen showed that there are only finitely many six-critical graphs on a fixed surface with Euler genus g. In this talk, I will describe a new short proof of this fact. In addition, I will describe some structural lemmas that were useful to the proof and describe a list-coloring extension that is helpful to ongoing work that there are finitely many six-list-critical graphs on a fixed surface. This is a joint project with Ken-ichi Kawarabayashi of National Institute of Informatics, Tokyo.

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MS12
Packing Hamilton Cycles in Random and Pseudo-random Hypergraphs

We say that a k-uniform hypergraph C is a Hamilton cycle of type ℓ, for some $1 \leq \ell \leq k$, if there exists a cyclic ordering of the vertices of C such that every edge consists of k consecutive vertices and for every pair of consecutive edges E_{i-1}, E_i in C (in the natural ordering of the edges) we have $|E_{i-1} - E_i| = \ell$. We prove that for $\ell \leq k < 2\ell$, with high probability almost all edges of a random k-uniform hypergraph $H(n, p, k)$ with $p(n) \gg \log^2 n/n$ can be decomposed into edge disjoint type ℓ Hamilton cycles. We also provide sufficient conditions for decomposing almost all edges of a pseudo-random k-uniform hypergraph into type ℓ Hamilton cycles, for $\ell \leq k \leq 2\ell$.

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MS12
Peer-to-Peer Clustering Protocols

Suppose n individuals (clusters of size 1) need to rapidly coalesce into a single cluster, where the elementary operation is to merge two existing clusters. In this talk, we analyze a randomized peer-to-peer clustering algorithm proposed by the Distributed Systems group at Microsoft Research, which empirically appeared to achieve the asymptotically optimal running time. We provide the first rigorous bounds on the performance of this and a related algorithm, extending an approach of Oded Schramm.

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MS12

Spectra of Lifted Ramanujan Graphs

Let G be a d-regular graph with all nontrivial eigenvalues at most λ in absolute value and let ρ be the spectral-radius of its universal cover. We show that with high probability the absolute value of every nontrivial eigenvalue of an n-lift of G is $O(\max\{\lambda, \rho\} \log \rho)$, translating to $O(\sqrt{d} \log d)$ for a Ramanujan base-graph. This result is thus tight up to a logarithmic factor, and for $\lambda \leq d^{2/3-\epsilon}$ it substantially improves the previously known upper bounds of Friedman (2003) and of Linial and Puder (2008). In particular, it implies that a typical n-lift of a Ramanujan graph is nearly Ramanujan.

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MS12

Expansion, Relaxation and Approximation

Small set expansion in a graph refers to the isoperimetric question of bounding the edge expansion when restricted to sets of vertices of small size, while *spectral profile* serves as its corresponding (functional) relaxation. Both notions have been of much interest lately, due to connections to mixing time in Markov chains and optimization over sparse subspaces. Further motivated by the computational complexity of the small set expansion problem, in joint work with D. Steurer and P. Raghavendra, we consider a semi-definite relaxation of the spectral profile and obtain logarithmic factor approximations for both the spectral profile and the isoperimetric profile. I hope to describe the relaxation and the basic ideas behind our approximation.

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MS12

Graphs Which are Hard to Make Triangle-free Can be Packed with Many Triangles

It is known that a graph can be made triangle-free by removing (slightly less than) half its edges. We call a graph triangle-bound if (essentially) half of its edges must be deleted in order to make it triangle-free. It is conjectured that the edges of a dense triangle-bound graph can be packed with (almost) $|E(G)|/3$ triangles. It is known that there is always a packing of size (almost) $|E(G)|/4$. We prove a result in this direction. For any $\beta > 0$ there is $\alpha > 0$, so that if G is a regular triangle-bound graph with degree βn then it has $|E(G)|(1/4 + \alpha)$ edge-disjoint triangles.

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MS13

The Hopf Monoid of Generalized Permutahedra

Joyal's notion of species constitutes a good framework for the study of certain algebraic structures associated to combinatorial objects. We discuss the notion of "Hopf monoid" in the category of species and illustrate it with several examples. We introduce the Hopf monoid of generalized permutahedra (the latter are certain polytopes recently studied by Postnikov, Reiner, and Williams, among others). Our main result is an explicit antipode formula for this Hopf monoid. We explain how reciprocity theorems of Stanley on graphs and of Billera, Jia and Reiner on matroids can be deduced from this result.

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MS13

On Noncommutative Combinatorial Inverse System

We introduce a notion of a combinatorial inverse system in non-commutative variables. We present two important examples, some conjectures and results. These conjectures and results were suggested and supported by computer investigations.

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MS13

Valuative Invariants for Polymatroids

Many important invariants of matroids and polymatroids, such as the Tutte polynomial, the Billera-Jia-Reiner quasi-symmetric function, and Derksen's invariant $\mathcal{G}$, are valuative. We construct the $\mathbf{Z}$-modules of all $\mathbf{Z}$-valued valuative functions and of valuative invariants for matroids and polymatroids on a fixed ground set. We give Hopf algebra structures for these objects and explicit formulas for their ranks.

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MS13

Multigraded Combinatorial Hopf Algebras and Refinements of Odd and Even Subalgebras

We develop a theory of multigraded combinatorial Hopf algebras modeled on the theory of graded combinatorial Hopf algebras developed by Aguiar, Bergeron, and Sottile [Compos. Math. 142 (2006), 1–30]. In particular we in-

troduce the notion of canonical **k**-odd and **k**-even subalgebras associated with any multigraded combinatorial Hopf algebra, extending simultaneously the work of Aguiar et al. and Ehrenborg. Among our results are specific categorical results for higher level quasisymmetric functions, several basis change formulas, and a generalization of the descents-to-peaks map.

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MS13

Noncrossing Partition Hopf Algebra

We introduce and study the incidence Hopf algebra H of the family of noncrossing partition lattices of finite linearly ordered sets. After presenting some basic combinatorial results on noncrossing partitions, we give two formulas for the antipode of H. The first of these is given as an alternating sum indexed by certain dissections of polygons and is cancellation-free. The second gives values on the canonical set of generators in terms of a second set of generators, related to the first by Lagrange inversion; this formula is not only cancellation-free but is in fact sign-free. Finally, we use an edge labeling of noncrossing partition lattices, defined by Richard Stanley, to construct an isomorphism between H and the Hopf algebra of symmetric functions and an embedding of H in the Hopf algebra of parking functions. These maps have sign-free expressions in terms of the canonical bases of these Hopf algebras.

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MS14

Pairs of Elements in Unavoidable Minors of 3-connected Binary Matroids

Ding, Oporowski, Oxley, and Vertigan proved that every sufficiently large 3-connected, binary matroid has a large minor isomorphic to a binary spike, $M(K_{3,n})$, $M^*(K_{3,n})$, or the n-spoke wheel. We will show that any element of a sufficiently large, 3-connected, binary matroid, M, is contained in one of six large minors related to these four, and we discuss the corresponding result for a pair of elements of M.

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MS14

The Excluded Minors for the Class of Matroids that are Binary or Ternary

Suppose that $\mathcal{M}$ and $\mathcal{N}$ are minor-closed classes of matroids. Then $\mathcal{M} \cup \mathcal{N}$ is also minor-closed. If we know the excluded minors for $\mathcal{M}$ and $\mathcal{N}$, we would naturally want to characterize the excluded minors for $\mathcal{M} \cup \mathcal{N}$. This is often a very difficult problem. Vertigan showed that $\mathcal{M} \cup \mathcal{N}$ need not have a finite number of excluded minors, even in the case that $\mathcal{M}$ and $\mathcal{N}$ themselves have only a single excluded minor each. However, it may be the case that if $\mathcal{M}$ and $\mathcal{N}$ are, respectively, the classes of matroids representable over two finite fields, then $\mathcal{M} \cup \mathcal{N}$ always has finitely many excluded minors. We show that this is true in the case that $\mathcal{M}$ and $\mathcal{N}$ are respectively the classes of GF(2)- and GF(3)-representable matroids.

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MS14

On the Number of Points in a Matroid with No n-point Line as a Minor

We give a tight upper bound for the number of elements in a simple rank-r matroid with no n-point line as a minor when r is sufficiently large relative to n, and show that the matroids attaining the bound are projective geometries. This result settles a conjecture made by Joseph Kung in 1993.

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MS14

Some Minor-minimal Unbalanced Matroids

Balanced matroids were introduced by Feder and Mihail in 1992, in connection with their study of random walks on basis-exchange graphs of matroids. We present a family which contains most known examples of minor-minimal unbalanced matroids, and determine exactly which matroids in this family are minor-minimally unbalanced. We conclude with a summary of what (little) is known about the set of excluded minors for balanced matroids.

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MS14

Stability, Fragility, and Rota's Conjecture

Rota conjectured that, for each finite field F, the class of F-representable matroids has finitely many excluded minors. A matroid is *N-fragile* if for each element either the deletion or the contraction has no N-minor. The *Bounded Canopy Conjecture* is that all GF(q)-representable N-fragile matroids have bounded branch width. We prove a result which implies that for GF(5) Rota's Conjecture reduces to the Bounded Canopy Conjecture.

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MS15

Hamiltonicity and Traceability of Strong k-traceable Oriented Graphs

In this talk the hamiltonicity and traceability of strong k-traceable oriented graphs are considered. Also, the strong component structure of k-traceable oriented graphs that are not traceable is investigated.

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MS15

Further Progress Towards the Traceability Conjecture

We show that for every integer $k \geq 2$ there exists an integer $t(k)$ ($< 2k^2$) such that every k-traceable oriented graph of order at least $t(k)$ is traceable. Furthermore, we establish an upper bound on the order of k-traceable oriented graphs with girth $g > 3$ and apply our findings to prove that the PPC holds for 1-deficient oriented graphs with girth at least 6.

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MS15

Independent Sets Which Meet All Longest Paths

The case $a = 1$ of the PPC may be stated as "Every digraph contains an independent set which meets every longest path'. In this talk I survey sufficient conditions for a digraph to have an independent set which meets all longest paths.

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MS15

An Introduction to the Path Partition Conjecture and Traceability Conjecture

A digraph D of order $n \geq k \geq 2$ is k-traceable if every k vertices of D induce a traceable subdigraph. The Traceability Conjecture (TC) states that every k-traceable oriented graph of order at least $2k - 1$ is traceable. D is 1-deficient if $\lambda(D) = n - 1$. In this talk we introduce background material on the PPC and the TC and establish a connection between the TC and the PPC for 1-deficient oriented graphs.

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MS15

Hypotraceable Oriented Graphs and the Traceability Conjecture

A digraph D is hypotraceable if D is not traceable but $D - v$ is traceable for every $v \in V(D)$. Every nontraceable k-traceable oriented graph of order n contains an induced hypotraceable oriented graph of order h for some $k < h \leq n$. We investigate the order and structure of hypotraceable oriented graphs and show that for $2 \leq k \leq 6$ every k-traceable oriented graph is traceable. This implies that the PPC holds for 1-deficient oriented graphs of order at most 12.

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MS16

Introduction to Linear Series on Tropical Curves

We will give an overview of Riemann-Roch and Abel-Jacobi theory on metric graphs and tropical curves.

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MS16

A Tropical Proof of the Brill-Noether Theorem

We produce Brill-Noether general graphs in every genus, confirming a conjecture of Baker and giving a new proof of the Brill-Noether Theorem, due to Griffiths and Harris. Our proof provides an explicit criterion for a curve to be Brill-Noether general over discretely valued fields of arbitrary characteristic.

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MS16

Rank-determining Sets of Tropical Curves

The rank of a divisor is a concept appearing in the Riemann-Roch theorem for finite graphs or tropical curves. A "rank-determining set" of a tropical curve Γ is defined to be a subset A of Γ such that the rank of a divisor D on Γ is always equal to the rank of D restricted on A. I will present a criterion for rank-determining sets and show constructively that there exist finite rank-determining sets. We can compute the rank of an arbitrary divisor on any tropical curve based on finite rank-determining sets. In addition, I will discuss general properties and further applications of rank-determining sets.

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MS16

Linear Systems on Tropical Curves

A tropical curve is a metric graph with possibly unbounded edges, and tropical rational functions are continuous piecewise linear functions with integer slopes. We define the complete linear system $|D|$ of a divisor D on a tropical curve analogously to the classical counterpart. Due to work of Baker and Norine, there is a rank function $r(D)$ on such linear systems, as well a canonical divisor K. Completely analogous to the classical case, this rank function satisfies Riemann-Roch and analogues of Riemann-Hurwitz. This talk will describe joint work with Josephine Yu and Christian Haase investigating the structure of $|D|$ as a cell complex. Among other results, we show that linear systems are quotients of tropical modules, finitely generated by vertices of the cell complex.

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MS16

Projective Embeddings of Tropical Curves

We study embedddings of a tropical curve into a projective space given by a finite set of tropical rational functions in a linear system of a divisor D. The image can be modified to a tropical curve of degree equal to deg(D). The tropical convex hull of the image realizes the linear system as a polyhedral complex. We also show that curves for which the canonical divisor is not very ample are hyperelliptic.

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MS17

Nowhere-Harmonic Colorings of Graphs

By studying the vertex Laplacian of a graph, we introduce nowhere-harmonic colorings along with analogues of the chromatic polynomial and Stanley's theorem relating negative evaluations of the chromatic polynomial to acyclic orientations. Our primary tool for these investigations is the theory of "inside-out polytopes," developed by M. Beck and T. Zaslavsky, and the theory of Ehrhart quasipolynomials for rational polytopes.

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MS17

Ehrhart Polynomials of Non-integral Polytopes

An active area of research is the characterization of the Ehrhart polynomials of polytopes. However, due to the phenomenon of quasi-period collapse, not all Ehrhart polynomials come from *integral* polytopes. Results regarding integral polytopes do not always generalize to arbitrary Ehrhart polynomials. We discuss recent progress in this more general context. In particular, we consider nonintegral analogues of reflexive polytopes and the generalization of Scott's bound (Scott 1978) to the non-integral case.

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MS17

Kneser's Theorem and Inequalities in Ehrhart Theory

We demonstrate how additive number theory can be used to produce new classes of inequalities in Ehrhart theory. More specifically, we use a classical result of Kneser to produce new inequalities between the coefficients of the Ehrhart h^*-vector of a lattice polytope. As an application, we deduce all possible 'balanced' inequalities between the coefficients of the Ehrhart h^*-vector of a lattice polytope containing an interior lattice point, in dimension at most 6.

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MS17

Counting With Rational Generating Functions

Consider the Ehrhart quasi-polynomial, $f(t)$, of a rational polytope, P (that is, $f(t)$ counts the number of integer points in tP). One often considers the (algebraically-manipulable) generating function $\sum_{t\geq 0} f(t)x^t$. Alternatively, $f(t)$ can be written as a "step-polynomial" (an explicit function built from floor functions). Fortunately, we do not have to choose between nimble generating functions and concrete step-polynomials for this and other counting problems, as one can convert back and forth between them in polynomial time (in fixed dimension). This is joint work with Sven Verdoolaege.

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MS18

Some Highly Arc Transitive Digraphs

Highly arc transitive digraphs are digraphs with the property that any two directed walks of equal length are equivalent under the automorphism group. These graphs were introduced by Cameron Praeger and Wormald, and have proved to be interesting objects both in combinatorics and group theory. Here we construct some highly arc transitive digraphs which resolve two conjectures from this original paper. This is joint work with Bojan Mohar and Robert

Samal.

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MS18

Graphs with No Octahedron Minor

We characterize graphs that don't contain the Octahedron as a minor. Related problems will also be discussed.

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MS18

The K Edge-Disjoint Paths Problem in Digraphs with Bounded Independence Number

In 1980, Fortune, Hopcroft, and Wyllie showed that the following algorithmic problem (k-EDP) is NP-complete with $k = 2$:

k Edge-Disjoint Paths (k-EDP)

Instance: A digraph G, and k pairs $(s_1, t_1), \ldots, (s_k, t_k)$ of vertices of G.

Question: Do there exist directed paths $P_1, \ldots, P_k$ of G, mutually edge-disjoint, such that P_i is from s_i to t_i for $i = 1, \ldots, k$?

In this talk we will present a polynomial time algorithm to solve k-EDP for fixed k in digraphs with bounded independence number. This is joint work with Paul Seymour.

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MS18

Pairs of Signed Graphs with the Same Even Cycles

We investigate the following question: Given two signed graphs with the same set of even cycles what is the relation between these signed graphs? We provide two answers to this question. We first show that any pair of such signed graphs are related by a sequence of operations that preserve even cycles at each step. We also show that for any family of edge sets S: we can partition, the set of all signed graphs whose even cycles are exactly S, into a constant number of equivalence classes. Moreover, the relation between any two signed graphs in the same equivalence class is much simpler than the relation between an arbitrary pair of signed graphs which have the same even cycles.

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MS18

On a Quadratic Upper Bound for the Number of Vertices in 6-Critical Graph

Thomassen proved that there are only finitely many 6-critical graphs embeddable in any fixed surface. We prove that if a graph G is a C-6-critical plane graph with outer cycle C, then G has at most $O(|C|^2)$ vertices. We then use discharging to show that there only $O(g^2)$ vertices in a 6-critical graph which embeds on a surface of genus g.

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MS20

Okounkov Bodies and Toric Degenerations of Schubert Varieties

We show how the Okounkov body construction developed recently by Kaveh-Khovanskii and Lazarsfeld-Mustaţă gives rise to flat degenerations of a variety to a toric variety, and apply this perspective to construct toric degenerations of Schubert varieties which are compatible with degenerations of their Bott-Samelson resolutions.

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MS20

Affine Schubert Positivity, Total Positivity, and Geometric Satake

Let G be a complex simple simply-connected algebraic group. A theorem proved independently by Ginzburg and Peterson states that the homology $H_*(Gr_G)$ of the affine Grassmannian of G is isomorphic to the ring of functions on the centralizer X of a principal nilpotent in the Langlands dual $G^\vee$. There is a notion of total positivity on X, using Lusztig's general definitions, and there is also a notion of Schubert positivity, using Schubert classes of Gr_G. We connect the two notions using the geometric Satake correspondence. In addition, we give an explicit parametrization of the positive points of X. This is joint work with Konstanze Rietsch, generalizing work of hers in type A.

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MS20

A Chevalley Formula in the Equivariant K-Theory

of Kac-Moody Flag Varieties

In previous work with Postnikov, we gave a Chevalley formula in the equivariant K-theory of finite type flag varieties in terms of our alcove model. I will present a generalization of this formula to Kac-Moody flag varieties using an extension of the alcove model; there is another version, based on Lakshmibai-Seshadri paths, similar to the one of Pittie-Ram. For the type A affine Grassmannian, the formula can be phrased using the Misra-Miwa partition model.

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MS20
Double Schubert Polynomials for Classical Groups

A classical problem in Schubert Calculus is to find polynomial representatives for Schubert classes in the flag manifolds. In type A, Lascoux and Schutzenberger's Schubert polynomials are canonical such representatives. The situation is more subtle in the other classical types. Using Schur's P and Q functions, Billey and Haiman constructed a canonical family of polynomials, which are solutions of certain divided-difference equations. In joint work with T. Ikeda and H. Naruse we use localization techniques, and the factorial P and Q-Schur functions of Ivanov, to extend Billey and Haiman's construction to equivariant cohomology. The resulting polynomials posses quite pleasant combinatorial properties: stability, positivity, symmetry.

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MS20
Circle Actions and Equivariant Cohomology of Peterson Varieties

A well-known algorithm called GKM theory computes equivariant cohomology for a large class of varieties with torus actions from purely combinatorial data. GKM theory works perfectly for generalized flag varieties, so it has been used widely in modern Schubert calculus. We generalize this theory, showing that a kind of GKM theory holds for a broader class of varieties having one-dimensional torus actions. As an application, we give a simple, combinatorial computation of equivariant and ordinary Schubert calculus of Peterson varieties.

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MS21
Viewing Market Price Discovery as an Algorithmic Process

Self-organizing behavior can often be viewed as arising from a distributed process. It is natural to ask when and why it occurs. Our thesis is that an algorithmic perspective may be helpful. One instance of such a distributed process is pricing in markets. A basic tenet of well-functioning markets is that they discover (converge toward) prices that simultaneously balance supplies and demands of all goods; these are called equilibrium prices. Further, the markets are self-stabilizing, meaning that they converge toward new equilibria as conditions change. This talk will seek to explain why this could happen. More specifically, we describe the setting of Ongoing Markets (by contrast with the classic Fisher and Exchange markets). An Ongoing Market allows trade at non-equilibrium prices, and, as its name suggests, continues over time. The main task remaining is to specify and analyze a suitable price update rule. We consider a (tatonnement-style) rule with the following characteristics: 1. There is a separate instance of the (price update) procedure for each good. 2. The procedure is distributed: (i) the instances are independent, and (ii) each instance uses limited "local" information. 3. It is simple. 4. It is asynchronous: price updates do not have to be simultaneous. And for appropriate markets the rule enables: 5. Fast convergence. 6. Robustness in the face of (somewhat) inaccurate data. This talk is based on joint works with Lisa Fleischer and Ashish Rastogi.

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MS21
New Convex Programs and Distributed Algorithms for Fisher Markets with Linear and Spending Constraint Utilities

We shed new light on convex programs and distributed algorithms for Fisher markets with linear and spending constraint utilities. We give a new convex program for the linear utilities case of Fisher markets. This program easily extends to the case of spending constraint utilities as well, thus resolving an open question raised by Vazirani. We show that the gradient descent algorithm with respect to a Bregman divergence converges with rate $O(1/t)$ under a condition that is weaker than having Lipschitz continuous gradient (which is the usual assumption in the optimization literature for obtaining the same rate). We show that the Proportional Response dynamics recently introduced by Zhang is equivalent to a gradient descent algorithm for solving the new convex program. This insight also gives us better convergence rates, and helps us generalize it to spending constraint utilities.

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MS21
Coordination Mechanisms for Selfish Scheduling and Routing

We investigate the influence of different algorithmic choices on the approximation ratio in selfish scheduling, and survey the recently developed results about coordination mechanisms for machine scheduling. Our goal is to design local policies that minimize the inefficiency of resulting equilibria. In particular, we present the first coordination mechanisms achieving a logarithmic bound for makespan over unrelated machines, and show strong lower bounds for a class of coordination mechanisms.

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MS21

On Scheduling Mechanisms: Theory, Practice and Pricing

Markets of computing resources typically consist of a Cloud and Jobs that arrive over time and request computing resources in exchange for payment. A Mechanism in this context consists of a scheduling algorithm and a pricing policy. We start with a theoretical impossibility result showing the Inapproximability of Randomized Dominant-Strategy Mechanisms for a natural scheduling problem on Unrelated-Machines (formulated as a mechanism design problem in the seminal paper of Nisan and Ronen). We then briefly model the dynamic interaction between the provider and the consumers as a simple one-shot game. Using a simulation-based approach we show that market stability in the form of symmetric Nash-Equilibrium is likely to be achieved (under the assumption of small risk aggressive group of users). If time permits, we shall briefly discuss Individually-Fair scheduling mechanisms. Joint work with: Lior Amar, Amnon Barak, Michael Schapira and Sergei Shudler.

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MS21

Aggregation and Manipulation in Prediction Markets

Prediction markets are markets established primarily to aggregate distributed information and forecast future events. In this talk, I will discuss recent results on strategic behavior and information aggregation in prediction markets, focusing on the market scoring rule (MSR) prediction markets introduced by Hanson (2003). MSR markets have an attractive incentive property: a trader trading only once optimizes her expected profit by trading honestly. We analyze strategic behavior in two realistic situations: when traders may trade multiple times, and when traders have a future payoff that creates a conflict of interest. In these situations, we characterize information distributions in which honest trading is optimal, as well as distributions in which there is bluffing or withholding of information in equilibrium. In the latter case, I also present a simple modification of the MSR that improves the rate of information aggregation in equilibrium.

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MS22

Distributive Lattices of Two-Rowed Standard Young Tableaux, with Applications to Symmetric Function Inequalities

In joint work with A. Cuttler and M. Skandera, the speaker has investigated partial orders defined on various families of symmetric functions, defined by the relation f ¡= g iff f(X) ¡= g(X) for every substitution of nonnegative variables X. This partial order includes many classical inequalities (e.g. AGM, Muirhead) as well as many new ones. In subsequent work (some of it joint with J. Lima) the speaker has investigated a stronger attribute, called Y-positivity, from which the original inequalities follow trivially. In one case, the arguments involve involve an interesting lattice defined on Standard Young Tableaux. When the tableaux have two rows, the lattice is distributive, and a key step in the proof of Y-positivity is based on the FKG inequality. We will describe these lattices and discuss some possible extensions of this work.

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MS22

Diamond-free Posets

Abstract not available at time of publication.

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MS22

Acyclic Sets in k-majority Tournaments

Given a set S of linear orders of a ground set X, the *majority digraph* of S is the directed graph on X where there is an edge from u to v when a majority of the orders in S rank u above v. For odd k, a *k-majority tournament* is a tournament that arises as the majority digraph of a set of k orders. When the orders in S are interpreted as a ranking of preferences among a set of alternatives X, acyclic sets in the majority tournament can be viewed as a consensus ranking of a subset of X. We study the maximum size of an acyclic set of vertices in k-majority tournaments. Every n-vertex 3-majority tournament contains an acyclic set of size $n^{1/2}$; we present a family of 3-majority tournaments which have no acyclic sets of size larger than $2n^{1/2}$. We show that every n-vertex 5-majority tournament contains an acyclic set of size $n^{1/4}$. For general k, every k-majority tournament contains an acyclic set of $n^{f(k)}$, where $f(k) = 3^{-(k-1)/2}$. On the other hand, there are k-majority tournaments in which every acyclic set has size at most $n^{g(k)}$, where $g(k) = O(\log\log k/\log k)$. This is joint work with Dan Schreiber and Douglas B. West.

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MS22

On Maximal F-free Subsets of Finite Posets

Say that a finite poset F has the *maximal antichain prop-*

erty (MAP) if every maximal F-free subset of every finite poset P contains a maximal antichain of P. Analogously we define the *maximal chain property* (MCP) and the *maximal element property* (MEP). We characterize all posets with the MAP, the MCP, and the MEP. We also give an application of our characterization of the MEP to a colouring problem for posets. Some of this work is joint with Jia Shen.

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MS22

Submodular Functions and Packing of Steiner Trees in Graphs

Nash-Williams proved that every $2k$-edge-connected graph has k edge-disjoint spanning trees. Kriesell conjectured more generally that if a set S in $V(G)$ is $2k$-edge-connected in G, then G has k edge-disjoint trees that contain S (a set is j*-edge-connected in* G if it cannot be separated by deleting fewer than j edges from G). Lap-Chi Lau proved that it suffices for S to be $24k$-edge-connected in G. We prove that it suffices for S to be $6.5k$-edge-connected in G. Our result follows from a common generalization of the Tree Packing Theorem and Hakimi's criterion for orientations with specified outdegrees. We prove the general theorem using submodular functions and the Matroid Union Theorem.

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MS23

On Rogers's Proof of Identifiability for the GTR + Gamma + I Model in Phylogenetics

In 2001, Rogers's gave a proof of identifiability for the popular general time reversible (GTR) Markov model with Gamma distributed rates mixed with invariable (I) sites for DNA evolution along a phylogeny. Recently, Allman, Ane, and Rhodes have pointed out an error in Rogers's proof and provided a proof using three-way species comparisons to show that the model without invariable sites is identifiable. We will discuss Rogers's approach and provide the proof of the missing link for the model with invariable sites using only pairwise species comparisons. There are a few exceptional cases that our method cannot handle, mainly the Jukes-Cantor model for DNA evolution. We will discuss what is known about that situation to date.

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MS23

Generalizing the Four Gamete Condition and Splits Equivalence Theorem: Local Conditions For Perfect Phylogeny

For binary input, the classical four gamete condition/splits equivalence theorem gives a concise necessary and sufficient condition for the existence of a perfect phylogeny and is the building block for many theoretical results and practical algorithms. In this talk, we discuss recent work to obtain local conditions that generalize the four gamete condition to multiple-state perfect phylogeny. In the special case of three-state perfect phylogeny, we further show that there is a set of four subpatterns such that any three-state characters not allowing a perfect phylogeny must contain one of these four subpatterns. This generalizes the four gamete condition which states that a pair of characters not allowing a binary perfect phylogeny must contain the subpattern of all four binary combinations. (Joint work with Dan Gusfield and Srinath Sridhar)

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MS23

Icosahedral Viral Assembly Pathway Enumeration Using Tree Orbits Under Permutation Group Action

We use combinatorics and group theory to answer questions about the assembly of icosahedral viral shells, or any symmetric macromolecular assembly. Although the final geometric structure of such assemblies is fairly well understood in terms of the constituent subunits, the assembly pathways are not. Specifically, it is of interest to obtain a probability distribution over valid assembly pathways. In this talk, the capsid is modeled by a polyhedron whose facets represent the monomers. The assembly is modeled by a rooted tree, the leaves representing the facets of the polyhedron, the root representing the assembled polyhedron, and the internal vertices representing intermediate stages of assembly (subsets of facets). The probability of an assembly pathway is influenced by the size of the orbit of a representative sassembly tree under the icosahedral group action. Besides its virological motivation, the enumeration of orbits of trees under the action of a finite group is of independent mathematical interest. If G is a finite group acting on a finite set X, then there is a natural induced action of G on the set $\mathcal{T}_{\mathcal{X}}$ of trees whose leaves are bijectively labeled by the elements of X. If G acts simply on X, then $|X| := |X_n| = n \cdot |G|$, where n is the number of G-orbits in X. The basic combinatorial results in this paper are (1) a formula for the number of orbits of each size in the action of G on $\mathcal{T}_{\mathcal{X}_\setminus}$, for every n, and (2) a simple algorithm to find the stabilizer of a tree $\tau \in \mathcal{T}_{\mathcal{X}}$ in G that runs in linear time and does not need memory in addition to its input tree. Joint work with Miklos Bóna and Andy Vince

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MS23

The Shape of Phylogenetic Treespace

Distances between trees are often NP-hard to compute. In this talk, we discuss recent work on efficiently approximating distances between trees. We focus on biological inspired ways to compare trees (SPR, TBR, geodesic distance in treespace, and tanglegrams), as well as rotation distance for ordered trees.

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MS23

Bayes Estimators for Phylogenetic Reconstruction

Tree reconstruction methods are often judged by their accuracy, measured by how close they get to the true tree. Yet most reconstruction methods like ML do not explicitly maximize this accuracy. To address this problem, we propose a Bayesian solution. Given tree samples, we propose finding the tree estimate which is closest on average to the samples. This "median' tree is known as the Bayes estimator (BE). The BE literally maximizes posterior expected accuracy, measured in terms of closeness (distance) to the true tree. We discuss a unified framework of BE trees, focusing especially on tree distances which are expressible as squared euclidean distances. Notable examples include Robinson–Foulds distance, quartet distance, and squared path difference. Using simulated data, we show Bayes estimators can be efficiently computed in practice by hill climbing. We also show that Bayes estimators achieve higher accuracy, compared to maximum likelihood and neighbor joining.

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MS24

The Cycle Switching Graph of the Steiner Triple Systems of Order 19 is Connected

Switching is a local transformation that when applied to a combinatorial object gives another object with the same parameters. It is here shown that the cycle switching graph of the 11,084,874,829 isomorphism classes of Steiner triple systems of order 19 as well as the cycle switching graph of the 1,348,410,350,618,155,344,199,680,000 labeled such designs are connected.

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MS24

The Degree Sequence Problem for Partial Steiner Triple Systems

A partial Steiner triple system is a collection of triples on a given set of vertices (or points) such that every pair of vertices is in at most one triple. The degree of a vertex in such a system is the number of triples that contain it. The degree sequence of a partial Steiner triple system is the list of its vertex degrees. The problem is when given a list of positive integers to determine if there is a partial Steiner triple system with this list as its degree sequence. Recent progress on this problem is presented.

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MS24

Colouring Block Designs

A block design with point set V and block set $\mathcal{B}$ is said to be c-colourable if the points of V can be partitioned into c sets called colour classes such that no block of $\mathcal{B}$ has all of its points in a single colour class. A design is said to be c-chromatic if it is c-colourable but not $(c-1)$-colourable. For all integers $c \geq 2$, $k \geq 6$ and $\lambda \geq 1$, we show that for sufficiently large v the obvious necessary conditions for the existence of a BIBD(v,k,λ) are sufficient for the existence of a c-chromatic BIBD(v,k,λ).

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MS24

Spanning Trees with Specified Differences in Cayley Graphs

Let G be a finite group of order n and L a multiset of $n-1$ group elements with L_s its underlying set. Let $C(G, L_s)$ be the undirected Cayley graph on G with generating set L_s. If there exists a tree in $C(G, L_s)$ whose multiset of edge labels is precisely L then it is necessary that L contain at most $n(1-1/([G:H]))$ for any $H < G$. We show that this condition is also sufficient.

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MS24

Transversals and Orthogonal Latin Squares

A transversal of a latin square is a selection of entries that hits each row, column and symbol exactly once. We can construct latin squares whose transversals are constrained in various ways. For orders that are not twice a prime, these constructions yield 2-maxMOLS, that is, pairs of orthogonal latin squares that cannot be extended to a triple of MOLS. If only Euclid's theorem was false, we'd have nearly solved the 2-maxMOLS problem!

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MS25

Connectivity and Forbidden Families for Hamiltonian Properties

We consider a number of new results dealing with hamiltonian properties in 3 or 4-connected claw-free graphs. We are especially interested in the relationship between connectivity and the family of pairs of forbidden subgraphs sufficient to ensure the property of interest. Properties of interest include being Hamiltonian, pancyclic and hamiltonian connected.

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MS25

Square Paths and Cycles

A square cycle (path) is a cycle (path) together with all of its 2-chords. I will survey results on square paths and cycles, and other related substructures.

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MS25

Closures and Forbidden Subgraphs for Paths and Cycles in Graphs

The closure concept for hamiltonicity in claw-free graphs has proved to be a useful tool for studying hamiltonian problems in claw-free graphs. However, its applicability is restricted only to properties P that are stable, i.e. such that G has P if and only if the closure of G has P. A well-known example of an ustable property is Hamilton-connectedness. In the talk we survey recent results on variations of the closure that are applicable to some other cycle and path properties (Hamilton-connectedness, 2-factor). As an application, we show that every 7-connected claw-free graph is Hamilton-connected, we obtain a degree condition for Hamilton-connectedness, we simplify the characterization of forbidden pairs for 2-factors, and we present recent progress in forbidden pairs for Hamilton-connectedness and discuss remaining open cases.

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MS25

Circumference of 3-connected Claw-free Graphs and Large Eulerian Subraphs of 3-edge-connected Graphs

The circumference of a graph is the length of its longest cycles. Results of Jackson, and Jackson and Wormald, imply that the circumference of a 3-connected cubic n-vertex graph is $\Omega(n^{\log_2(1+\sqrt{5})-1})$, and the the circumference of a 3-connected claw-free graph is $\Omega(n^{\log_{150} 2})$. We generalise the first result by showing that every 3-edge-connected graph with m edges has an Eulerian subgraph with $\Omega(m^{\log_2(1+\sqrt{5})-1})$ edges. We use this result together with the Ryjácek closure operation to improve the lower bound on the circumference of a 3-connected claw-free graph to $\Omega(n^{\log_2(1+\sqrt{5})-1})$.

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MS26

Reduced Divisors and Embeddings of Tropical Curves

Given a divisor D on a tropical curve Γ, we show that reduced divisors define an integer affine map from the tropical curve to the complete linear system $|D|$. We consider the cases where this map defines an embedding of the curve into the linear system, and in this way classify all the tropical curves with a very ample canonical divisor. As an application of the reduced-divisor map, we show the existence of Weierstrass points on tropical curves of genus at least two.

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MS26

The 4x4 Minors of a 5xn Matrix are a Tropical Basis

We compute the space of 5 5 matrices of tropical rank at most 3 and show that it coincides with the space of 5 5 matrices of Kapranov rank at most 3, that is, the space of five labeled coplanar points in TP4. We then prove that the Kapranov rank of every 5n matrix equals its tropical rank; equivalently, that the 44 minors of a 5n matrix of variables form a tropical basis. This answers a question asked by Develin, Santos, and Sturmfels. Joint work with Anders Jensen and Elena Rubei.

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MS26

Lifting Tropical Curves

Tropical Geometry is an area of mathematics that associates polyhedral complexes to algebraic varieties by a process called *tropicalization*. The combinatorial properties of the complex reflects the geometry of the variety. Under tropicalization, an algebraic curve becomes a very special graph embedded in space. We give a combinatorial obstruction for a graph to be a tropicalization of a curve. This obstruction is phrased in the language of linear systems on tropical curves.

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MS26

Harmonic Morphisms of Graphs

Harmonic morphisms of graphs are natural discrete analogues of holomorphic maps between Riemann surfaces. We will talk about applications of harmonic morphisms to the analysis of the structure of graph Jacobians. We will also discuss a possible discrete analogue of the correspondence lemma by Castelnuovo and Severi. Based partially on joint work with Matthew Baker and Peter Whalen.

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MS26

Computing Reduced Divisors on Graphs

It is known that, relative to any fixed vertex q of a finite graph, there exists a unique q-reduced divisor in each linear equivalence class of divisors. We give an efficient algorithm for finding such reduced divisors. We also give applications, including a new and completely algebraic algorithm for generating random spanning trees. Other applications include algorithms related to chip-firing games and sandpile model, as well as certain algorithmic problems about the Riemann-Roch theory on graphs.

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MS27

Structure and Enumeration of One-face Maps

A *one-face map*, or *polygon gluing*, is a graph embedded on a topological surface such that its complement is a topological disk. I will describe a bijective decomposition that relates one-face maps on a fixed surface to plane trees with distinguished vertices. In particular, this bijection gives a (long awaited) combinatorial interpretation to the fact that for each orientable surface, one-face maps are enumerated by the product of a polynomial and a Catalan number.

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MS27

$K_{1,1,2}$-linkage for Planar Triangulations

Given graphs G and H, we say G is H*-linked* if for every injective mapping $f : V(H) \to V(G)$ there is a subgraph H' of G that is a subdivision of H, with $f(v)$ being the vertex of H' corresponding to each vertex v of H. Goddard showed that 4-connected planar triangulations are C_4-linked; we strengthen this by showing that they are $K_{1,1,2}$-linked ($K_{1,1,2}$ is K_4 with one edge deleted).

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MS27

On the Structure of Crossing Critical Graphs

A graph G is said to be crossing critical if the removal of any edge of G decreases its crossing number. In the talk we shall discuss the structure of crossing critical graphs.

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MS27

Vertex-face Curves for Bipartite Quadrangulations on the Torus

A *vertex-face* m*-curve* for a map G on a surface S is a set of pairwise disjoint m simple closed curves on S which visit all vertices of G exactly once, all faces of G exactly once, but cross no edges of G. We shall prove that every bipartite quadrangulation on the torus admits a vertex-face 1-curve and a vertex-face 2-curve. Applying them, we can get results on Hamiltonicity and book embedding for torus quadrangulations.

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MS27

Symmetric Maps and Residual Finiteness

Automorphism groups of tessellations of the infinite plane are known to be residually finite, which means that for any non-identity element the group contains a subgroup of finite index avoiding that element. It is also well known that maps on surfaces, and 'highly symmetric' maps in particular, are quotients of such tessellations. Residual finiteness may therefore help in proving results for highly symmetric maps. We briefly outline the corresponding theory and present illustration examples.

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MS28

Limiting the Rate of Locally Testable Codes

Motivated by the question of whether an asymptotically good family of locally testable codes (LTCs) exists, we show three results that have a common theme. They all give subconstant upper bounds on the rate of certain families of LTCs, showing these families are not asymptotically good. Based on joint works with Venkatesan Guruswami, Tali Kaufman, Madhu Sudan and Michael Viderman.

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MS28

Succinct Representation of Codes with Applications to Testing

Motivated by questions in property testing, we search for linear error-correcting codes that have the "single local orbit' property: i.e., they are specified by a single local constraint and its translations under the symmetry group of the code. We show that the dual of every "sparse' binary code whose coordinates are indexed by elements of F_{2^n} for prime n, and whose symmetry group includes the nonsingular affine transformations of F_{2^n}, has the single local orbit property.

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MS28

Error-free List Decoding Algorithms with Linear Complexity for Binary Reed-Muller Codes

In contrary to randomized algorithms we consider deterministic list decoding algorithms which being error-free cannot have complexity smaller than linear for any family of codes with constant relative distance, in particular, for Reed-Muller codes of any fixed order. It is well known that such RM codes can be list decoded with linear complexity for the decoding radius not exceeding half of the code distance. For RM codes of first order such radius allowing error-free list decoding with linear complexity can be increased up to the code distance but for general RM codes we can prove it only for the decoding radius not exceeding the Johnson bound. Based on joint works with Ilya Dumer and Cedric Tvernier.

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MS28

Testing and Decoding Sparse Random Linear Codes from High Error

We show that sparse random linear codes are locally testable and locally list-decodable from $(\frac{1}{2}-\epsilon)$-fraction errors, for every constant $\epsilon > 0$. More precisely, we show that any linear code $C \subseteq F_2^n$ which is:

- sparse (i.e., has only poly(n) codewords)
- unbiased (i.e., each nonzero codeword has Hamming weight $\in [1/2 - n^{-\gamma}, 1/2 + n^{-\gamma}]$ for some constant $\gamma > 0$)

can be locally tested and locally list decoded from $(\frac{1}{2}-\epsilon)$-fraction errors using only poly$(1/\epsilon)$ queries to the received word. This generalizes a result of Kaufman and Sudan, who gave a local tester and local (unique) decoder for such codes from some constant fraction of errors. For a particularly prominent family of sparse, unbiased codes, the dual-BCH codes, we show that these local testing and list-decoding algorithms can be implemented in time polylogarithmic in the length of the codeword.

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MS28

The Extended Norm-trace Function Field and Applications

The extended norm-trace function field is a generalization of the Hermitian and norm-trace function fields which are of importance in coding theory. In this talk, we provide explicit bases for certain Riemann-Roch spaces on the extended norm-trace function field. These bases provide explicit generator and parity check matrices for certain algebraic geometry codes on the extended norm-trace function field. This includes certain one-point codes and multipoint codes.

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MS28

Matching Vector Codes

An r-query locally decodable code encodes a message to a codeword, such that every message bit can be recovered with a high probability, by a randomized decoding procedure that reads only r bits, even if the codeword is corrupted in up to delta fraction of locations. Recently a new class of locally decodable codes, based on families of vectors with restricted dot products has been discovered. We refer to those codes as Matching Vector (MV) codes. In this work we develop a new view of matching vector codes and uncover certain similarities between MV codes and classical Reed Muller codes. Our view allows us to obtain a deeper insight into power and limitations of MV codes. (Joint work with Zeev Dvir and Parikshit Gopalan).

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MS29

Online Linear Discrepancy

The linear discrepancy of a poset $\mathbf{P}$ is the least k for which there is a linear extension L of $\mathbf{P}$ such that if x and y are incomparable in $\mathbf{P}$, then $|h_L(x) - h_L(y)| \leq k$, where $h_L(x)$ is the height of x in L. In this paper, we consider linear discrepancy in an online setting and devise an on-

line algorithm that constructs a linear extension L of a poset $\mathbf{P}$ so that $|h_L(x) - h_L(y)| \leq 3k - 1$, when the linear discrepancy of P is k. This inequality is best possible, even for the class of interval orders. Furthermore, if the poset $\mathbf{P}$ is a semiorder, then the inequality is improved to $|h_L(x) - h_L(y)| \leq 2k$. Again, this result is best possible.

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MS29

The Subexponential Upper Bound for On-line Chain Partitioning Problem

Abstract not available at time of publication.

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MS29

On-line Chain Partitions of Orders: Recent Results and Open Problems

Abstract not available at time of publication.

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MS29

First Fit Coloring of Interval Graphs

Kierstead/Trotter's online coloring algorithm uses at most $3k - 2$ colors on k-chromatic interval graphs, best possible. Kierstead showed that first-fit uses at most $40k$ colors on k-chromatic interval graphs. Pemmaraju/Raman/Varadarajan improved this to $10k$. This can be lowered to $8k$. Chrobak/Ślusarek showed that first-fit uses asymptotically $4.45k$ colors on some k-chromatic interval graphs. We raise this to $5k$.

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MS29

The Total Linear Discrepancy of a Poset

In this talk we discuss the *total linear discrepancy* of a poset. If L is a linear extension of a poset P, and x, y is an incomparable pair in P, the height difference between x and y in L is $|L(x) - L(y)|$. The total linear discrepancy of P in L is the sum over all incomparable pairs of these height differences. The total linear discrepancy of P is the minimum of this sum taken over all linear extensions L of P. While the decision problem of determining whether the (ordinary) linear discrepancy of a poset is at most k is NP-complete, the total linear discrepancy can be computed in polynomial time. In this talk we characterize those linear extensions that are optimal for total linear discrepancy. The characterization provides an easy way to count the number of optimal linear extensions.

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MS30

Strings, Trees, and RNA Folding

Understanding the folding of RNA sequences into three-dimensional structures is one of the fundamental challenges in molecular biology. In this talk, we focus on understanding how an RNA viral genome can fold into the dodecahedral cage known from experimental data. Using strings and trees as a combinatorial model of RNA folding, we give mathematical results which yield insight into RNA structure formation and suggest new directions in viral capsid assembly.

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MS30

Averaging Metric Trees

The space of metric phylogenetic trees is a polyhedral complex, and as constructed by Billera, Holmes, and Vogtmann

(2001), also non- positively curved. This additional property ensures a well-defined notion of an average or mean tree for a given set of trees. In this talk, I will describe this mean tree and how to compute it, as well as discuss what it represents and some applications.

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MS30

Computational Problems in Cancer Genome Sequencing

Cancer is a disease driven by somatic mutations that accumulate in the genome during an individuals lifetime. These somatic mutations occupy a continuum of scales ranging from single nucleotide mutations through structural rearrangements that include deletions, insertions, inversions, and translocations of large blocks of DNA sequence. Recent improvements in DNA sequencing technology are enabling the measurement of numerous cancer genomes of diverse types. I will describe solutions to several computational problems that arise in the analysis of cancer genome sequence data. These include: (i) a framework for classifying and comparing structural variants measured using a variety of DNA sequencing technologies; (ii) combinatorial algorithms to find the most parsimonious sequence of rearrangements and duplications that transform a normal genome into a cancer genome; (iii) a technique to identify groups of interacting genes, or pathways, that are mutated at significant frequency in specific cancer types. I will illustrate applications of these approaches to data from The Cancer Genome Atlas.

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MS30

Simultaneous Alignment and Phylogeneic Tree Estimation

Molecular sequences evolve under processes that include substitutions, insertions, and deletions (jointly called "indels"), as well as other mechanisms (e.g., duplications and rearrangements). The inference of the evolutionary history of these sequences has thus been performed in two stages: the first estimates the alignment on the sequences, and the second estimates the tree given that alignment. While such methods seem to work well on relatively small datasets, these two-stage approaches can produce highly incorrect trees and alignments when applied to large datasets, or ones that evolve with many indels. In this talk, I will present a new method, SATe, that my lab has been developing that uses maximum likelihood to estimate the alignment and tree at the same time, and that can be used to analyze datasets with up to 1000 sequences on a desktop in 24 hours. Our study, using both real and simulated data, shows that this method produces much more accurate trees than the current best methods. Joint work with Kevin Liu, Sindhu Raghavan, Serita Nelesen, and Randy Linder.

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MS31

Existence Conditions for a Stable Set Meeting all Maximum Cliques

Rabern recently proved that any graph with $\omega \geq \frac{3}{4}(\Delta+1)$ contains a stable set meeting all maximum cliques. We strengthen this result, proving that such a stable set exists for any graph with $\omega > \frac{2}{3}(\Delta+1)$. The proof of this result uses a newly observed existence condition for independent transversals over sets of unequal size, which we extend to a result on weighted fractional total colourings.

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MS31

Perfect Matchings in Claw-free Cubic Graphs

Lovász and Plummer conjectured that there exists a fixed positive constant c such that every cubic n-vertex graph with no cutedge has at least 2^{cn} perfect matchings. Their conjecture has been verified for bipartite graphs by Voorhoeve and planar graphs by Chudnovsky and Seymour. We prove that every claw-free cubic n-vertex graph with no cutedge has more than $2^{n/12}$ perfect matchings, thus verifying the conjecture for claw-free graphs.

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MS31

Discrepancy in Graphs and Hypergraphs

How uniformly can the edges of a graph or hypergraph be distributed? How much or little can two graphs or hypergraphs be made to overlap when placed on the same set of vertices? I will discuss some substantial extensions of classical results of Erdős and Spencer and of Erdős, Goldberg, Pach and Spencer on the first problem, and some surprising new results on the (closely related) second problem. This is joint work with Béla Bollobás.

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MS31

The Edge-disjoint Paths Problem in Four-edge-connected graphs

Suppose we are given k pairs of vertices of a graph, and want to test whether there exist k vertex-disjoint paths linking the pairs. For fixed k, Robertson and the speaker gave a polynomial-time algorithm to answer this; but the proof of the correctness of the algorithm was complicated, and used the Graph Minors structure theorem. What if we only ask that the paths be pairwise edge-disjoint? One way to solve this is to apply the algorithm for vertex-disjoint paths to the line graph. But it turns out that for four-edge-connected graphs there is also a much easier algorithm, which is explained in this talk.

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MS31

Co-strongly Perfect Clawfree Graphs. Fractional and Integral Version.

Strongly perfect graphs have been studied by several authors (e.g. Berge, Duchet, Ravindra, Wang). This talk deals with a fractional relaxation of strong perfection. Motivated by a wireless networking problem, we consider claw-free graphs that are fractionally strongly perfect in the complement. We obtain a forbidden induced subgraph characterization and display graph-theoretic properties of such graphs. It turns out that the forbidden induced subgraphs that characterize claw-free fractionally co-strongly perfect graphs are precisely the cycle of length 6, all cycles of length at least 8, four particular graphs, and a collection of graphs that are constructed by taking two graphs, each a copy of one of three particular graphs, and joining them by a path of arbitrary length in a certain way. Wang gave a characterization of strongly perfect claw-free graph. As a corollary we obtain a characterization of claw-free graphs whose complements are strongly perfect.

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MS32

Tree Reconstruction and a Waring-type Problem on Partitions

The "line graph" of a graph G is a new graph $L(G)$ whose vertices are the edges of G, with a new edge in $L(G)$ from e to f if e and f were incident in G. Graham's Tree Reconstruction Conjecture says that, if T is a tree (a connected, acyclic graph), then the sequence of sizes of the iterated line graphs of T uniquely determine T. That is, T can be reconstructed from $\{|L^{(j)}(G)|\}_{j=0}^{\infty}$, where $L^{(0)}(G) = G$ and $L^{(j+1)}(G) = L(L^{(j)}(G))$. Call two trees equivalent if they yield the same sequence; we call the resulting equivalence classes "Graham classes." Clearly, the conjecture is equivalent to the statement that the number of Graham classes of n-vertex trees is equal to the number of isomorphism classes of such trees, which is known to be about 2.955765^n. We show that the number of Graham classes is at least superpolynomial in n (namely, $\exp(c \log n^{3/2})$) by converting the question into the following Waring-type problem on partitions. For a partition $\lambda = \{\lambda_1, \ldots, \lambda_k\}$ of the integer n and a degree d polynomial $f \in \mathbf{R}[\mathbf{x}]$, define $f(\lambda) = \sum_{j=1}^{k} f(\lambda_j)$. We show that the range of $f(\lambda)$ over all partitions λ of n grows as $\Omega(n^{d-1})$. The proof employs a well-known family of solutions to the Prouhet-Tarry-Escott problem. Evidence suggests the conjecture that the size of the range is actually $\Theta(n^d)$.

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MS32

The Number of Shi Regions with a Given Separating Wall

For an irreducible crystallographic root system Φ spanning a Euclidean vector space V and a positive integer m, the extended Shi arrangement is the collection of hyperplanes $H_{\alpha,k} = \{x \in V | (x, \alpha) = k\}$ for $\alpha \in \Phi$ and $k = 1, \ldots, m$. This arrangement dissects the dominant chamber into regions. Athanasiadis generalized the Narayana numbers by enumerating the regions which have k walls of the form $H_{\alpha,m}$ which separate them from the origin. In this talk, we discuss the enumeration of these regions which have $H_{\alpha,m}$, for a fixed $\alpha \in \Phi$, as a separating wall when $\Phi = A_{n-1}$. This is joint work with E. Tzanaki and M. Vazirani.

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MS32

Affine K-theoretic Tableaux

Among many other applications, Young tableaux can be used to define Schur functions and to encode the cohomology structure of the Grassmannian variety by way of Pieri and Littlewood-Richardson rules. The study of K-theory of affine Grassmannians led us to discover affine set-valued tableaux. We prove that these tableaux define certain affine Grothendieck polynomials and encode their associated Pieri rules. This extends our earlier work showing that tableaux tied to the type-A affine Weyl group give a natural approach to the quantum cohomology of Grassmannians, (co)homology of affine Grassmannians, Gromov-Witten invariants, and Macdonald polynomials.

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MS32

Reduced Kronecker Coefficients

The *reduced Kronecker coefficients* is a family of positive integers that until recently has been overlooked. In this talk we aim to introduce and present several results on the reduced Kronecker coefficients as well as to illustrate their applicability in the understanding of the Kronecker coefficients (structure coefficients for the internal product of Schur functions). We also show that the reduced Kronecker coefficients are related to the Heisenberg product on symmetric functions as defined by Aguiar, Ferrer and Moreira.

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MS32

Rational Classes of Permutations

A permutation class is a set of permutations closed under the natural combinatorial notion of subpermutation. It is commonly believed that most permutation classes have very complicated, in fact, non-holonomic, generating functions. Yet some permutation classes possess rational generating functions. I will discuss the ongoing problem of characterizing such classes.

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MS33

K-theory of Cominuscule Grassmannians

The K-theoretic Schubert structure constants of a homogeneous space G/P are known to have signs that alternate with codimension by a result of Brion. For Grassmannians of type A, these constants are computed by a generalization of the classical Littlewood-Richardson rule that counts set-valued tableaux. I will report on recent results on the K-theory of Lagrangian and maximal orthogonal Grassmannians, including a Pieri rule (with Vijay Ravikumar) for multiplying an arbitrary Schubert class with a special Schubert class.

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MS33

Towards Generalizing Schubert Calculus in Symplectic Category

We extend some of the ideas from Schubert calculus to the more general setting of Hamiltonian torus actions on compact symplectic manifolds with isolated fixed points. Given a generic component Φ of the moment map, which is a Morse function, we define a canonical class α_p in the equivariant cohomology of the manifold M for each fixed point $p \in M$. When they exist, canonical classes form a natural basis of the equivariant cohomology of M; in particular, when M is a flag variety, these classes are the equivariant Schubert classes. We show that the restriction of a canonical class α_p to a fixed point q can be calculated by a rational function which depends only on the value of the moment map, and the restriction of other canonical classes to points of index exactly two higher. Therefore, the structure constants can be calculated by a similar rational function. Our restriction formula is manifestly positive in many cases, including when M is a flag manifold. We also prove the existence of integral canonical classes in the case that M is a GKM space (after Goresky, Kottwitz and MacPherson) and Φ is index increasing. In this case, our restriction formula specializes to an easily computable rational sum which depends only on the GKM graph. This is joint with Susan Tolman.

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MS33

Wronskians and Schubert Calculus

I will talk about some of the consequences of the Mukhin-Tarasov-Varchenko Theorem (formerly the Shapiro-Shapiro conjecture), which states that if the Wronskian of d polynomials has only real roots, then the vector space spanned by these polynomials has a real basis.

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MS33

A Littlewood-Richardson Rule for K-theory of Orthogonal Grassmannians

We present a Littlewood-Richardson rule for the K-theory of the odd orthogonal Grassmannian $OG(n, 2n + 1)$. We conjectured this rule in previous work; it is now proved by a combination of (i) a Pieri rule due to Buch-Ravikumar, (ii) a result of Feigenbaum-Sergel showing that the Buch-Ravikumar Pieri rule agrees with our conjecture, and (iii) new combinatorial results showing that our conjectural rule gives rise to an associative product.

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MS34

Dependent Randomized Rounding in Matroid Polytopes and Applications

We describe algorithms for randomly rounding a fractional solution in a matroid (base) polytope to an integral one. We consider the pipage rounding technique and also present a new technique, randomized swap rounding. Our main technical results are concentration bounds for functions of random variables arising from these rounding techniques. We prove Chernoff-type concentration bounds for linear functions of random variables arising from both techniques, and also a lower-tail exponential bound for monotone submodular functions of variables arising from randomized swap rounding. The rounding schemes have several applications that we plan to briefly discuss.

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MS34

Submodular Function Minimization and Approximation

In this talk, we will review recent developments in submodular optimization. In particualar, we will focus on combinatorial algorithms for submodular function minimization. We also discuss approximating submodular functions everywhere, which provides a generic method to design approximation algorithms for combinatorial optimization problems with submodular cost functions.

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MS34

Non-monotone Submodular Maximization: Randomized Local Search and

In this talk, we will discuss two results for non-monotone submodular maximization. In one part, we give a randomized local search 0.4-approximation algorithm for non-negative functions. In the second part, we present the PASS (Parametrize As a Structure of the Solution) approximation framework, and give a tight approximation algorithm for maximizing a monotone submodular function minus an additive function.

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MS34

Local Search Algorithms for Submodular Maximization Problems

Submodular-function maximization is a central problem in combinatorial optimization, generalizing many important NP-hard problems including Max Cut in digraphs, graphs and hypergraphs, certain constraint satisfaction problems, maximum-entropy sampling, and maximum facility-location problems. Local search algorithms are among most popular when it comes to practical algorithms. We briefly survey the previous work on the analysis of the performance of such algorithms for various variants of submodular maximization problem. We will also discuss recent results on maximizing a submodular functions under multiple matroid or knapsack constraints. We conclude with the list of open problems.

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MS34

PTAS for Matroid Matching

We consider the classical matroid matching problem, which can be solved optimally for linear matroids [Lovasz '80] but not for general matroids in the oracle model. We present a PTAS for every matroid; the algorithm is a simple local search. More generally, we prove that local search achieves a (k/2+epsilon)-approximation for matroid matching in k-uniform hypergraphs, which is a problem generalizing both k-set packing and intersection of k matroids. In contrast, we show that known linear-programming approaches including the Sherali-Adams hierarchy do not achieve any non-trivial approximation.

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MS35

Bicriticality for Independent Domination and Total Domination

A graph is independent domination bicritical if the removal of any two vertices reduces the independent domination number. Likewise a graph is total domination bicritical if the removal of any two vertices that do not produce an isolated vertex lowers the total domination number. Structural properties and construction techniques for independent domination bicritical and total domination bicritical graphs will be presented.

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MS35

Eternal Domination (Gamma Forever!)

At each time interval, a vertex of G is attacked and a subset of the guards positioned on vertices must move to adjacent vertices so that a guard is on the vertex that was attacked. In eternal domination, the guards must be prepared for an infinite series of attacks. We will discuss some variations and give a characterisation of when m defenders are sufficient to defend G by examining the reduced canonical form of a related game.

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MS35
Saturation Point: A Two Player Game

A k-limited packing P in a graph is a subset of the vertices with the property that the closed neighbourhood of any vertex in the graph contains at most k members of P. This could model, for instance, the wish to limit the number of undesirable facilities in one's backyard. We consider the following two player game based on this concept. The players alternate choosing a vertex in a graph. The only restriction is that at most k vertices can be selected in the closed neighbourhood of any vertex. Some observations from this investigation will be outlined.

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MS35
The Game Domination Number of Graphs

The domination game on a graph G consists of two players, Dominator and Staller, who alternate choosing a vertex from G. If C denotes the set of vertices already chosen, then the next player may choose vertex w if $N[C \cup \{w\}] - N[C]$ is nonempty. Dominator pursues a strategy designed to end the game in the fewest steps while Staller plays in such a way as to prolong the game as much as possible. We consider several invariants that arise from this game and their relationship to ordinary domination.

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MS36
Cellular Automorphisms and Self-Dual Embeddings for the Torus and Klein Bottle

We classify all cellular automorphisms of the torus and Klein bottle, and explain how these automorphisms can be used to construct all self-dual graph-embeddings in these surfaces. Our approach follows that of Archdeacon-Richter (1992) and Archdeacon-Negami (1994).

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MS36
Finding Shortest Non-trivial Cycles in Directed Graphs on Surfaces

Let D be a weighted directed graph cellularly embedded in a surface of genus g. We describe an algorithm to compute a shortest non-contractible and a shortest surface non-separating cycle of D in time $O(\min\{n^2 \log n, \sqrt{g}\, n^{3/2} \log n\})$, where n is the total number of vertices and arcs of D. Previous results only dealt with undirected graphs. Our algorithm uses a divide-and-conquer technique that simplifies the graph while preserving the topological properties of its cycles.

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MS36
Shortest Cut Graph of a Surface with Prescribed Vertex Set

A *cut graph* is a graph embedded on a surface that splits it into a topological disk. Erickson and Whittlesey [SODA 2005] found a very nice greedy algorithm to compute the shortest one-vertex cut graph of a combinatorial surface. This talk will show how their algorithm extends to the computation of a shortest cut graph with given vertex set. Moreover, a simpler proof will be given, revealing that the algorithm actually computes a minimum-weight basis of some matroid.

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MS36
Shortest Non-Crossing Walks in the Plane

Let G be a plane graph with non-negative edge weights, and let k terminal pairs be specified on h face boundaries. We present an algorithm to find k non-crossing walks in G of minimum total length that connect all terminal pairs, if any such walks exist, in $2^{O(h2)} n \log k$ time. The computed walks may overlap but may not cross each other or themselves. Our algorithm generalizes a result of Takahashi, Suzuki, and Nikizeki [Algorithmica, 1996] for the special case $h \leq 2$. We also describe an algorithm for the corresponding geometric problem, where the terminal points lie on the boundary of h polygonal obstacles of total complexity n, again in $2^{O(h2)} n$ time, generalizing an algorithm of Papadopoulou [Int. J. Comput. Geom. Appl. 1999] for the special case $h \leq 2$. In both settings, shortest non-crossing walks can have complexity exponential in h. We also describe algorithms to determine in $O(n)$ time whether the terminal pairs can be connected by *any* non-crossing walks.

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MS36

Title Not Available at Time of Publication

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MS37

On Mixed Ramsey Numbers

For graphs G and H, an edge-coloring of K_n is (G, H)-good if has neither a monochromatic copy of G nor a totally multicolored copy of H. Let $S(n, G, H)$ be the set of number of colors used in some (G, H)-good coloring of K_n. We prove asymptotically tight bound for $maxS(n, G, H)$, $minS(n, G, H)$ for large classes of graphs, and investigate the graphs for which $S(n, G, H)$ is an interval.

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MS37

Typical Structure of Combinatorial Structures

Erdős, Kleitman and Rothschild in 1976 proved that almost all triangle-free graphs are bipartite. This initiated much research on approximating ”typical” member of a complicated set with a simple structure. In this work we study the structure of the largest sum-free subsets of random subset of groups. It is joint work with Morris and Samotij.

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MS37

Giant Components in Random Subgraphs of General Graphs

Erdős and Rényi observed that a curious phase transition in the size of the largest component in a random graph $G(n, p)$: If $pn < 1$, then all components have size $O(\log n)$, while if $pn > 1$ there exists a unique component of size $\Theta(n)$. Similar transitions can be seen to exist in so called (n, d, λ) graphs (Frieze, Krivelevich and Martin), dense graphs (Bollobás et. al) and several other special classes of graphs. Here we consider the story for graphs which are sparser and irregular. In this regime, the answer will depend on our definition of a 'giant component'; but we will show a phase transition for graphs satisfying a mild spectral condition. In particular, we present some results which supersede our earlier results in that they have weaker hypotheses and (in some sense) prove stronger results. Additionally, we construct some examples showing the necessity of our new hypothesis.

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MS37

The Structure of Typical Hypergraphs with Local Constraints

We prove hypergraph versions of the well-known result of Erdos-Kleitman-Rothschild that almost all triangle-free graphs with vertex set [n] are bipartite. Our main tool is the Frankl-Rodl hypergraph regularity lemma.

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MS37

Multipartite Graph Packing

Given two graphs H and G, a perfect H-packing of G is a spanning subgraph of G which consists of vertex disjoint copies of H. The graph packing problem is a generalization of the matching problem and has been widely studied. In this talk we study the minimum degree threshold for G containing a perfect H-packing when G and H are both r-partite graphs for $r \leq 4$. Some results are joint work with Albert Bush and Ryan Martin.

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MS38

The Number of Numerical Semigroups of a Given Genus

A numerical semigroup is a subset of the non-negative integers that contains 0, is closed under addition, and has a finite complement. The size of the complement is called the genus of the semigroup. In this talk I will describe some lower and upper bounds on the number n_g of numerical semigroups of genus g. Starting from a known construction of a tree of all numerical semigroups, we approximate it by simpler generating trees whose nodes are labeled by certain parameters of the semigroups. The succession rules of these trees are then translated into functional equations for the generating functions that enumerate their nodes, which are solved to obtain the bounds.

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MS38

Ribbon Graphs and Twisted Duality

We consider two operations on the edge of an embedded (*i.e.* ribbon) graph: giving a half-twist to the edge and taking the partial dual with respect to the edge. These two operations give rise to an action of ${S_3}^{e(G)}$, the *ribbon group of* G, on G. We show that this ribbon group action gives a complete characterization of duality in that if G is any cellularly embedded graph with medial graph G_m, then the orbit of G under the group action is precisely the set of all graphs with medial graphs isomorphic (as abstract graphs) to G_m. We then show how the ribbon group action leads to a deeper understanding of the properties of, and relationships among, various graph polynomials such as the generalized transition polynomial, an extension of the Penrose polynomial to embedded graphs, and the topological Tutte polynomials of Las Vergnas and also Bollobás and Riordan, as well as various knot and link invariants.

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MS38

Rectangulations and Baxter Permutations

Baxter permutations are a class of permutations described by a simple pattern-avoidance condition, and having a pleasant enumeration formula. A closely related class of pattern-avoiding permutations, dubbed the twisted Baxter permutations, arose (via lattice theory) as a natural basis for a sub Hopf algebra of the Malvenuto-Reutenauer Hopf algebra of permutations. Using generating trees, West verified that the two classes of permutations share the same enumeration. The starting point of this research is the project of finding an intrinsic description of the Hopf algebra of twisted Baxter permutations in terms of a set of combinatorial objects in bijection with Baxter permutations. This was accomplished using the (diagonal) rectangulations studied by Ackerman, Barequet, and Pinter, which are closely related to the twin binary trees of Dulucq and Guibert. In addition to the Hopf-theoretic results, we obtain a combinatorial characterization of the natural lattice structure on rectangulations, analogous to the Tamari lattice of triangulations, and gain some insight into the graph, analogous to the associahedron, whose vertices are rectangulations, and whose edges are given by certain pivot moves. We also find a new explicit bijection between Baxter permutations and twisted Baxter permutations. The main tools include a surjective map from permutations to diagonal rectangulations, as well as combinatorial and lattice-theoretic results on a related family of maps from permutations to triangulations. This is joint work with Shirley Law.

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MS38

Combinatorial and Colorful Proofs of Cyclic Sieving Phenomena

Let S be a set which admits an action of the cyclic group C_n of order n. Let ω_d denote a root of unity of order d in the group of roots of unity. Finally, let $f(q)$ be a polynomial in q. Usually $f(q)$ will be the generating function for some statistic on S. We say that the triple $(S, C_n, f(q))$ exhibits the *cyclic sieving phenomenon (CSP)* if, for every $c \in C_n$, we have

$$f(\omega_d) = \text{the number of element of } S \text{ fixed by } c,$$

where d is the order of c in C_n. This concept was first introduced and studied by Reiner, Stanton and White, in part as a generalization of Stembridge's $q = -1$ phenomenon which is the case $n = 2$. It is quite amazing that plugging a root of unity into a generating function would produce a nonnegative integer, much less that these integers would count something. But it appears that the CSP is quite wide spread and there is a growing literature on the subject. Most proofs that a triple exhibits the CSP use either algebraic manipulations involving roots of unity or representation theory. We will present the first completely combinatorial proof of such a result. We will also discuss colored versions of some known examples of the CSP involving triangulations of a convex polygon.

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MS38

Alternating Permutations and q-Euler Numbers

The Euler number E_n counts the number of alternating permutations on the set [n]. It is well known that its exponential generating function equals Tan z + Sec z. For this reason, E_{2n} and E_{2n+1} are called secant numbers and tangent numbers, respectively. Certain polynomials arising in series expansions for zeros of generalized Rogers-Ramanujan functions provide a q-analog of the tangent numbers, which is part of a wider class of polynomials with similar combinatorial interpretations. In this talk, we will discuss various q-Euler numbers. This is joint work with Tim Huber from the University of Texas-Pan American

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MS39

Learning Submodular Functions

We study learning submodular functions in a distributional setting. A problem instance consists of a distribution and a non-negative, monotone, and submodular over $\{0, 1\}^n$. We are given poly(n) samples from this distribution, along with the values of the function at those sample points. The task is to approximate the value of the function to within a multiplicative factor on points drawn from the distribution, with high probability. We prove several results for this problem.

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MS39

Algorithm for Partitioning Hypergraphs and Submodular Systems

A k-cut of a hypergraph is a set of hyperedges whose removal divides the hypergraph into k connected components. The hypergraph k-cut problem is one of computing a minimum capacity k-cut. The submodular system k-partition problem is a problem of partitioning a given finite set V into k non-empty subsets $V_1, V_2, \ldots, V_k$ so that $f(V_1) + f(V_2) + \cdots + f(V_k)$ is minimized where f is a nonnegative submodular function on V. In this talk, we review recent progress on algorithms for these problems.

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MS39

Submodularity in Combinatorial Optimization and Mechanism Design

Submodularity is a central phenomenon in many real-world world applications related to auctions and combinatorial optimization since it captures the economies of scale and the diminishing returns property. In this talk, I will first describe our results on the approximability of various covering problems under submodular cost functions, and then I will present our results on a submodular mechanism design problem that has applications in TV ad auctions.

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MS39

Matroids from Lossless Expander Graphs

A set function is partially defined by specifying some sets to take a very large value and some other sets to take a very small value. Can we choose values for the remaining sets so that the resulting function is non-negative and submodular? We show that this is possible if the specified sets are chosen using a lossless expander graph. There are several applications of this construction.

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MS39

Submodular Optimization Based on Combinatorial Convex Structures

It is known that a set function defined on the power set of a finite set is submodular if and only if the so-called Lovasz extension of that function is convex. In this talk, we consider constrained submodular minimization and maximization problems, and design approximation algorithms or practical heuristics based on the discrete convexity of the submodular function.

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MS40

Analyzing Social Networks of Zebras, Humans, and other Animals

Interactions among individuals are often modeled as social networks, individuals being nodes and interactions becoming edges. The traditional model is static; it aggregates interactions over time and discards all information about the timing and ordering of interactions. We have extended computational methods for social network analysis to explicitly address the dynamic nature of interactions among individuals. We will present our approach and demonstrate its applicability by analyzing social behavior of animals and its ecological implications.

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MS40

Robotics-Inspired and Dimension Reduction Methods for the Analysis of Protein Flexibility and Function

Proteins are involved either directly or indirectly in all biological processes in living organisms. It is now widely accepted that modeling protein flexibility is key to understanding protein function. This talk will present recent computational work on modeling the flexibility of proteins using a robotics-inspired approach. It will also discuss the development of non-linear dimension reduction methods tailored to proteins and the impact they can have in the analysis of protein flexibility.

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MS40

Predicting Evolutionary Trajectories in Principle and Practice

The discrete nature of DNA defines a large, albeit enumerable number of mutational trajectories between any two sequence variants. This raises the question of whether or not all such trajectories between given endpoints are also interchangeable in the eyes of natural selection. We demonstrate that for the evolution of an enzyme conferring heightened bacterial resistance to a widely used antibiotic, the answer is no: only a very small fraction of these many mutational trajectories are selectively accessible. We conclude by showing that a principled consideration of protein biology and biochemistry implies that such evolutionary constraints on enzyme evolution may be widespread.

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MS40
Models for Teardrop Spots in 2-DE Gels

Spot detection and spot matching are essential first steps for proteomics investigations based on two-dimensional gel electrophoresis (2-DE). Many 2-DE gels exhibit teardrop spots that cannot be modeled by current analysis software packages as those assume a Gaussian spot model. We investigated different spot models for these teardrop spots and developed a parametric algorithm that uses a variety of different models for spot intensity distribution.

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MS40
Fast Hash-Based Algorithms for Analyzing Tens of Thousands of Evolutionary Trees

Evolutionary trees represent the genealogical relationships among a collection of organisms. Evolutionary trees have been used to improve global agriculture and understand disease transmission. Current techniques to reconstruct the evolutionary tree for a group of organisms can produce tens of thousands of candidate trees. We present a family of fast hash-based algorithms to quickly store and retrieve the genealogical relationships among large collections of evolutionary trees. Extensive experimental results show the effectiveness of our algorithms.

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MS41
Graphs without Subdivisions

Graphs without a subdivision of a big graph do not behave as well as those without a minor of a big graph. This is partially because we do not really know what the graphs without a subdivision of a big graph look like. We shall discuss this issue. In particular, assuming some moderate connectivity, we can say something, which will be presented in this talk.

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MS41
Algorithmic Metatheorems for Classes of Sparse Graphs

Building on structural results for classes of sparse graphs, we design a linear time algorithm for deciding first-order logic (FOL) properties in classes of graphs with bounded expansion, which include proper minor-closed classes of graphs, and an almost linear time algorithm for deciding FOL properties in classes of graphs with locally bounded expansion, which include classes of graphs with locally bounded tree-width or locally excluding a minor. Our results also translate to corresponding classes of relational structures.

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MS41
Packing Minors Half-integrally

Given graphs G and H, a *k-half integral packing of H-minors in G* is a collection of subgraphs $G_1, G_2, \ldots, G_k$ of G such that each vertex of G belongs to at most two of them, and each G_i contains H as a minor. We prove a conjecture of Thomas, showing that the Erdős-Pósa property holds for half-integral packing of H-minors. That is, for every graph H there exists a function $f_H(k)$ such that every graph G either contains a half-integral packing of H minors or a set X of at most $f_H(k)$ vertices such that $G-X$ has no H minor.

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MS41
Open Questions on Well-quasi-orders

A well-quasi-order is a reflexive and transitive relation where all descending chains and anti-chains are finite. There have been extensive advances in well-quasi-order theory for graphs and matroids over the past thirty years. Still, the area has many interesting concrete open problems and the natural progression toward testing the observation of Crispin Nash-Willliams that all natural well-quasi-orders are better-quasi-orders has only a few highlights, in works of Igor Kriz and Robin Thomas, now nearly 20 years old. This short lecture will describe what seem to me to be the central questions and describe work by two of my former students, respectively, Yared Nigussie and Christian Altomare, toward transforming WQO into BQO, and formulating a conjecture including Richard Laver's theorem about scattered total orders and the graph minor WQO theorem.

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MS41
Toroidal Triangulations with few Odd-degree Vertices, Structure and Coloring

The only known families of orientable triangulations with unbounded facewidth which are not 4-vertex colorable, have exactly two odd vertices and an edge joining them. They are possible counterexamples to Grünbaum conjecture: any simple triangulation of an orientable surface can be 3-edge-colored such that three colors appear in the boundary of each face. The conjecture was disproved for surfaces of genus 5 and higher. We will classify all triangulations of the torus with exactly two odd vertices and show the existence of Grünbaum coloring for each class.

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MS42
Characterizations of Finite Geometries as Extremal Graphs

It is a classical problem in extremal graph theory to look for those graphs that maximize the number of copies of a subgraph H and are F-free; the Turan problem being the most well known example of such problem. In this talk I will discuss how the incidence graphs of some of the most important finite geometries, the so-called generalized polygons, arise as extremal graphs in the above sense. After an overview of some of the older results, I will address more recent results on characterizations of generalized triangles, i.e. projective planes. I will also show how these characterizations lead to some very interesting and intriguing geometric questions.

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MS42
Computing the Edit Distance Function

We will describe the so-called edit distance function, a function of a hereditary property $\mathcal{H}$ and of p, which measures the maximum proportion of edges in a density-p graph that need to be inserted/deleted in order to transform it into a member of $\mathcal{H}$. We will describe a technique for computing this function and apply it to several hereditary properties $\mathcal{H}$, including those with no induced cycle of length ℓ, for $\ell \leq 9$.

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MS42
Extremal Multigraphs for Edge-colouring

For a multigraph G, the chromatic index χ' of G is the minimum number of colours needed to colour the edges of G such that no two edges sharing a vertex have the same colour. There are many well-known upper bounds for χ', including bounds by Shannon, Vizing, Goldberg and Steffen. In this talk we explore the question of which multigraphs actually achieve these bounds. As part of the discussion we present a new partial characterization of those multigraphs achieving Vizing's upper bound, a result obtained jointly with P. Haxell.

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MS42
An Extremal Problem for a Constant Number of 1-factors

A simple result of Hetyei states that an n-vertex graph with a unique 1-factor has at most $n^2/4$ edges. We extend this result to when the graph has a small fixed constant number of 1-factors.

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MS43
Crystal Graphs and Dual Equivalence Graphs

In this talk, we present connections between crystal graphs for classical groups and dual equivalence graphs for the corresponding Weyl groups using tableaux combinatorics and local characterizations of the graphs.

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MS43
Masks for Kazhdan–Lusztig Polynomials

The Iwahori–Hecke algebra is a deformation of the group algebra of a Coxeter group. In 1979, Kazhdan and Lusztig constructed a basis for this algebra that has found fascinating applications in geometry and representation theory. Unfortunately, the Kazhdan–Lusztig polynomials used to define this basis are given recursively, and no simple manifestly positive description is known for them, even in the symmetric group case. In this talk, we describe a framework developed by Deodhar that gives formulas for Kazhdan–Lusztig bases in terms of combinatorial objects called masks. We explain how to interpret a formula of Lascoux and Schützenberger for Kazhdan–Lusztig polynomials associated to co-Grassmannian permutations in terms of masks. This is joint work with Alex Woo.

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MS43
Loop Groups, R-matrices, and a Birational Action of the Symmetric Group

I will talk about a birational action of the symmetric group on a polynomial ring, and in particular the invariants of this action. We encountered this action studying total positivity in loop groups, but the action also occurs as an R-matrix in Berenstein-Kazhdan's theory of geometric crystals, and also in the theory of discrete Painleve dynamical systems as studied by Noumi-Yamada. This is joint work with Pavlo Pylyavskyy.

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MS43
From Macdonald Polynomials to a Charge Statistic in Classical Types

The charge is an intricate statistic on words, due to Lascoux and Schützenberger, which gives positive combinatorial formulas for Lusztigs q-analogue of weight multiplicities and the energy function on affine crystals, both of type A. It has been a long-standing problem to generalize charge to all classical types. I present a method to address this problem based on the recent Ram-Yip formula for Macdonald polynomials and the quantum Bruhat order on the corresponding Weyl group.

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MS43
Universal Characters for Spinor Representations

We introduce a family of symmetric functions with coefficients in the ring of integers adjoining a new element e with the property $e^2 = 1$, and investigate their properties. These symmetric functions can be used to describe the structure of the representation ring involving spinor representations of the Pin groups.

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MS44
List Colorings of K_5-minor-free Graphs with Special List Assignments

A *list assignment* L of G is a function that assigns to every vertex v of G a set (list) $L(v)$ of colors. The graph G is called *L-list colorable* if there is a coloring φ of the vertices of G such that $\varphi(v) \in L(v)$ for all $v \in V(G)$ and $\varphi(v) \neq \varphi(w)$ for all $vw \in E(G)$. Joan Hutchinson mentioned the following question asked by Bruce Richter, where $d(v)$ denotes the degree of v in G: Let G be a planar, 3-connected graph that is not a complete graph. Is G L-list colorable for every list assignment L with $|L(v)| = \min\{d(v), 6\}$ for all $v \in V$? More generally, we ask for which pairs (r, k) the following question is answered in the affirmative. Let r and k be integers and let G be a K_5-minor-free r-connected graph that is not a Gallai tree. Is G L-list colorable for every list assignment L with $|L(v)| = \min\{d(v), k\}$? Recall that a *Gallai tree* is a graph G such that every block of G is either a complete graph or an odd cycle. We investigate this question by considering the components of $G[S_k]$, where $S_k := \{v \in V(G) \mid d(v) < k\}$ is the set of vertices with small degree in G. We are especially interested in the minimum distance $d(S_k)$ in G between the components of $G[S_k]$.

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MS44
Choosing a Central Location for Multiple Deliveries

A delivery person must leave the central location of the business, deliver packages at a number of addresses, and then return. Naturally, he/she wishes to reduce costs by finding the most efficient route. This motivated the definition of $(k-1)$-stop-return distance by Gadzinski, Sanders, and Xiong, which has since become k-circuit distance. Given a set of k distinct vertices $\mathcal{S} = \{x_1, x_2, \ldots, x_k\}$ in a simple graph G, the k-circuit-distance of set $\mathcal{S}$ is defined to be

$$d_k(\mathcal{S}) = \min_{\theta \in \mathcal{P}(\mathcal{S})} \Big(d(\theta(x_1), \theta(x_2)) + d(\theta(x_2), \theta(x_3)) + \ldots + d(\theta(x_k), \theta(x_1)) \Big),$$

where $\mathcal{P}(\mathcal{S})$ is the set of all permutations from $\mathcal{S}$ onto $\mathcal{S}$. In other words, $d_k(x_1, \ldots, x_k)$ is the length of the shortest circuit through the vertices $\{x_1, \ldots, x_k\}$. The 2-circuit distance is twice the standard distance between two vertices. We present results about the k-circuit radius, k-circuit diameter, k-circuit center and k-circuit periphery, with particular attention to the case $k = 3$. We also note some relationships between k-circuit distance and Steiner distance. Recall that the Steiner distance of a set of vertices is the minimum number of edges in a connected subgraph containing those vertices.

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MS44
Triangular Line Graphs: Tools for Word Ambiguity Detection in Automated Search

One of the chief concerns of linguists is the pervasive ambiguity of natural language. At the lexical level, this manifests in the existence of the multiplicity of senses that a word may have. A natural representation for word relationships is an undirected graph $G = (V, E)$, were V is the vocabulary and vertices are adjacent in G if and only if the words they represent co-occur in a relevant pattern in the text. Ideally, the words in the same semantic field give rise to the vertices of a component of the graph. However, when words that have multiple senses are part of the graph, the distinct semantic fields will not be given by the components of G. In response, Dorow *et al.* provided a tool

that transforms a graph showing word relationships into a new graph for which, generally, each individual component contains only one meaning of the polysemous words. They introduced the *link graph* of a graph whose construction is similar to the construction of line graphs. The link graph is identical to the triangular line graph, a special case of the H-line graph introduced by Chartrand *et al*: the triangular line graph of G, denoted by $T(G)$, is the graph with vertex set $E(G)$, with two distinct vertices v_e and v_f adjacent in $T(G)$ if and only if there exists a subgraph $H \cong K_3$ of G with $e, f \in E(H)$. The properties of the T transformation have been studied by Jarrett for K_n and Dorrough for arbitrary G, with emphasis on stabilization of iterations of $T(Kn)$ and $T(G)$, respectively. This presentation summarizes the main known results, and examines how the structural properties of triangular line graphs can aid predictions of the curvature metric on the triangular line graph, thereby helping to identify polysemous words.

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MS44
Generalization of the Friendship Theorem

The Friendship Theorem states that if any two people in a party have exactly one common friend, then there exists a politician who is a friend of everybody. In this paper, we prove the following generalization of the Friendship Theorem. If every pair of strangers in a party has exactly one common friend, then either 1) there exists a politician who is a friend of everybody; or 2) everyone has exactly the same number of friends and every pair of friends has exactly the same number of common friends; or 3) there exist two fixed numbers d and r such that each person has either d friends or r friends. (The corresponding graphs for Cases 2 and 3 are strongly regular graphs and bi-regular graphs, respectively.)

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MS44
Domination in Functigraphs

Let G_1 and G_2 be copies of a graph G, and let $f : V(G_1) \rightarrow V(G_2)$ be a function. Then a *functigraph* $C(G, f) = (V, E)$ is a generalization of a permutation graph, where $V = V(G_1) \cup V(G_2)$ and $E = E(G_1) \cup E(G_2) \cup \{uv : u \in V(G_1), v \in V(G_2), v = f(u)\}$. We study domination in functigraphs.

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