Programme and Abstracts

The 35th Australasian Conference on Combinatorial Mathematics and Combinatorial Computing

Monash University, Australia
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CMSA (Inc.)

Sponsored by:

School of Mathematical Sciences, Monash University
Clayton School of Information Technology, Monash University
Combinatorial Mathematical Society of Australasia (CMSA)
The Institute of Combinatorics and its Applications (ICA)

Monday

9:00	**Cheryl Praeger** *Symmetry of codes in graphs* (p10) Chair: McKay	
10:00	Catherine Greenhill *Making Markov chains less lazy* (p23) Chair: McKay	Kazuhiko Ushio *Balanced (C_5, C_{20})-foil designs and related designs* (p46) Chair: Zhang
10:25	Morning Tea	
10:50	Sanming Zhou *$L(2,1)$-labellings of outerplanar graphs with maximum degree three* (p48) Chair: Praeger	Judy-anne Osborn *On small-order Hadamard matrices from the Williamson and octonion constructions* (p37) Chair: Rao
11:15	Bin Jia *A construction of imprimitive symmetric graphs which are not multicovers of their quotients* (p27) Chair: Praeger	Padraig Ó Catháin *Classification of cocyclic Hadamard matrices* (p36) Chair: Rao
11:40	Hamid Mokhtar *A review of approaches toward routing and wavelength assignment problem in telecommunication* (p34) Chair: Praeger	Paul Leopardi *Constructions for Hadamard matrices, Clifford algebras, and their relation to amicability - anti-amicability graphs* (p30) Chair: Rao
12:05	Hideaki Suto *Independent spanning trees of star graphs* (p45) Chair: Praeger	Yuqing Chen *Constructions of abelian and non-abelian Paley type group schemes* (p17) Chair: Rao
12:30	Lunch	
2:00	**Brendan McKay** *Practical graph isomorphism II* (p9) Chair: Östergård	
3:00	Guillermo Pineda-Villavicencio *Characterisations of graphs of small defects and some of its applications* (p39) Chair: Östergård	Zoe Bukovac *Certificates for properties of chromatic polynomials of graphs* (p16) Chair: Osborn
3:25	Afternoon Tea	
3:50	Uwe Schwerdtfeger *Kernel method and Brownian motion areas* (p41) Chair: Garoni	Sarada Herke *Perfect 1-factorisations of circulant graphs* (p24) Chair: Combe
4:15	Clemens Heuberger *The number of maximum matchings in a tree* (p25) Chair: Garoni	Tatsuya Maruta *On optimal ternary linear codes* (p31) Chair: Combe
4:40	Michael Haythorpe *Genetic theory of cubic graphs* (p24) Chair: Garoni	Fatih Demirkale *Enumeration of orthogonal arrays* (p20) Chair: Combe
5:05	Jerzy Filar *A polynomial complexity "snakes and ladders heuristic" for the Hamiltonian cycle problem* (p21) Chair: Garoni	William Pettersson *Cycle decomposition problem for complete graphs* (p38) Chair: Combe
5:30	CMSA AGM	

Tuesday

9:00	**Elizabeth J. Billington** *Metamorphoses of graph designs* (p7) Chair: Webb	
10:00	Marcel Jackson *The reduction of CSP dichotomy to digraphs.* (p26) Chair: Filar	Michael Brand *Tightening the bounds on the baron's omni-sequence* (p15) Chair: Farr
10:25	Morning Tea	
10:50	Daniel Harvey *On Hadwiger's Conjecture for circular arc graphs* (p23) Chair: Barát	Frank Bennett *Schröder quasigroups with a specified number of idempotents* (p14) Chair: Cavenagh
11:15	Guangjun Xu *Hamiltonicity and Hamilton-connectedness of 3-arc graphs* (p47) Chair: Barát	Diana Combe *Our difficulties in finding designs over a group of order 36* (p18) Chair: Cavenagh
11:40	**Keith Edwards** *Graph detachments* (p8) Chair: Barát	
12:40	Lunch	
2:00	**Bridget Webb** *Infinite designs: the interplay between results in the finite and infinite case* (p11) Chair: Alspach	
3:00	Xiande Zhang *The α-arboricity of complete uniform hypergraphs* (p48) Chair: Greenhill	Jamie Simpson *Intersecting rational Beatty sequences* (p43) Chair: Osborn
3:25	Afternoon Tea	
3:50	Daria Schymura *Probabilistic matching of solid shapes in arbitrary dimension* (p42) Chair: Wood	Gordon Royle *Minimum degree, graph minors and binary matroids* (p40) Chair: Whittle
4:15	Michael S. Payne *Finding k-angulations on point sets* (p38) Chair: Wood	Dillon Mayhew *Superfluous excluded minors* (p32) Chair: Whittle
4:40	Raiji Mukae *Converting quadrangulations into even triangulations* (p35) Chair: Wood	Michael Snook *The problem with counting bases* (p44) Chair: Whittle
5:05	Naoki Matsumoto *The number of diagonal transformations in quadrangulations on the sphere* (p32) Chair: Wood	Nick Brettell *Removing elements relative to a minor and a fixed basis* (p15) Chair: Whittle
5:30	Benjamin Burton *Challenges of combinatorial enumeration in low-dimensional topology* (p17) Chair: Wood	Ben Clark *$\{U_{2,5}, U_{3,5}\}$-fragile matroids* (p18) Chair: Whittle
7:00	Penguin excursion	

Wednesday

9:00	**Petr Vojtěchovský** *Computational aspects of loop theory* (p11) Chair: Wanless	
10:00	Nina S. Schmuck *Greedy trees, caterpillars, and Wiener-type graph invariants* (p41) Chair: Giudici	Barbara Maenhaut *Almost regular edge colourings of complete bipartite graphs* (p30) Chair: Billington
10:25	Morning Tea	
10:50	**Nick Cavenagh** *A comparative study of defining sets in designs* (p8) Chair: Billington	
12:00	Excursion	

Thursday

9:00	**Anthony B. Evans** *A class of orthogonal latin square graphs* (p9) Chair: Stones	
10:00	Charles Little *A characterization of PM-compact bipartite and near-bipartite graphs* (p30) Chair: McLeod	David Fear *Cyclotomic orthomorphisms* (p21) Chair: Evans
10:25	Morning Tea	
10:50	Ivan Lazar Miljenovic *Generating d-angulations of girth d* (p33) Chair: Edwards	Günter Steinke *Homotheties in Minkowski planes* (p44) Chair: Zhou
11:15	Mohammadreza Jooyandeh *Generation of planar graphs based on their faces* (p27) Chair: Edwards	John Bamberg *Low dimensional models of the split Cayley hexagon* (p13) Chair: Zhou
11:40	**Peter J. Cameron** *Combinatorial properties of transformation monoids* (p7) Chair: Edwards	
12:40	Lunch	
2:00	**David Wood** *On the graph minor structure theorem* (p12) Chair: Barát	
3:00	Amy Glen *On a generalisation of trapezoidal words* (p22) Chair: Wanless	Johann A. Makowsky *On the complexity of graph polynomials* (p31) Chair: Barát
3:25	Afternoon Tea	
3:50	Kosuke Shinkai *Better approximate algorithm for $(r \times s)$-puzzle* (p43) Chair: Farr	Alessandro Conflitti *Chains and antichains in the Bruhat order for a class of binary matrices* (p19) Chair: Vojtěchovský
4:15	Bao Ho *Two variants of Wythoff's game preserving its P-positions* (p26) Chair: Farr	Thomas Kalinowski *Maximal antichains in the Boolean lattice* (p28) Chair: Vojtěchovský
4:40	Marcin Krzywkowski *The hat problem on a directed graph* (p29) Chair: Farr	Mitchel T. Keller *Linear extension diameter and reversal ratio* (p28) Chair: Vojtěchovský
5:05	Marsha Minchenko *Some vertex transitive integral graphs* (p34) Chair: Farr	Abdullahi Umar *Some combinatorial results for the semigroup of order-decreasing partial isometries of a finite chain* (p46) Chair: Vojtěchovský
6:00	Conference Banquet	

Friday

9:00	**Patric R. J. Östergård** *A dynamic programming approach to counting Hamiltonian cycles in bipartite graphs* (p10) Chair: McKay	
10:00	Atsuhiro Nakamoto *Polychromatic 4-coloring of cubic bipartite plane graphs* (p35) Chair: McKay	János Barát *Greedy dismantling of an atomic cube* (p14) Chair: Wood
10:25	Morning Tea	
10:50	Marston Conder *The smallest regular polytopes of each rank* (p19) Chair: Horsley	Thomas Britz *On vector matroid chains* (p16) Chair: Royle
11:15	Brian Alspach *Paley graphs are Hamilton-decomposable* (p13) Chair: Horsley	Geoff Whittle *Random real-representable matroids* (p47) Chair: Royle
11:40	Donald L. Kreher $2(n+1)$ *regular connected Cayley graphs on rank n elementary abelian groups are Hamilton decomposable* (p29) Chair: Horsley	Carolyn Chun *Towards a splitter theorem for internally 4-connected binary matroids* (p18) Chair: Royle
12:05	Tomaž Pisanski *Classifying vertex-transitive graphs according to their arc-types* (p39) Chair: Horsley	Mike Newman *Axiomatic descriptions of real-representable matroids* (p36) Chair: Royle
12:30	Lunch	
1:30	Michael Giudici *Generalised quadrangles with a group acting primitively on points and lines* (p22) Chair: Cameron	Daniel Horsley *Compressed sensing and hash families* (p25) Chair: Bryant
1:55	Shoetsu Ogata *Normality of lattice polytopes* (p37) Chair: Cameron	Akito Oshima *Enlarging the classes of edge-magic 2-regular graphs* (p38) Chair: Bryant
2:20	Ludmila Scharf *On inducing polygons and related problems* (p40) Chair: Cameron	Douglas S. Stones *NetMODE: Network motif detection without Nauty* (p45) Chair: Bryant
2:45	Kerri Morgan *Some algebraic properties of chromatic polynomials of theta graphs* (p35) Chair: Cameron	Jeanette McLeod *Graph connectivity in the streaming model* (p33) Chair: Bryant
3:10	Graham Farr *Algebraic properties of chromatic polynomials* (p20) Chair: Cameron	P. Selvaraju *On cordial labeling: quadrilateral snake related silo and chaplet graphs* (p42) Chair: Bryant
3:35	Ian Wanless *The number of subsquares in a Latin square* (p47) Chair: Cameron	
4:00	Survivor's party	

Abstracts of invited talks

Metamorphoses of graph designs

Elizabeth J. Billington

University of Queensland

A lambda-fold graph design, or G-design of order n, is an edge-disjoint decomposition of a λ-fold complete graph, λK_n, into isomorphic copies of some graph G. (Here λK_n denotes the graph on n vertices with precisely λ edges between every pair of vertices.) Let H be a subgraph of G. A metamorphosis of a G-design into an H-design is obtained when the following is possible.

Suppose there are b copies of G (called blocks) in the G-design, say G_i, $1 \leqslant i \leqslant b$. For each block G_i, we retain its subgraph H_i, isomorphic to H, and we rearrange all the "discarded" edges, $\{E(G_i \setminus H_i) \mid 1 \leqslant i \leqslant b\}$, into further copies of the graph H. The result is a lambda-fold H-design of order n, obtained by metamorphosis of the G-design.

Metamorphoses of graph designs were first considered late in the last century. This talk will present a survey of results in this area, some open problems and new directions.
(Tuesday 9:00)

Combinatorial properties of transformation monoids

Peter J. Cameron

Queen Mary, University of London

The field of permutation groups has had close links with combinatorics for nearly a century, and includes the work of Witt on Steiner systems and the Mathieu groups, Sims on graphs and permutation groups, Higman on coherent configurations, and many other topics. By contrast, the study of transformation monoids is not well developed, and potential links with combinatorics await study.

A transformation monoid is *synchronizing* if it contains a transformation whose image has cardinality 1. Study of synchronizing monoids was initiated by the celebrated Černý conjecture, more than forty years old and still open. It is conjectured that the probability that two random transformations on n points generate a synchronizing monoid tends to 1 as $n \to \infty$. This would be an analogue of Dixon's theorem, asserting that the probability that two random permutations generate the symmetric or alternating group tends to 1. As in Dixon's theorem, the proof strategy would involve describing the maximal non-synchronizing monoids (this has been done, in terms of graphs), and then doing inclusion-exclusion (this step has not been done yet).

By abuse of language, a permutation group G is said to be *synchronizing* if the monoid $\langle G, f\rangle$ is synchronizing for any non-bijective transformation f. This condition on permutation groups implies primitivity but is strictly stronger; testing it for a specific permutation group

G involves an analysis of G-invariant graphs, and for many important families of groups leads to deep problems in extremal combinatorics and finite geometry.

Finally, we can examine regularity properties of transformation monoids, concerning pseudo-inverses of elements. (Thursday 11:40)

A comparative study of defining sets in designs

Nick Cavenagh

University of Waikato

A *defining set* for a design is a subset of the design which determines it uniquely. We examine what is known about the defining sets of two quite different designs: Latin squares and $(0,1)$-matrices. Intriguingly, while these designs may superficially seem quite different, empirical evidence suggests that in certain cases they have the same minimum defining set size: exactly one quarter of the total size of the design. We call this ratio the *surety* of a type of design; thus Latin squares are conjectured to have a surety of 1/4. We show that a $2m \times 2m$ $(0,1)$-matrix with constant row and columns sum m has surety equal to 1/4 and explain why a problem which appears difficult to solve for Latin squares becomes tractable for $(0,1)$-matrices. We also briefly explore the notion of surety and its generalizations as comparative tools for analysing designs. (Wednesday 10:50)

Graph detachments

Keith Edwards

University of Dundee

A detachment of a graph is obtained from it by splitting some or all of its vertices into two or more subvertices, so that the edges incident with an original vertex are shared out arbitrarily among its subvertices.

This notion goes right back to the beginnings of graph theory; an eulerian trail in a graph can be regarded as a detachment of the graph into a cycle or a path. In this case Euler found simple necessary and sufficient conditions for the existence of such a detachment.

This talk will consider the extent to which similar necessary and sufficient conditions can be found in other more general cases, and consider the complexity of the problem. I will also briefly discuss the case of directed graphs. (Tuesday 11:40)

A class of orthogonal latin square graphs

Anthony B. Evans

Wright State University

An orthogonal latin square graph is a graph whose vertices are latin squares of the same order, adjacency being synonymous with orthogonality. We are interested in orthogonal latin square graphs in which each square is orthogonal to the Cayley table M of a group G and is obtained from M by permuting columns. These permutations, regarded as permutations of G, are orthomorphisms of G and the graphs so obtained are orthomorphism graphs. We will discuss results and problems in the study of orthomorphism graphs. (Thursday 9:00)

Practical graph isomorphism II

Brendan McKay

Australian National University

This talk is a continuation of one given at the Tenth Manitoba Conference on Numerical Mathematics and Computing in 1980.

We are concerned with the practical aspects of computing the automorphism groups of graphs, and determining canonical labellings of graphs. The speaker's program `nauty` has been around since 1976, though it wasn't called that until about 1983. Until a few years ago, there wasn't very much competition, but then came `saucy`, `bliss`, `conauto`, and some other programs that could outperform `nauty` in many cases.

Our aim in the talk is to describe our response to the challenge. In particular, `nauty` is now bundled with a highly innovative program called `Traces` first developed by Adolfo Piperno. We contend that the present edition of `Traces` is now the performance champion.
(Monday 2:00)

A dynamic programming approach to counting Hamiltonian cycles in bipartite graphs

Patric R. J. Östergård

Aalto University

The Hamiltonian cycles in a bipartite graph $\Gamma = (V, E)$ can be obtained by exhaustively building up subpaths of the cycles. Consider a partition of V into (independent) sets V_i with the property that every edge in E has its endpoints in consecutive sets V_k and V_{k+1} for some $k \geqslant 0$. Subpaths of Hamiltonian cycles are here obtained by iteratively considering the subgraphs induced by $\cup_{i=0}^{j} V_i$ for $j = 0, 1, \ldots$. When counting the number of Hamiltonian cycles, the internal structure of subpaths is irrelevant; solutions may then be grouped and the algorithm can proceed in a dynamic programming manner. The automorphism group of the graph may also be utilized for further speed-up. The developed algorithm is applied to several types of graphs including the n-cube (Q_n), emphasizing the celebrated open case of Q_6.

This is joint work with Harri Haanpää. (Friday 9:00)

Symmetry of codes in graphs

Cheryl Praeger

University of Western Australia

In 1973, Philippe Delsarte introduced the notion of a code in a distance regular graph - a vertex subset whose elements are the codewords and with distance between codewords being the natural distance in the graph. He defined a special class of such codes, now called completely regular codes, 'which enjoy combinatorial (and often algebraic) symmetry akin to that observed for perfect codes'. I traded in some of the restrictions of complete regularity for a stronger symmetry condition called neighbour transitive codes. These have recently been studied in the Johnson graphs (by Bob Liebler and me) and the Hamming graphs (by my PhD student Neil Gillespie), leading to new constructions, a body of theory, and some significant open questions. (Monday 9:00)

Computational aspects of loop theory

Petr Vojtěchovský

University of Denver

Loop theory is concerned with the algebraic structure of normalized Latin squares. In this talk I will present several carefully chosen areas of loop theory where the proofs depend substantially on computation (often of combinatorial nature) and where the results should be of interest to the audience.

For instance, we will discuss

- generalizations of Lagrange's theorem from group theory to certain classes of loops, using a greedy algorithm on partial latin squares,
- enumeration of nilpotent loops up to isomorphism, using a rather transparent cohomology,
- existence of simple automorphic loops, using cliques in graphs constructed from subsets of permutations in primitive groups,
- the structure of inner mappings of latin squares, using automated deduction.

All these results were obtained in the last 3 years in joint work with (subsets of) these coauthors: Dan Daly, Přemysl Jedlička, Ken Johnson, Michael Kinyon, Gábor Nagy, Kyle Pula, Bob Veroff. (Wednesday 9:00)

Infinite designs: the interplay between results in the finite and infinite case

Bridget Webb

Open University

In this talk we will look at examples of infinite designs and see that rather than being esoteric they are pretty much ubiquitous. We restrict our attention to designs with both t and λ finite so v=b=r and we may use the usual t-(v,k,λ) notation. We look at how finite design concepts such as Block's Lemma and resolvability apply to infinite designs, before moving to looking at properties such as homogeneity and $\aleph_0$-categoricity which typically arise in the infinite case. We conclude by showing that these properties can depend on interesting problems in finite design theory. (Tuesday 2:00)

On the graph minor structure theorem

David Wood

University of Melbourne

What is the structure of a graph with no H-minor, for some fixed graph H? For example, the graphs with no K_3-minor are precisely the forests. The graphs with no K_4-minor are the so-called series-parallel graphs. Wagner proved that the graphs with no K_5-minor are the planar graphs, a sporadic example V_8, plus the graphs that can be obtained from 3-sums of planar graphs and V_8.

Much more generally, Robertson and Seymour proved an analogous structure theorem for an arbitrary graph H. In particular, they showed that every graph with no H-minor can be constructed by a combination of four ingredients: graphs embedded in a surface of bounded genus, a bounded number of vortices of bounded width, a bounded number of apex vertices, and the clique-sum operation.

This talk will introduce this theorem and related topics. Little graph theoretic background will be assumed. I will conclude with some recent work by Gwenaël Joret and the speaker on the following question: What is the maximum size of a complete graph minor in a graph constructed using the above four ingredients? We give a precise answer to this question.
(Thursday 2:00)

Abstracts of contributed talks

Paley graphs are Hamilton-decomposable

Brian Alspach*, Darryn Bryant and Danny Dyer

University of Newcastle

The Paley graph $P(q)$ of order q, where q is a prime power congruent to 1 modulo 4, has the elements of the finite field of order q for its vertices. Two vertices are adjacent if and only if their difference is a quadratic residue in the field. In this talk I will discuss a proof of the fact that every Paley graph has a Hamilton decomposition. The main feature of the proof is the application of the Edmonds-Fulkerson matroid partition theorem. (Friday 11:15)

Low dimensional models of the split Cayley hexagon

John Bamberg* and Nicola Durante

University of Western Australia

The *split Cayley hexagons* are the natural geometries for the Chevalley groups of type G_2, and the most common model of a split Cayley hexagon is as a subset of the points and lines of six-dimensional projective space. Cameron and Kantor (1979) gave a model of this generalised hexagon, which when after applying the Klein correspondence, has its points and lines as objects that reside naturally in three-dimensional projective space with respect to a fixed anti-flag. In other words, there we can construct $G_2(q)$ from the linear group $\mathsf{L}_3(q)$. We will show how one can produce a twisted version of Cameron and Kantor's model by starting with the unitary group $\mathsf{U}_3(q)$. (Thursday 11:15)

Greedy dismantling of an atomic cube

János Barát* and I. M. Wanless

Monash University

We build an $n \times n \times n$ cube from n^3 unit cubes. Every small cube has six faces. Two such cubes are *neighbours*, if they touch along a face. In each step of the *dismantling* process, we may remove a small cube, which has precisely three neighbours. The n^3 unit cubes naturally correspond to the vertices of a graph Q_n, where adjacent vertices correspond to geometric neighbours. Dismantling is an ordered process of successively removing vertices of degree 3. In the extremal case, there are n^2 independent small cubes at the end of the process. These end-positions are *solutions* for short. A move is *balanced*, if the three neighbours are in different directions. We show that for any integer n, $n \geqslant 2$, there is a dismantling using only balanced moves and ending with n^2 independent small cubes. If this particular solution is projected to three orthogonal faces, we get the entire $n \times n$ square in each direction. These *perfect* solutions naturally correspond to Latin squares. The dismantling can be naturally reversed to a build-up. For small values, we enumerate, how many Latin squares correspond to solutions, from which we can build up the entire $n \times n \times n$ cube. We also prove the following results:

1. If all moves are balanced in a dismantling to a solution B, then B is perfect.
2. If B is a perfect solution, then any build-up uses balanced moves only.
3. If B is a solution, then adding vertices of degree three in any order leads to the full cube. (Friday 10:00)

Schröder quasigroups with a specified number of idempotents

Frank E. Bennett* and Hantao Zhang

Mount Saint Vincent University

Schröder quasigroups have been studied quite extensively over the years. Most of the attention has been given to idempotent models, which exist for all the feasible orders v, where $v \equiv 0, 1$ $(mod\ 4)$ except for $v = 5, 9$. There is no Schröder quasigroup of order 5 and the known Schröder quasigroup of order 9 contains 6 non-idempotent elements. It is known that the number of non-idempotent elements in a Schröder quasigroup must be even and at least four. In this paper, we investigate the existence of Schröder quasigroups of order v with a specified number k of idempotent elements, briefly denoted by SQ(v, k). The necessary conditions for the existence of SQ(v, k) are $v \equiv 0, 1$ $(mod\ 4)$, $0 \leqslant k \leqslant v$, $k \neq v-2$, and $v-k$ is even. We show that these conditions are also sufficient for all the feasible values of v and k with few definite exceptions and a handful of possible exceptions. Our investigation relies on the construction of holey Schröder designs (HSDs) of certain types. Specifically, we have established that there exists an HSD of type $4^n u^1$ for $u = 1, 9$, and 12 and $n \geqslant max\{(u + 2)/2, 4\}$. In the process, we are able to provide constructions for a very large variety of non-idempotent Schröder quasigroups of order v, all of which correspond to $v^2 \times 4$ orthogonal arrays that have the Klein 4-group as conjugate invariant subgroup. (Tuesday 10:50)

Tightening the bounds on the baron's omni-sequence

Michael Brand

Monash University Faculty of IT

"The Baron's Omni-sequence", first defined by Khovanova and Lewis in 2011, is a sequence that gives for each n the minimal number of weighings on balance scales that can verify the correct labeling of n identically-looking coins with distinct integer weights between 1 gram and n grams.

Khovanova and Lewis provide upper and lower bounds for this sequence, where the upper bound follows from the use of a particular algorithmic scheme. We continue this investigation by providing new algorithms that provide better upper bounds, within a factor of 2 from the lower bounds (improving on Khovanova and Lewis's 2.96). Furthermore, we show that these new algorithms are, under certain criteria, optimal within the framework of the present algorithmic scheme. (Tuesday 10:00)

Removing elements relative to a minor and a fixed basis

Nick Brettell

University of Canterbury

A standard matrix representation of a matroid M represents M relative to a fixed basis B, where contracting elements of B and deleting elements of $E(M) - B$ corresponds to removing rows and columns, respectively. If M is 3-connected, it is often desirable to perform such a removal while maintaining 3-connectivity. Whittle and Williams (2011) showed that, provided M doesn't contain any 4-element fans, there are at least four distinct elements k_i, for $i \in \{1, 2, 3, 4\}$, such that $\mathrm{si}(M/k_i)$ is 3-connected when $k_i \in B$, and $\mathrm{co}(M \backslash k_i)$ is 3-connected when $k_i \in E(M) - B$. We show that, subject to a mild essential restriction, either there are at least two distinct elements that can be removed in this way and also retain a copy of a specified N-minor of M, or M has a 4-element fan with a specific labelling of basis elements. We also investigate the structure of M when there are precisely two such elements. This is joint work with Charles Semple. (Tuesday 5:05)

On vector matroid chains

Thomas Britz

University of New South Wales

Given a sequence of linear codes, each contained in the next, what can be said about the corresponding vector matroids? Conversely, given a sequence of matroids, can we determine whether these might arise from a sequence of codes as described? I consider these and related questions, and provide a few simple answers. (Friday 10:50)

Certificates for properties of chromatic polynomials of graphs

Zoe Bukovac*, Graham Farr and Kerri Morgan

Monash University

The chromatic polynomial $P(G;\lambda)$ gives the number of possible colourings of a graph G using λ colours. In general, calculating the chromatic polynomials of graphs is hard, so any means of reducing the difficulty of finding out information about them are of interest. Certificates of equivalence and certificates of factorisation can provide proofs about the relationships between the chromatic polynomials of graphs. The lengths of these proofs may provide insight into the computational complexity of determining if two non-isomorphic graphs share the same chromatic polynomial and if the chromatic polynomial of one graph can be expressed as the product of the chromatic polynomials of several smaller graphs. (Monday 3:00)

Challenges of combinatorial enumeration in low-dimensional topology

Benjamin Burton

The University of Queensland

Combinatorial enumeration is important in topology: it allows us to form "censuses" of triangulations, much like the well-known "dictionaries" of knots. In this setting, enumeration offers some interesting challenges. Fast counting techniques are of limited use, since topologists need the full combinatorial data for each object in the census. Moreover, almost all combinatorial triangulations should be discarded, since they are either topologically invalid or equivalent to smaller triangulations.

The latter point means that most of the search is "wasted", and a key challenge is to identify these wasted regions of the search tree using fast combinatorial techniques as the enumeration runs. Here we describe the enumeration process and outline several powerful techniques of this type, based on union-find, skip lists, and 4-valent face pairing graphs. (Tuesday 5:30)

Constructions of abelian and non-abelian Paley type group schemes

Yuqing Chen

Wright State University

Paley type group schemes are special 2-class association schemes which give rise to skew Hadamard designs or Paley type strongly regular graphs. Classical examples of such schemes include quadratic residues of finite fields of odd characteristics.

In this talk I will present new constructions of abelian and non-abelian Paley type group schemes. This is a joint work with Tao Feng. (Monday 12:05)

Towards a splitter theorem for internally 4-connected binary matroids

Carolyn Chun*, Dillon Mayhew, and James G. Oxley

Victoria University of Wellington

Seymour's Splitter Theorem asserts that, for a 3-connected matroid M with a proper 3-connected minor N, then there is an element e such that M/e or $M\backslash e$ is 3-connected with an N-minor unless $r(M) \geqslant 3$ and M is a wheel or whirl. In this talk, we present a similar result for internally 4-connected binary matroids.
(Friday 11:40)

$\{U_{2,5}, U_{3,5}\}$-fragile matroids

Ben Clark*, Dillon Mayhew, Geoff Whittle, and Stefan van Zwam

Victoria University of Wellington

A fundamental problem in matroid theory is to characterise the classes of matroids that arise naturally from matrices. The most commonly sought way to characterise these classes is via a list of excluded minors for the class, that is, a list of the smallest matroids that are not in the class. In this talk we discuss the existing proof techniques for finding excluded-minor characterisations, including the crucial concept of fragility. We then describe the structure of a class of matroids that are fragile with respect to the matroids $U_{2,5}$ and $U_{3,5}$, and outline how this can be used as a step towards finding new excluded-minor characterisations.
(Tuesday 5:30)

Our difficulties in finding designs over a group of order 36

R Julian R Abel, Diana Combe*, Adrian M Nelson and William D Palmer

The University of New South Wales and The University of Sydney

There are well established necessary conditions on v, λ, G for the existence of a generalized Bhaskar Rao design GBRD$(v, 3, \lambda; G)$. We have shown that these conditions are sufficient for many infinite classes of groups G, and for nearly all groups of order less that 100. In this talk we look at some of the difficulties we encounter when trying to construct designs over one particular 'difficult' group of order 36 (Tuesday 11:15)

The smallest regular polytopes of each rank

Marston Conder

University of Auckland, New Zealand

An abstract *n-polytope* is a partially-ordered set endowed with a rank function (plus a unique minimum and unique maximum element, of ranks -1 and n respectively), such that all maximal chains have length $n+2$. Elements of ranks 0, 1,2 and $n-1$ are the vertices, edges, 2-faces and facets of the polytope, and the maximal chains are called *flags*. Two other conditions (motivated by geometric considerations) are required. First, a certain *diamond condition* must hold, so that (for example) if a vertex is incident with a 2-face, then there are exactly two edges incident with both. Also the poset must be *strongly connected*, which means that any flag can be transformed into any other flag by a sequence of steps replacing just one element at a time.

A polytope is called *regular* if its automorphism group has a single orbit on flags. In that case, the automorphism group is a smooth quotient of a Coxeter group $[p_1, p_2, \ldots, p_n]$ where p_1 is the valency of each vertex, and so on. In this talk I will report on recent work on finding for each n the regular n-polytopes with the smallest numbers of flags, under the assumption that all $p_i > 2$. With a few small exceptions, these are also the regular n-polytopes with the smallest numbers of elements, and those with the smallest number of links in the Hasse diagram. Somewhat surprisingly, for $n > 3$ the smallest instances are not the regular n-simplices (of type $[3, 3, \ldots, 3]$).

[Note: this is the talk I was to give at last year's ACCMCC, before I had to cancel my travel plans.]   (Friday 10:50)

Chains and antichains in the Bruhat order for a class of binary matrices

Alessandro Conflitti*, C.M. da Fonseca and Ricardo Mamede

CMUC, Centre for Mathematics, University of Coimbra, Portugal

Let m and n be two positive integers and let $R = (r_1, \ldots, r_m)$ and $S = (s_1, \ldots, s_n)$ be positive integral vectors: the set of all $m \times n$ matrices over $\{0, 1\}$ with row sum vector R and column sum vector S, denoted by $\mathcal{A}(R, S)$, is a very interesting mathematical structure, whose combinatorial properties have been thoroughly explored over the years. Specifically, one of the key result is the Gale–Ryser Theorem, which characterizes vectors R and S for $\mathcal{A}(R, S)$ to be nonempty.

A very important case in which nonemptiness is assured occurs when $m = n$, k is an integer such that $0 \leqslant k \leqslant n$, and $R = S = (k, \ldots, k)$ is the constant vector having each component equal to k; in this case we write $\mathcal{A}(n, k)$ instead of $\mathcal{A}(R, S)$.

In a recent couple of papers, Richard A. Brualdi et al. defined a partial order $\preceq$ on such a nonempty class of matrices which generalizes the classical Bruhat order on the symmetric group S_n, seen as the set of permutation matrices $\mathcal{A}(n, 1)$, and characterize all families of the class $\mathcal{A}(n, k)$ having a unique minimal element. Besides the case of permutation matrices

$\mathcal{A}(n,1)$, the only other non trivial instance is when $n = 2k$, i.e. the family of binary square matrices with all rows and columns having as many zeros as many ones.

In this talk I shall present the solution of two open problems presented in one of the aforementioned papers, namely the maximal length of a chain and the largest size of an antichain in the poset $(\mathcal{A}(2k,k), \preceq)$. (Thursday 3:50)

Enumeration of orthogonal arrays

Ben Burton, Fatih Demirkale* and Diane Donovan

University of Queensland

In this talk, a new and efficient combinatorial algorithm for the enumeration of orthogonal arrays will be presented. This algorithm generates all non-isomorphic orthogonal arrays with a given number of rows N, a given number of symbols s, a given strength t, and all possible numbers of columns k. Hence this algorithm also finds the maximal number of columns k for which an $OA(N,k,s,t)$ exist. (Monday 4:40)

Algebraic properties of chromatic polynomials

Adam Bohn (Queen Mary), Peter Cameron (Queen Mary), Graham Farr* (Monash), Bill Jackson (Queen Mary) and Kerri Morgan (Monash)

Monash University

We give a survey of some recent work on algebraic properties of chromatic polynomials, including their roots (as algebraic numbers), factors and Galois groups.

Work supported in part by ARC Discovery Grant DP110100957. (Friday 3:10)

Cyclotomic orthomorphisms

David Fear* and Ian Wanless

Monash University

An *orthomorphism*, θ, is a permutation for which the mapping $\theta \mapsto \theta - i$ is also a permutation, where i is the identity permutation. These are of interest for their application in creating large sets of MOLS (Mutually Orthogonal Latin Squares). A cyclotomic orthomorphism is one which is created by permuting the cosets of a (cyclic) subgroup of a field to create an orthomorphism. These are known for creating large families of MOLS, and have some interesting properties. The *degree* of a cyclotomic orthomorphism is the index of the subgroup used in this construction. I will be talking about cyclotomic orthomorphisms of different degrees, and how these interact with each other, and under transformation.
(Thursday 10:00)

A polynomial complexity "snakes and ladders heuristic" for the Hamiltonian cycle problem

Jerzy Filar

Flinders University

The famous Hamiltonian cycle problem (HCP) - to determine whether a graph possesses a simple cycle that passes through all vertices exactly once - is known to be NP-complete. Despite the latter it appears that polynomial complexity, albeit heuristic, algorithms can be constructed that successfully solve "most" instances of graphs with the number, N, of vertices not exceeding 5000. In particular, we describe a recently designed "Snakes and Ladders Heuristic" (SLH, for short) that has the worst case complexity of $O(N^4)$ but which seems to be performing much better in preliminary experimentation. Salient features of SLH will be described and real-time demonstration of the algorithm will be included. (Monday 5:05)

Generalised quadrangles with a group acting primitively on points and lines

Michael Giudici

The University of Western Australia

A generalised quadrangle is an incidence structure of points and lines such that the bipartite incidence graph has diameter 4 and girth 8. The classical examples are the low dimensional polar spaces associated with the classical groups $\mathrm{PSp}(4,q)$, $\mathrm{PSU}(4,q)$ and $\mathrm{PSU}(5,q)$, and their duals. In this talk I will discuss recent work aimed at characterising the classical examples in terms of the action of their automorphism group on points and lines. This is joint work with John Bamberg, Joy Morris, Gordon F. Royle and Pablo Spiga. (Friday 1:30)

On a generalisation of trapezoidal words

Amy Glen* and Florence Levé

Murdoch University, Perth

The *factor complexity function* $C_w(n)$ of a finite or infinite word w associates to each integer $n \geqslant 0$ the number of distinct *factors* (i.e., blocks of consecutive letters) in w of length n. A finite word w of length $|w|$ is said to be *trapezoidal* if the graph of its factor complexity $C_w(n)$ as a function of n (for $0 \leqslant n \leqslant |w|$) is that of a regular trapezoid (or possibly an isosceles triangle); that is, $C_w(n)$ increases by 1 with each n on some interval of length r, then $C_w(n)$ is constant on some interval of length s, and finally $C_w(n)$ decreases by 1 with each n on an interval of the same length r. Necessarily $C_w(1) = 2$ (since there is one factor of length 0, namely the *empty word*), so any trapezoidal word is on a binary alphabet. Trapezoidal words were first introduced by A. de Luca (1999) when studying the behaviour of the factor complexity of *finite Sturmian words*, i.e., factors of infinite "cutting sequences", obtained by coding the sequence of cuts in an integer lattice over the positive quadrant of $\mathbf{R}^2$ made by a line of irrational slope. Every finite Sturmian word is trapezoidal, but not conversely. However, both families of words (trapezoidal and Sturmian) are special classes of so-called *rich words* – a new (wider) class of finite and infinite words characterised by containing the maximal number of palindromes – recently introduced by the speaker, together with J. Justin, S. Widmer, and L.Q. Zamboni (2009).

In this talk, I will introduce a natural generalisation of trapezoidal words over an arbitrary finite alphabet A consisting of at least two distinct letters, called *generalised trapezoidal words* (or *GT-words* for short). In particular, I will discuss some combinatorial properties of this new class of words when $|A| \geqslant 3$ and I will show that, unlike in the binary case ($|A| = 2$), not all GT-words are rich in palindromes, but we do have a neat characterisation of those that are.

This work was inspired by a question of Ian Wanless at the 54th Annual Conference of the Australian Mathematical Society last year (2010). (Thursday 3:00)

Making Markov chains less lazy

Catherine Greenhill

University of New South Wales

There are only a few methods for analysing the rate of convergence of an ergodic Markov chain to its stationary distribution. One such is the canonical path method of Jerrum and Sinclair. This is essentially a counting method which is used to show that the underlying graph of the Markov chain does not contain any bottlenecks.

In order to use this approach, we need to know that all eigenvalues of the Markov chain are nonnegative. Authors often achieve this by making their chain lazy, so that at every step the chain does absolutely nothing with probability $1/2$. Although this is accepted practice for theoreticians it is quite frustrating to practitioners, who want to use the most efficient (fastest) Markov chain possible.

I will discuss how laziness can be avoided by the use of a twenty-year old lemma of Diaconis and Stroock's, or my recent modification of that lemma. As an illustration, I will apply the new lemma to Jerrum and Sinclair's well-known chain for sampling perfect matchings in a bipartite graph. (Monday 10:00)

On Hadwiger's Conjecture for circular arc graphs

Daniel Harvey

Department of Mathematics and Statistics, University of Melbourne

Hadwiger's conjecture is one of the most well known conjectures in graph theory. It states that the *Hadwiger number* $h(G)$ of a graph G, the order of the largest complete minor of G, is greater than the chromatic number $\chi(G)$. A *circular arc graph* is a graph constructed from a collection of arcs of a circle, such that each vertex represents an arc and two vertices are adjacent if and only if their corresponding arcs intersect. A *proper circular arc graph* is a circular arc graph in which no arc completely covers any other. Belkale and Chandran have proved Hadwiger's conjecture for this class of graphs. However, Hadwiger's conjecture for circular arc graphs remains unsolved and challenging. We define the cover number $\beta(G)$ of a circular arc graph to be the size of the smallest set of arcs that entirely covers the circle. As a first attempt at proving Hadwiger's conjecture for circular arc graphs, we show that $h(G) \geqslant \chi(G) - 1$ whenever $\beta(G) > 3$. (Tuesday 10:50)

Genetic theory of cubic graphs

Michael Haythorpe*, Pouya Baniasadi, Vladimir Ejov and Jerzy Filar

Flinders University

We propose a partitioning of the set of unlabelled, connected cubic graphs into two disjoint subsets named genes and descendants, where the cardinality of the descendants is much larger than that of the genes. The key distinction between the two subsets is the presence of special edge cut sets, called crackers, in the descendants. We show that every descendant can be created by starting from a finite set of genes, and introducing the required crackers by special breeding operations. We prove that it is always possible to identify which genes are used to generate a descendant, and provide inverse operations that enable their reclamation. A number of interesting properties of genes may be inherited by the descendant, and we therefore propose a natural algorithm that decomposes a descendant into its ancestor genes. We conjecture that each descendant can only be generated by starting with a unique set of ancestor genes. (Monday 4:40)

Perfect 1-factorisations of circulant graphs

Sarada Herke* and Barbara Maenhaut

University of Queensland

A 1-factor (or perfect matching) of a graph G is a 1-regular spanning subgraph of G. A 1-factorisation of G is a decomposition of G into edge-disjoint 1-factors, and a perfect 1-factorisation is a 1-factorisation in which the union of any two of the 1-factors is a Hamilton cycle. A circulant graph on n vertices with distance set $S \subseteq \{1, 2, \cdots, \frac{n}{2}\}$ has vertex set labeled by the elements of $\mathbb{Z}_n$ and edge set given by $\{\{x, x+s \pmod{n}\} \mid x \in \mathbb{Z}_n, s \in S\}$. We consider the problem of the existence of perfect 1-factorisations in even order circulant graphs with small degree. In particular, we will discuss some new results for circulant graphs with distance sets $\{1, \frac{n}{2}\}$ and $\{1, 3\}$. We will look at some computer search results for existence and nonexistence of perfect 1-factorisations in small order circulant graphs with distance sets of size two and discuss some related conjectures. (Monday 3:50)

The number of maximum matchings in a tree

Clemens Heuberger* and Stephan G. Wagner

Graz University of Technology

We completely determine all trees maximising $m(T)$ over all trees of a given order n, where $m(T)$ is defined to be the number of maximum matchings (i.e., matchings of maximum cardinality) of a tree.

It turns out that for $n \notin \{6, 34\}$, there is a unique tree T_n^* of order n that maximises $m(T)$. While T_n^* almost always has maximum degree 4, the precise shape of T_n^* depends on n modulo 7. Asymptotically,

$$m(T_n^*) \sim c_{n \bmod 7} \lambda^{n/7},$$

where $\lambda = \frac{1}{2}(11 + \sqrt{85}) \approx 10.1097722286464$ is the larger root of the polynomial $x^2 - 11x + 9$ and the constants c_j, $j \in \{0, \ldots, 6\}$ are known and lie in the interval $[0.78, 0.8]$.

Some results for the related problem of maximal matchings (matchings which are maximal with respect to inclusion) have been studied by Górska and Skupień in 2007. The number of matchings (without maximality assumptions) is called the Hosoya index in mathematical chemistry and has been studied under many additional constraints. (Monday 4:15)

Compressed sensing and hash families

Charles Colbourn, Daniel Horsley*, Christopher McLean and Violet Syrotiuk.

Monash University

Compressed sensing is a recently developed paradigm for signal sampling which takes advantage of the sparseness or compressibility of many naturally occurring signals. In discrete compressed sensing, the signal takes the form of a vector of real-valued components and the sampling process can be described as multiplication of this vector by a matrix, called the sensing matrix. The construction of "good" sensing matrices is a central theme in compressed sensing research.

In this talk I will give a quick introduction to compressed sensing and discuss how hash families (a class of combinatorial arrays) can be used to construct good sensing matrices via a technique called column replacement. (Friday 1:30)

Two variants of Wythoff's game preserving its P-positions

Bao Ho

La Trobe University

Wythoff's game is a variant of Nim involving two piles of tokens. Two players move alternately, either removing an arbitrary number of tokens from one pile as in Nim or removing the same arbitrary number of tokens from both piles. The game ends when the two piles become empty. The player who makes the last move wins.

We present two variants of Wythoff's game. The first game is a restriction of Wythoff's game in which if the two entrees are not equal then removing tokens from the smaller pile is not allowed. The second game is an extension of Wythoff's game obtained by adjoining a move allowing players to remove k tokens from the smaller pile and l tokens from the other pile provided $l < k$. We show that both games preserve the P-positions of Wythoff's game. This resolves a question of Duchêne, Fraenkel, Nowakowski and Rigo. We establish formulas for positions of Sprague-Grundy value 1 for both games. We also present several results on the Sprague-Grundy functions. (Thursday 4:15)

The reduction of CSP dichotomy to digraphs.

Jakub Bulin, Dejan Delic, Marcel Jackson* and Todd Niven

La Trobe University

If **A** is a finite relational structure, then the *constraint satisfaction problem* (CSP) over the fixed template **A** is the problem of deciding if a given structure of the same type as **A** admits a homomorphism into **A**. Graph k-colouring problems are familiar examples of fixed template constraint satisfaction problems (is there a homomorphism into K_k?), where the edge relation is the only (binary) relation.

The *dichotomy conjecture* of Feder and Vardi states that a fixed template CSP is either solvable in polynomial time or is NP-complete; the conjecture is known to be true for undirected graphs (Hell and Nesetril), for digraphs with no sources or sinks (Barto, Kozik and Niven) amongst other special cases.

Feder and Vardi showed that every fixed template CSP is polynomial time equivalent to a digraph homomorphism problem: so it suffices to prove the dichotomy conjecture for directed graph templates. However it is also known that no reduction to digraphs can hope to preserve all of the fine structure of arbitrary fixed template CSP problems. In particular, it is known that the complexity of the CSP over the relational structure **A** is exactly determined by the family of polymorphisms of **A** (polymorphisms are essentially higher arity endomorphisms), and a recent result of Kazda has shown that the possible polymorphism structure of digraph CSPs is more restrictive than for general reduction of arbitrary CSP problems.

We show that not only is the CSP over **A** polynomial time equivalent to a digraph CSP, but in fact there is a logspace reduction from the CSP over **A** to the CSP over a balanced digraph $\mathbf{D_A}$ with $\mathbf{D_A}$ sharing *almost* identical polymorphism structure to **A**: the property identified by Kazda is essentially the only "naturally-occuring" polymorphism property that is not preserved. This shows that not only is the general dichotomy conjecture equivalent to its restriction to digraphs (shown by Feder and Vardi), but so too are basically all other existing conjectures relating to the finer classification of CSPs into computational classes within P (such as L, NL for example). (Tuesday 10:00)

A construction of imprimitive symmetric graphs which are not multicovers of their quotients

Bin Jia

The University of Melbourne

Let Σ be a finite X-symmetric graph of valency $\tilde{b} \geqslant 2$, and $s \geqslant 1$ an integer. In this article we give a sufficient and necessary condition for the existence of a class of finite imprimitive (X, s)-arc-transitive graphs which have a quotient isomorphic to Σ and are not multicovers of that quotient, together with a combinatorial method, called the double-star graph construction, for constructing such graphs. Moreover, for any X-symmetric graph Γ admitting a nontrivial X-invariant partition $\mathcal{B}$ such that Γ is not a multicover of $\Gamma_{\mathcal{B}}$, we show that there exists a sequence of $m+1$ X-invariant partitions

$$\mathcal{B} = \mathcal{B}_0, \mathcal{B}_1, \cdots, \mathcal{B}_m$$

of $V(\Gamma)$, where $m \geqslant 1$ is an integer, such that $\mathcal{B}_i$ is a proper refinement of $\mathcal{B}_{i-1}$, $\Gamma_{\mathcal{B}_i}$ is not a multicover of $\Gamma_{\mathcal{B}_{i-1}}$ and $\Gamma_{\mathcal{B}_i}$ can be reconstructed from $\Gamma_{\mathcal{B}_{i-1}}$ by the double-star graph construction, for $i = 1, 2, \cdots, m$, and that either $\Gamma \cong \Gamma_{\mathcal{B}_m}$ or Γ is a multicover of $\Gamma_{\mathcal{B}_m}$.
(Monday 11:15)

Generation of planar graphs based on their faces

Mohammadreza Jooyandeh* and Brendan D. McKay

Australian National University

In this talk we describe how k-angulations (planar graphs with faces of size k) can be generated. The algorithm uses the fast algorithm for generating triangulations and quadrangulations and two operations in a recursive manner. The generator is based on the canonical construction path method to avoid isomorphic copies. The families which can be generated with this approach are k-angulations and 2-connected k-angulations. More generally adding another operation we are able to generate all planar graphs with faces of size in a given set.
(Thursday 11:15)

Maximal antichains in the Boolean lattice

Thomas Kalinowski*, Uwe Leck, Ian T. Roberts

University of Newcastle

We study maximal families $\mathcal{A}$ of subsets of $[n] = \{1, 2, \ldots, n\}$ such that $\mathcal{A}$ is an antichain with respect to inclusion, i.e. $A \nsubseteq B$ for all distinct $A, B \in \mathcal{A}$. In particular, we are interested in minimizing the size of a maximal antichain subject to the condition that $\mathcal{A}$ contains only sets whose sizes are in a fixed small set K. We generalize the methods that were used to solve the case $K = \{2, 3\}$ to derive lower bounds for $K = \{2, 3, 4\}$ and $K = \{2, 4\}$. These lower bounds almost match the upper bounds coming from the constructions that are conjectured to be optimal. In addition, we present partial results on the existence of maximal antichains which are also r-regular, i.e. every point $x \in [n]$ is contained in exactly r members of $\mathcal{A}$. (Thursday 4:15)

Linear extension diameter and reversal ratio

Graham Brightwell and Mitchel T. Keller*

London School of Economics and Political Science

Felsner and Reuter introduced the linear extension diameter of a partially ordered set $\mathbf{P}$, denoted $\text{led}(\mathbf{P})$, as the maximum distance between two linear extensions of $\mathbf{P}$, where distance is defined to be the number of incomparable pairs appearing in opposite orders (reversed) in the linear extensions. We introduce the reversal ratio $RR(\mathbf{P})$ of $\mathbf{P}$ as the ratio of the linear extension diameter to the number of (unordered) incomparable pairs. We use probabilistic techniques to provide a family of posets $\mathbf{P}_k$ on at most $k \log k$ elements for which the reversal ratio $RR(\mathbf{P}_k) \leqslant C/\log k$, where C is a constant. We also examine the questions of bounding the reversal ratio in terms of order dimension and width. (Thursday 4:40)

$2(n+1)$ regular connected Cayley graphs on rank n elementary abelian groups are Hamilton decomposable

Cafer Caliskan and Donald L. Kreher*

Michigan Technological University

We show that every odd order $2(n+1)$-regular connected Cayley graph on a rank n elementary abelian group is Hamilton decomposable. This result is applied to Paley graphs to show that when given odd prime power $q = p^n$, and even order multiplicative subgroup S of the finite field $\mathbb{F}_q$, that the Cayley graph with connection set S is Hamilton decomposable, whenever $|S| \geqslant 2n^2$. This extends the recent result of Alspach, Bryant and Dyer on Paley graphs.
(Friday 11:40)

The hat problem on a directed graph

Rani Hod and Marcin Krzywkowski*

Gdańsk University of Technology, Poland

A team of n players plays the following game. After a strategy session, each player is randomly fitted with a blue or red hat. Then, without further communication, everybody can try to guess simultaneously his own hat color by looking at the hat colors of the other players. Visibility is defined by a directed graph; that is, vertices correspond to players, and a player can see each player to whom he is connected by an arc. The team wins if at least one player guesses his hat color correctly, and no one guesses his hat color wrong; otherwise the team loses. The team aims to maximize the probability of a win, and this maximum is called the hat number of the graph.

Previous works focused on the hat problem on complete graphs and on undirected graphs. Some cases were solved, e.g., complete graphs of certain orders, trees, cycles, bipartite graphs. These led Uriel Feige to conjecture that the hat number of any graph is equal to the hat number of its maximum clique.

We show that the conjecture does not hold for directed graphs. Moreover, for every value of the maximum clique size, we provide a tigth characterization of the range of possible values for the hat number. We also determine the hat number of tournaments to be one half.
(Thursday 4:40)

Constructions for Hadamard matrices, Clifford algebras, and their relation to amicability - anti-amicability graphs

Paul Leopardi

Australian National University

This talk is essentially a repeat of a talk I gave at the Hadamard workshop at ANU in May 2010. It is known that the Williamson construction for Hadamard matrices can be generalized to constructions using sums of tensor products. I will discuss a specific construction using a basis for the real representation of Clifford algebras, and its connection with graphs of amicability and anti-amicability. I will give some results for small dimensions, and describe prospects for further research. (Monday 11:40)

A characterization of PM-compact bipartite and near-bipartite graphs

Charles Little

Massey University

A graph is PM-compact if the symmetric difference of any two perfect matchings is a single alternating circuit. We characterise PM-compact bipartite and near-bipartite graphs.
(Thursday 10:00)

Almost regular edge colourings of complete bipartite graphs

Sarada Herke and Barbara Maenhaut*

University of Queensland

A graph G is almost regular on $S \subseteq V(G)$ if the degrees of any two vertices of S differ by at most 1. An edge-colouring of the complete bipartite graph $K_{m,n}$ is almost regular on $S \subseteq V(K_{m,n})$ if the spanning subgraph induced by each colour is almost regular on S. In this talk I will illustrate the proof of the following lemma in which an edge-colouring of a complete bipartite graph is transformed into an almost regular edge-colouring of that complete bipartite graph.

Lemma Let the vertex set of $K_{m,n}$ be comprised of the partite sets A and B where $|A| = m$ and $|B| = n$. Let γ be an edge colouring of $K_{m,n}$ and let $S \subseteq V(K_{m,n})$ such that either $S \subseteq A$ or $S \subseteq B$. Then there exists an edge colouring γ' of $K_{m,n}$ such that the following conditions hold:

- For each colour c, the number of edges of colour c is the same for γ and γ'.

- For each $x \in V(K_{m,n}) \setminus S$ and each colour c, the number of edges of colour c incident with x is the same for γ and γ'.
- For $x, y \in V(K_{m,n}) \setminus S$, the colour of the edge xy is the same for γ and γ'.
- The edge colouring γ' is almost regular on S.

Applications of this lemma to prove classical results and new results will be presented. (Wednesday 10:00)

On the complexity of graph polynomials

Johann A. Makowsky

Faculty of Computer Science, Technion - Israel Institute of Technology, Haifa, Israel

The complexity of evaluating the chromatic polynomial and the Tutte polynomial (and many of its variations) exhibit a dichotomy. For fixed points $\mathbf{x}$ the graph parameter defined by the evaluation of the polynomial at $\mathbf{x}$ is either $\sharp\mathbf{P}$-hard or computable in polynomial time. Furthermore the set of points where evaluation is $\mathbf{P}$-time computable is a finite union of algebraic sets of strictly lower dimension which can be described explicitely (Jaeger, Vertigan and Welsh, 1990). This result is a hybrid statement: It uses Turing complexity ($\sharp\mathbf{P}$) to express hardness, but really speaks about computing over arbitrary fields in the sense of the Blum-Shub-Smale (BSS) model of computation.

In this talk I will formulate several conjectures in the (non-hybrid) BSS model of computation asserting variations of dichotomy theorems for a wide class of graph polynomials, and report about the current state of these conjectures. For the Bollobás-Riordan polynomials, the interlace polynomials, the cover polynomial for directed graphs, and the most general edge elimination polynomial, and many others, weak forms of the conjecture have been verified by I. Averbouch, M. Blaeser, H. Dell, C. Hoffmann, T. Kotek and the author. (Thursday 3:00)

On optimal ternary linear codes

T. Maruta* and Y. Oya

Osaka Prefecture University

An $[n, k, d]_q$ code is a linear code of length n, dimension k and minimum weight d over the field of q elements. A fundamental problem in coding theory is to find $n_q(k, d)$, the minimum length n for which an $[n, k, d]_q$ code exists for given q, k, d. An $[n, k, d]_q$ code is called *optimal* if $n = n_q(k, d)$. In this talk we will report some recent progress on the research finding $n_3(6, d)$. (Monday 4:15)

The number of diagonal transformations in quadrangulations on the sphere

Naoki Matsumoto

Yokohama National University

A *quadrangulation* G on a surface F^2 is a simple graph embedded on F^2 such that each face of G is bounded by a cycle of length four. *Diagonal transformations* in quadrangulations consist of two transformations, called a *diagonal slide* and a *diagonal rotation*, respectively. For any closed surface F^2, it is known that any two bipartite quadrangulations on F^2 with the same and sufficiently large number of vertices can be transformed into each other by diagonal transformations.

In this talk, we shall consider that the number of diagonal transformations in quadrangulations on the sphere. (Tuesday 5:05)

Superfluous excluded minors

Rhiannon Hall, Dillon Mayhew*, and Stefan van Zwam

Victoria University of Wellington

Wagner's version of Kuratowski's Theorem says that we can obtain the class of planar graphs by excluding all those graphs that have a minor isomorphic to $K_{3,3}$ or K_5. A classical result by Hall shows that we do not gain much by relaxing this constraint, and excluding only those graphs that have a minor isomorphic to $K_{3,3}$. In particular, there is only one 3-connected graph (namely K_5) that does not have a $K_{3,3}$ minor, but which is non-planar. This motivates us to make the following definition. If $\mathcal{X}$ is a set of graphs (or matroids), let $\mathrm{EX}(\mathcal{X})$ be the set of graphs (matroids) that do not contain a minor isomorphic to a member of $\mathcal{X}$. We will say that the subset $\mathcal{X}' \subseteq \mathcal{X}$ is *superfluous* if $\mathrm{EX}(\mathcal{X} - \mathcal{X}') - \mathrm{EX}(\mathcal{X})$ contains only finitely many 3-connected graphs (matroids). Thus $\{K_5\}$ is a superfluous subset of $\{K_{3,3}, K_5\}$. We have characterized the superfluous subsets of several well-known families of excluded minors.
(Tuesday 4:15)

Graph connectivity in the streaming model

Jeanette McLeod* and Dominic Welsh

University of Canterbury; University of Oxford

Over the past decade there has been a significant amount of interest in the study of massive graphs whose edge sets are too large to be stored in memory. This has given rise to the streaming model of computation where algorithms are restricted to a single pass over the edge set and have significantly less memory than would be required to store the entire graph. Determining the types of graph problems that can be solved efficiently in this model is difficult, and in fact, for many graph properties, the restrictions of the model make it is impossible to determine whether a given graph has the property (Feigenbaum et al., 2005).

In this talk, three single-pass streaming algorithms based on results of Nagamochi and Ibaraki (1992), and Zelke (2007) will be presented. The first is an algorithm for finding the block-cutpoint graph of a simple input graph $G = (V, E)$ presented as a stream of edges. It has worst case complexity $O(|E|)$. The second is an algorithm for finding all 2-(vertex) separators of a 2-connected simple graph $G = (V, E)$, and has worst case complexity $O(|V|^2)$. Finally we give an algorithm which will find all 2-edge cuts of a 2-connected graph $G = (V, E)$ in time $O(|V|^2)$. (Friday 2:45)

Generating d-angulations of girth d

Ivan Lazar Miljenovic

The Australian National University

A d-angulation is a planar graph where each face is of size d. Algorithms for generating triangulations, quadrangulations and pentangulations are available, but – with the exception of recent work on $(d, d+2)$-angulations by Mohammadreza Jooyandeh – these algorithms are specialised for each specific value of d, and thus cannot be used to generate d-angulations for $d > 5$.

In this talk, I shall be discussing implementation of an algorithm that is able to generate all d-angulations with the added constraint of also having a girth of d (that is, the shortest cycle within the graph is also of length d) based upon a bijection used within a counting argument by Olivier Bernardi and Eric Fusy. (Thursday 10:50)

Some vertex transitive integral graphs

Marsha Minchenko* and Ian Wanless

Monash University

An *integral* graph is a graph whose adjacency matrix has only eigenvalues that are integers. The *spectrum* of a graph is the eigenvalues with their multiplicity. In this talk, we take previous results that give a list of spectra that are possible for a graph that is connected, 4-regular, bipartite, and integral; and consider the subgraph configurations necessary for these spectra to also be vertex transitive. Additionally, we determined that some of these integral spectra are realized by Cayley graphs and these results are given. (Thursday 5:05)

A review of approaches toward routing and wavelength assignment problem in telecommunication

Hamid Mokhtar

Department of Mathematics and Statistics, The University of Melbourne

A telecommunication network, which is modelled as a graph, using limited resources on optical fibers to respond some requests of connection. The problem contains *routing* sub-problem and *wavelength assignment* sub-problem and it is a NP-complete problem. In the corresponding graph, every link can carry several messages, provided that they should be transmitted on different wavelengths. There are many research works on routing and wavelength assignment problem to introduce a sharper lower and upper bound. While some researchers model the problem with integer programming, it can be formulated as a *graph colouring* problem. Some good results, and polynomial time algorithms for specific graphs are produced.

Telecommunication is a problem with growing demand and applications in industry. And, it received considerable attention. An encompassing review of different kind of telecommunication problems and different solution methods and algorithms for the problem and a comparison of results are presented. (Monday 11:40)

Some algebraic properties of chromatic polynomials of theta graphs

Kerri Morgan* and Daniel Delbourgo

Monash University

The chromatic polynomial $P(G; \lambda)$ gives the number of proper colourings of a graph G in at most λ colours. We are interested in the relationship between the structure of a graph and the algebraic properties of the chromatic polynomial. Chromatic polynomials of cycles are basically the cyclotomic polynomials and thus their algebraic properties are well understood. A θ-graph can be obtained from a cycle by adding a path between a pair of non-adjacent vertices on the cycle. In this talk we look at the chromatic polynomials of θ-graphs and some of their algebraic properties. (Friday 2:45)

Converting quadrangulations into even triangulations

Raiji Mukae

Yokohama National University

A triangulation (resp., quadrangulation) is a simple graph on a surface with each face triangular (resp., quadrilateral). An even triangulation is a triangulation in which every vertex has even degree. It is easy to see that every quadrangulation on surfaces can be extended to a multi-triangulation by adding one diagonal-edge into every quadrangle. Moreover, we can see that every planar triangulation has a quadrangulation as a subgraph.

Zhang and He showed that every quadrangulation of any orientable surface can be extended to an even multi-triangulation by adding one diagonal-edge into every quadrangle.

In our talk, we consider the projective planar and Klein bottle cases.
(Tuesday 4:40)

Polychromatic 4-coloring of cubic bipartite plane graphs

Elad Horev, Matthew J. Katz, Roi Krakovski, Atsuhiro Nakamoto*

Yokohama National University

We shall prove that every cubic bipartite plane graph G admits a *polychromatic* 4-*coloring*, that is, a proper vertex-4-coloring such that for each face f of G, all four colors appear on the boundary walk of f. We note that "4" is best possible, since G always has a quadrilateral face. In order to prove the theorem, we use a generating theorem for Eulerian plane triangulations.
(Friday 10:00)

Axiomatic descriptions of real-representable matroids

Dillon Mayhew, Mike Newman*, Geoff Whittle

University of Ottawa

Matroids are defined axiomatically, in a way that can be thought of as generalizing finite point sets of vector spaces. Whitney asked whether it was possible to give a similar description of real-representable matroids. Vamos gave a negative answer of sorts to this question, in that he showed that no finite set of first order axioms could characterize real-representable matroids. However this didn't really settle the question, since an infinite number of such axioms are required to characterize matroids.

We consider second order axioms more natural for matroid theorists, and in fact show that these are not sufficient to characterize real-representable matroids. This gives an extreme contrast with Rota's conjecture, which would imply that such a characterization is possible for matroids representable over a finite field. (Friday 12:05)

Classification of cocyclic Hadamard matrices

Padraig Ó Catháin

National University of Ireland, Galway

A $\{\pm 1\}$-matrix, H, of order n is called Hadamard if it satisfies the equation $HH^\top = nI_n$. Hadamard matrices can exist only if $n = 1, 2$, or $4 \mid n$. The classification of Hadamard matrices of order at most 28 involved many mathematicians over several decades, and was completed in the 1990s. The total number of Hadamard matrices of orders 32 and 36 are as yet unknown.

Cocyclic Hadamard matrices, introduced by de Launey and Horadam in the 1990s, have algebraic properties not shared by all Hadamard matrices. A matrix is cocyclic if its entries satisfy a cocycle-type identity. This is equivalent to the existence of a regular subgroup in a certain quotient group of the automorphism group of H. A result of de Launey relates regular subgroups of this quotient and $(4t, 2, 4t, 2t)$-relative difference sets.

This result can be refined and combined with a classification of $(4t, 2, 4t, 2t)$-relative difference sets to produce a classification of all cocyclic Hadamard matrices of order $4t$.

Marc Röder and I have carried out this programme for $t \leqslant 9$. In this talk I will cover all necessary background results, explain our algorithm, and describe some of the data that we generated. (Monday 11:15)

Normality of lattice polytopes

Shoetsu Ogata

Tohoku University

In this talk I will give new examples distinguishing very ampleness from normality of lattice polytopes.

A pair (X, L) of a projective toric variety X of dimension n and an ample line bundle L on it corresponds to a lattice polytope P of the same dimension so that the space of global sections of L is parametrized by the set of lattice points in P as a vector space. From a lattice polytope we can construct the pair (X, L) with this correspondence. The notions of very ampleness and normality of P corresponds to that of the ample line bundle L.

We knew only two examples of very ample but not normal lattice polytopes in dimension three and five, which were provided by Bruns and Gubeladze. We construct very ample but not normal lattice polytopes in any dimension greater than two.

Our examples are the Minkowski sums of lattice line segments and lattice simplices. If the polytope is the Minkowski sum with a line segment, then the corresponding toric variety has a surjective morphism to the projective line.

I also show that if the Minkowski sum of a line segment and a lattice polytope of dimension three is nonsingular, then it is normal. (Friday 1:55)

On small-order Hadamard matrices from the Williamson and octonion constructions

Judy-anne Osborn* and Richard Brent

University of Newcastle

I will describe some investigations into the well-known Williamson and lesser known Octonion constructions for some small Hadamard matrices. (Monday 10:50)

Enlarging the classes of edge-magic 2-regular graphs

Akito Oshima* and Rikio Ichishima

Tokyo University of Science, JAPAN

A graph G of order p and size q is called *edge-magic labeling* if there is a bijective function $f : V(G) \cup E(G) \to \{1, \ldots, p+q\}$ such that $f(u) + f(v) + f(uv)$ is a constant for each $uv \in E(G)$. An edge-magic labeling of a graph G to be a *super edge-magic labeling* with additional property that $f(V(G)) = \{1, 2, \ldots, p\}$.

In this talk, we enlarge the classes of (super) edge-magic 2-regular graphs by presenting a construction that allows to generate (super) edge-magic 2-regular graphs from previously known (super) edge-magic 2-regular graphs.

Especialy the construction in this talk gives a heretofore unknown way of obtaining super edge-magic 2-regular graphs from other super edge-magic 2-regular graphs of smaller order. (Friday 1:55)

Finding k-angulations on point sets

Helmut Alt, Michael S. Payne*, Jens M. Schmidt and David R. Wood

University of Melbourne

We consider the general question, given a class C of planar graphs and a set P of points in the plane, does P admit a drawing of some graph in C? That is, is there a straight-line drawing of some graph in C in the plane with vertex set P?

In particular, we consider C to be the k-angulations, plane graphs in which every face is a k-gon except for one external face. We investigate the conditions under which a point set P admits a 2-connected k-angulation, and find that (for large enough point sets) the only obstructions are topological ones given by Euler's formula. (Tuesday 4:15)

Cycle decomposition problem for complete graphs

William Pettersson*, Darryn Bryant and Daniel Horsley

University of Queensland

In 1981 Brian Alspach asked whether the obvious necessary conditions for the existence of a decomposition of the complete graph into edge-disjoint cycles of specified lengths were also sufficient. A lot of work has been done on this problem over the last 30 years. In this talk I will outline a very promising new approach, and focus on one particular aspect of this approach which involves cycle decompositions of certain circulant graphs. (Monday 5:05)

Characterisations of graphs of small defects and some of its applications

Ramiro Feria-Purón, Mirka Miller and Guillermo Pineda-Villavicencio*

University of Ballarat

We consider the *degree/diameter problem for the network class* $\mathcal{C}$, namely, given a network class $\mathcal{C}$ and bounds for the degree and diameter of any network in $\mathcal{C}$, how large (in terms of number of nodes) can a network of $\mathcal{C}$ be? In this context, there are a couple of known upper bounds; for general graphs we have the *Moore bound* $\mathrm{M}(\Delta, D)$ and for bipartite graphs the bipartite Moore bound $\mathrm{M}^b(\Delta, D)$.

(Bipartite) Graphs of maximum degree Δ, diameter D and order $(\mathrm{M}^b(\Delta, D))$ $\mathrm{M}(\Delta, D)$ are called *(bipartite) Moore graphs.* These graphs turned out to be very rare.

In this talk we look at recent characterisations of general and bipartite graphs of order close to the corresponding Moore bounds. These are called *graphs of small defect.* In addition we show how these characterisations can be used to solve some old open problems in the area. (Monday 3:00)

Classifying vertex-transitive graphs according to their arc-types

Tomaž Pisanski*, Primož Potočnik and Gabriel Verret

University of Ljubljana and University of Primorska

In this talk we propose a program for classification of vertex-transitive graphs by their arc-types. It turns out that the number of vertex-transitive types of graphs of valence d coincides with the number of possible root types of real polynomials. The latter have been studied for half-a-century. Our classification system of arc-types enables identification of most well-known classes of vertex-transitive graphs, such as arc-transitive, half-arc-transitive and 0-symmetric graphs. (Friday 12:05)

Minimum degree, graph minors and binary matroids

Gordon Royle

University of Western Australia

The degeneracy number $d(G)$ of a graph G is a fundamental graph invariant defined as the maximum over all subgraphs H of G of the minimum degree of H. It plays a role in the theory of graph colourings, for example providing a strengthening of Brooks' Theorem, and in complexity theory where various algorithms can be shown to be efficient when the input is restricted to graphs of bounded degeneracy.

Given the central role that graph minors play in structural graph theory, it is then natural to consider the "contraction degeneracy" which is defined as the maximum of the minimum degrees over all *minors* of G. This has the advantage that the classes of graphs of bounded contraction degeneracy are *minor-closed* classes of graphs and therefore, by the seminal results of Robertson & Seymour, can be characterised by a finite collection of excluded minors (along with various other consequences of the general theory).

Fijavž & Wood considered the question of determining the excluded minors for the classes of graphs of contraction degeneracy no more than k and obtained a variety of results both for small values of k and for general k.

All of these concepts have immediate extensions to binary matroids, and in fact it could be argued that the matroidal version of contraction degeneracy when restricted to graphic matroids is actually stronger and *more* natural than the original version.

In this accessible talk, where the modest amount of necessary matroid terminology will be introduced, I will report on some preliminary observations, computations and conjectures on this parameter as it relates to binary matroids. More questions will be raised than answered! (Tuesday 3:50)

On inducing polygons and related problems

Eyal Ackerman, Rom Pinchasi, Ludmila Scharf*, Marc Scherfenberg

Freie Universität Berlin

Bose et al. asked whether for every simple arrangement A of n lines in the plane there exists a simple n-gon P that induces A by extending every edge of P into a line. We prove that such a polygon always exists and can be found in $O(n \log n)$ time. In fact, we show that every finite family of curves C such that every two curves intersect at least once and finitely many times and no three curves intersect at a single point possesses the following Hamiltonian-type property: the union of the curves in C contains a simple cycle that visits every curve in C exactly once. (Friday 2:20)

Greedy trees, caterpillars, and Wiener-type graph invariants

Nina S. Schmuck*, Stephan G. Wagner and Hua Wang

Graz University of Technology

The extremal questions of maximising or minimising various distance-based graph invariants among trees with a given degree sequence have been vigorously studied. In many cases, the so-called greedy tree and some caterpillars are found to be extremal. Therefore, the following question naturally arises: What do the distance-based graph invariants look like when the optimal solution of the minimisation problem is the greedy tree and, analogously, when the optimal solution of the maximisation problem is a caterpillar.

We obtain that the greedy tree is optimal for all graph invariants of the form

$$W_f(T) = \sum_{\{u,v\} \subseteq V(T)} f(d(u,v))$$

for any nonnegative, nondecreasing function f. Furthermore, if f is any increasing, convex function, we find that $W_f(T)$ is maximised by a caterpillar. From this result, we also achieve a partial characterisation of the structure of the extremal caterpillars. Additionally, our solutions of both the minimisation and the maximisation problems include not only the classical Wiener index ($f(x) = x$), but also the hyper-Wiener index ($f(x) = \frac{x(x+1)}{2}$) and the generalised Wiener index ($f(x) = x^\alpha$ with $\alpha > 1$). (Wednesday 10:00)

Kernel method and Brownian motion areas

Uwe Schwerdtfeger

RMIT University and University of Melbourne

We derive new recursion formulas for the moments of the area distribution of the Brownian meander and the Brownian excursion (Airy distribution), which occur frequently as limit distributions in combinatorial probability. We do so by studying a simple functional equation relating the generating functions of discrete Bernoulli meanders $M(z,q,u)$ and excursions $E(z,q)$ (Dyck paths), where z, q and u mark the length, area and height of the end point. Their derivatives w.r.t. q (evaluated at $q = 1$, $u = 1$) are essentially the generating functions of the respective area moments and can be recursively computed from said equation, by repeated applications of the kernel method.

A generalisation of the method carries over to a variety of functional equations amenable to the kernel method, and leads to limit distributions of meander area or Airy type for suitably defined parameters, e.g. the area of generalised discrete lattice paths or polyominoes. (Monday 3:50)

Probabilistic matching of solid shapes in arbitrary dimension

Daria Schymura

Freie Universität Berlin

I will describe simple probabilistic algorithms that approximately maximize the volume of overlap of two solid, i.e. full-dimensional, shapes under translations or rigid motions. The shapes are modeled as subsets of the d-dimensional Euclidean space, $d \geqslant 2$. Apart from measurability assumptions, it is only required from the shapes that uniformly distributed random points can be generated. In 2D, an important example of such shapes are polygonal regions.

The algorithms approximate with respect to an prespecified additive error and succeed with high probability. More precisely, let t^{opt} be a translation or rigid motions that maximizes the volume of overlap of two shapes A and B, and let $|\cdot|$ denote the Lebesgue measure. Given an error bound $\varepsilon \in (0,1)$ and an allowable probability of failure $p \in (0,1)$, the algorithms compute a translation or rigid motion t^* such that the difference between optimum and approximation $|t^{opt}(A) \cap B| - |t^*(A) \cap B|$ is at most $\varepsilon|A|$ with probability at least $1-p$.

For translations, the idea of the algorithm is as follows. Given two shapes A and B, a point $a \in A$ and a point $b \in B$ are picked uniformly at random. This tells us that the translation t that is given by the vector $b-a$ maps some part of A onto some part of B. We record this as a "vote" for t and repeat this procedure very often. Then we determine the densest cluster of the resulting point cloud of translation vectors, and output the center of this cluster. Intuitively, this translation maps a large part of A onto B. In the talk, I will describe the algorithm more precisely and also explain the proof idea that it indeed approximates the maximal volume of overlap in the above sense. (Tuesday 3:50)

On cordial labeling: quadrilateral snake related silo and chaplet graphs

P. Selvaraju*, B. Nirmala Gnanam Pricilla

Vel Tech

The motivation of result by I. Cahit and G. Sethuraman et. al., is that every tree is cordial and one edge union of shell graphs and one vertex union of complete bipartite graphs are cordial; we have given cordial labeling for the following graphs.

1. Silo graph $C_{4r} \times tP_n$, $\forall\, r, t \geqslant 1$ and $n > 1$
2. Chaplet graph $C_p \times C'_q$, p, q and t

and also given cordial labeling for the quadrilateral snake graph QS_n attached with each vertex of Silo graph $QS_n(C_{4r} \times tP_n)$ and Chaplet graphs $QS_n(C_p \times C'_q)$. (Friday 3:10)

Better approximate algorithm for $(r \times s)$-puzzle

Kosuke Shinkai* and Toshinori Yamada

Graduate School of Science and Engineering, Saitama University

The $(r \times s)$-puzzle problem consists of rs tiles, $rs-1$ ones numbered from 1 to $rs-1$ and a special one, called the blank tile. These tiles are placed on an $r \times s$ board so that each location of the board is occupied by exactly one tile. An instance of the $(r \times s)$-puzzle problem consists of the board configurations B_1, called the initial configuration, and B_2, final configuration, A *move* is an exchange of two orthogonally adjacent tiles, the blank tile and another one. The goal of the $(r \times s)$-puzzle problem is to find a shortest sequence of moves that transforms B_1 to B_2 if it exists. It is known that it can be checked in a polynomial-time whether there exists a sequence of moves transforming B_1 to B_2. However, the $(r \times s)$-puzzle problem was proved to be $\mathcal{NP}$-hard [D.Ratner *et al.*, "The (n^2-1)-Puzzle and Related Relocation Problems", J.Symbolic Computation, vol.10, pp.111-137, 1990], so the problem cannot be solved in a polynomial-times unless $\mathcal{P} = \mathcal{NP}$. In addition, a polynomial-time constant-approximation algorithm for the $(n \times n)$-puzzle was proposed by the same paper. However, the approximation ratio of the algorithm is quite large, about 200.

In this talk, a new algorithm for the $(r \times s)$-puzzle problem is proposed, and its performance ratio is proved to be at most 58. (Thursday 3:50)

Intersecting rational Beatty sequences

Jamie Simpson

Curtin University

A rational Beatty sequence has the form $\{\lfloor pi/q, b \rfloor : i \in \mathbb{Z}\}$ where $p > q > 0$ and $\gcd(p, q) = 1$. We call p/q the *modulus* of the sequence and b the *offset.* Morikawa gave a condition on the moduli of two Beatty sequences such that they would be disjoint for a suitable choice of offsets. Holzman and Fraenkel showed that the sequence formed by the intersection of two Beatty sequences with moduli p_1/q_1 and p_2/q_2, $q_2 \leqslant q_1$, could have as many as $q_2 + 3$ distinct consecutive differences. In this note we show that if the moduli satisfy the Morikawa condition but the sequences do intersect then the consecutive differences take on at most three different values. (Tuesday 3:00)

The problem with counting bases

Michael Snook

Victoria University of Wellington

It is #P-complete to count the number of bases of a representable matroid over any fixed field. This result was claimed by Vertigan in 1991. However, no publication was produced and this result has somewhat fallen in to Myth. We will discuss similar results and our progress towards remedying this situation. (Tuesday 4:40)

Homotheties in Minkowski planes

Günter Steinke

Department of Mathematics and Statistics, University of Canterbury, New Zealand

Minkowski planes are incidence geometries with points, lines (also called generators) and blocks (normally called circles). They are extensions of affine planes by a family of hyperbolic ovals. A finite Minkowski plane of order n is equivalent to a sharply 3-transitive set of permutations of degree $n+1$. All known finite Minkowski planes have order a prime power q and correspond to $\mathsf{PSL}(2,q) \cup (\mathsf{PGL}(2,q) \setminus \mathsf{PSL}(2,q))\alpha$ where α is an automorphism of the Galois field of order q.

A $\{p,p'\}$-*homothety* of a Minkowski plane $\mathcal{M}$ is an automorphism of $\mathcal{M}$ that fixes the two points p and p' and induces a homothety with centre p' in the derived affine plane of $\mathcal{M}$ at p. Monica Klein investigated in 1992 the set of all 2-sets $\{p,p'\}$ for which the group of all $\{p,p'\}$-homotheties in a given group Γ of automorphisms of $\mathcal{M}$ is transitive on $C \setminus \{p,p'\}$ where C is any circle through p and p'. She obtained a list of 23 possible configurations for this set, called the type of Γ. There are examples of groups of automorphisms of (certain) Minkowski planes for each of the 23 types. It has been shown since that many of these types can only occur for proper subgroups of the full automorphism group of the so-called miquelian Minkowski planes (those planes corresponding to the group $\mathsf{PGL}(2,F)$ where F is a field).

In this talk we review what is known about the types of the full automorphism groups of Minkowski planes. We further extend these results by excluding several more types in the case of finite Minkowski planes. (Thursday 10:50)

NetMODE: Network motif detection without Nauty

Xin Li, Douglas S. Stones*, Haidong Wang, Hualiang Deng, Xiaoguang Liu, Gang Wang

Clayton School of Information Technology, Monash University

A motif in a network is a connected graph that occurs significantly more frequently as an induced subgraph than would be expected in a similar randomized network. By virtue of being atypical, it is thought that motifs might play a more important role than arbitrary subgraphs. Motif detection is typically performed by subgraph enumeration in the input network and an ensemble of comparison networks; this poses a significant computational problem.

We implement a motif detection package, which we call *NetMODE*. NetMODE can only perform motif detection for k-node subgraphs when $k \leqslant 6$, but does so without the use of Nauty. To avoid using Nauty, NetMODE has an initial pretreatment phase, where k-node graph data is stored in memory ($k \leqslant 5$). For $k = 6$ we take an approach which relates to the Reconstruction Conjecture for directed graphs. We find that NetMODE can perform up to around 30 times faster than its predecessors when $k \leqslant 5$ and up to around 20 times faster when $k = 6$ (the exact improvement varies considerably). (Friday 2:20)

Independent spanning trees of star graphs

Hideaki Suto* and Toshinori Yamada

Graduate School of Science and Engineering, Saitama University

Let G be a connected graph, and $V(G)$ and $E(G)$ denote the vertex and the edge set of G, respectively. Let T and T' be two spanning trees of G, and r be a vertex in G. T and T' are called independent spanning trees, ISTs for short, rooted at r if, for any vertex $v \in V(G)$, the unique path connecting r and v on T and that on T' are internally vertex-disjoint. It is important to find ISTs of a given graph as many as possible because ISTs can be used for a fault-tolerant oblivious broadcasting on a network represented by the graph.

A graph G is said to be k-connected if the graph obtained from G by deleting any $k-1$ vertices is connected. Menger's Theorem states that A graph G is k-connected if and only if G has k internally vertex-disjoint path connecting any pair of vertices. Thus, If G has k ISTs rooted at r for any vertex $r \in V(G)$ then G is k-connected. However, it is open whether any k-connected graph G has k ISTs rooted at r for any vertex $r \in V(G)$, which is conjectured by Zehavi and Itai [A. Zehavi and A. Itai, "Three Tree-Paths," J. Graph Theory, vol.13, pp.175–188, 1989].

In this talk, the n-star graph S_n, which is $(n-1)$-connected, is shown to have $n-1$ ISTs rooted at r for any vertex $r \in V(S_n)$. In addition, for any vertex $v \in V(S_n)$, it is proved that the length of the unique path connecting r and v on each of $n-1$ ISTs is at most the distance between r and v on S_n plus 4. (Monday 12:05)

Some combinatorial results for the semigroup of order-decreasing partial isometries of a finite chain

R. Kehinde, S. O. Makanjuola and A. Umar*

Sultan Qaboos University, OMAN

Let $X_n = \{1, 2, \cdots, n\}$ and $\mathcal{I}_n$ be the partial one-to-one transformation semigroup on X_n under composition of mappings. Then $\mathcal{I}_n$ is an *inverse* semigroup (that is, for all $\alpha \in \mathcal{I}_n$ there exists a unique $\alpha' \in \mathcal{I}_n$ such that $\alpha = \alpha\alpha'\alpha$ and $\alpha' = \alpha'\alpha\alpha'$). The importance of $\mathcal{I}_n$ (more commonly known as the symmetric inverse semigroup or monoid) to inverse semigroup theory may be likened to that of the symmetric group $\mathcal{S}_n$ to group theory. The symmetric inverse semigroup is an enormously rich algebraic structure with many interesting subsemigroups. In this talk we discuss two subsemigroups of $\mathcal{I}_n$: the subsemigroup of order-decreasing partial isometries $\mathcal{DDP}_n$ and the subsemigroup of order-preserving and order-decreasing partial isometries $\mathcal{ODDP}_n$. We investigate the cardinalities of some natural equivalences on $\mathcal{DDP}_n$ and $\mathcal{ODDP}_n$ which lead naturally to obtaining the orders of the subsemigroups.
(Thursday 5:05)

Balanced (C_5, C_{20})-foil designs and related designs

Kazuhiko Ushio

Kinki University

Let K_n denote *the complete graph* of n vertices. Let C_5 and C_{20} be *the* 5-*cycle* and *the* 20-*cycle*, respectively. *The* (C_5, C_{20})-$2t$-*foil* is a graph of t edge-disjoint C_5's and t edge-disjoint C_{20}'s with a common vertex. When K_n is decomposed into edge-disjoint sum of (C_5, C_{20})-$2t$-foils and every vertex of K_n appears in the same number of (C_5, C_{20})-$2t$-foils, we say that K_n *has a balanced* (C_5, C_{20})-$2t$-*foil decomposition*. This decomposition is to be known as *a balanced* (C_5, C_{20})-$2t$-*foil design*.

Theorem 1. K_n has a balanced (C_5, C_{20})-$2t$-foil design if and only if $n \equiv 1 \pmod{50t}$.
Theorem 2. K_n has a balanced C_{25}-t-foil design if and only if $n \equiv 1 \pmod{50t}$.
Theorem 3. K_n has a balanced (C_{10}, C_{40})-$2t$-foil design if and only if $n \equiv 1 \pmod{100t}$.
Theorem 4. K_n has a balanced C_{50}-t-foil design if and only if $n \equiv 1 \pmod{100t}$.
Theorem 5. K_n has a balanced C_{75}-t-foil design if and only if $n \equiv 1 \pmod{150t}$.
Theorem 6. K_n has a balanced C_{100}-t-foil design if and only if $n \equiv 1 \pmod{200t}$.
Theorem 7. K_n has a balanced C_{125}-t-foil design if and only if $n \equiv 1 \pmod{250t}$.
Theorem 8. K_n has a balanced C_{150}-t-foil design if and only if $n \equiv 1 \pmod{300t}$.
Theorem 9. K_n has a balanced C_{175}-t-foil design if and only if $n \equiv 1 \pmod{350t}$.
Theorem 10. K_n has a balanced C_{200}-t-foil design if and only if $n \equiv 1 \pmod{400t}$.
Theorem 11. K_n has a balanced C_{225}-t-foil design if and only if $n \equiv 1 \pmod{450t}$.
Theorem 12. K_n has a balanced C_{250}-t-foil design if and only if $n \equiv 1 \pmod{500t}$.
(Monday 10:00)

The number of subsquares in a Latin square

Josh Browning, Michael Kinyon, Doug Stones, Petr Vojtěchovský, Ian Wanless*

Monash University

A subsquare of a latin square is a submatrix that is itself a latin square. I will survey old and new results relating to the question 'How many subsquares of order k can there be in a latin square of order n?'. I will consider the minimum possible (usually zero, though not always easy to show it is), the maximum possible, and talk briefly about the typical number (if a latin square is generated randomly). Unsurprisingly, the squares with the maximum number of subsquares tend to have interesting algebraic structure. (Friday 3:35)

Random real-representable matroids

Geoff Whittle

Victoria University

Matroids capture the notion of a finite geometrical configuration. Real-representable matroids are particularly natural—they are essentially the finite configurations of classical projective geometry. There is a natural notion of isomorphism for real-representable matroids and, modulo this, it makes sense to study the properties of random real-representable matroids. The talk will focus on our disgraceful ignorance of the properties of random real-representable matroids. (Friday 11:15)

Hamiltonicity and Hamilton-connectedness of 3-arc graphs

Guangjun Xu* and Sanming Zhou

The University of Melbourne

An arc of a graph is an oriented edge and a 3-arc is a 4-tuple (v, u, x, y) of vertices such that both (v, u, x) and (u, x, y) are paths of length two. The 3-arc graph of a graph G is defined to have vertices the arcs of G such that two arcs uv, xy are adjacent if and only if (v, u, x, y) is a 3-arc of G. In this paper we study the Hamiltonicity and Hamilton-connectedness of 3-arc graphs. We present a necessary and sufficient condition for a 3-arc graph to be Hamiltonian, and prove that the 3-arc graphs of Hamilton-connected graphs are also Hamilton-connected. (Tuesday 11:15)

The α-arboricity of complete uniform hypergraphs

J.-C. Bermond, Y. M. Chee, N. Cohen and X. Zhang*

Monash University

There is a natural bijection between database schemas and hypergraphs, where each attribute of a database schema D corresponds to a vertex in a hypergraph $\mathcal{H}$, and each relation R of attributes in D corresponds to an edge in $\mathcal{H}$. Many properties of databases have therefore been studied in the context of hypergraphs. One such property of databases is the important notion of α-acyclicity. Many NP-hard problems concerning databases can be solved in polynomial time when restricted to instances for which the corresponding hypergraphs are α-acyclic. The α-arboricity of a hypergraph $\mathcal{H}$ is the minimum number of α-acyclic hypergraphs that partition the edge set of $\mathcal{H}$. This talk will describe some methods of determining α-arboricities of complete uniform hypergraphs based on the existence of Steiner systems. (Tuesday 3:00)

$L(2,1)$-labellings of outerplanar graphs with maximum degree three

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An $L(2,1)$-labelling of a graph G is an assignment of a nonnegative integer to each vertex of G such that adjacent vertices receive integers that differ by at least two and vertices at distance two receive different integers. The span of such a labelling is the difference between the largest and smallest integers used. The λ-number of G, denoted by $\lambda(G)$, is the minimum span over all $L(2,1)$-labellings of G.

Bodlaender *et al.* conjectured that if G is an outerplanar graph of maximum degree Δ, then $\lambda(G) \leqslant \Delta + 2$. Calamoneri and Petreschi proved that this conjecture is true when $\Delta \geqslant 8$ but false when $\Delta = 3$. Meanwhile, they proved $\lambda(G) \leqslant \Delta + 5$ for any outerplanar graph with $\Delta = 3$ and asked whether this bound is sharp. Answering this question, we prove that $\lambda(G) \leqslant \Delta + 3$ for any outerplanar graph with $\Delta = 3$. We also show that $\Delta + 3$ can be achieved by infinitely many outerplanar graphs with $\Delta = 3$. (Monday 10:50)

Monday	Tuesday	Wednesday	Thursday	Friday
Praeger	**Billington**	**Vojtechovsky**	**Evans**	**Ostergard**
Greenhill/Ushio	Jackson/Brand	Schmuck/Maenhaut	Little/Fear	Nakamoto/Barat
Tea	**Tea**	**Tea**	**Tea**	**Tea**
Zhou/Osborn	Harvey/Bennett	**Cavenagh**	Miljenovic/Steinke	Conder/Britz
Jia/OCathain	Xu/Combe		Jooyandeh/Bamberg	Alspach/Whittle
Moktar/Leopardi	**Edwards**	**Excursion**	**Cameron**	Kreher/Chun
Suto/Chen				Pisanski/Newman
Lunch	**Lunch**		**Lunch**	**Lunch**
				Giudici/Horsley
McKay	**Webb**		**Wood**	Ogata/Oshima
				Scharf/McLeod
Pineda/Bukovac	Zhang/Simpson		Glen/Makowsky	Morgan/Stones
Tea	**Tea**		**Tea**	Farr/Selvaraju
				Wanless / ––
Schwerdtfeger/Herke	Schymura/Royle		Shinkai/Conflitti	**Survivor's Party**
Heuberger/Maruta	Payne/Mayhew		Ho/Kalinowski	
Haythorpe/Demirkale	Mukae/Snook		Krzywkowski/Keller	
Filar/Pettersson	Matsumoto/Brettell		Minchenko/Umar	
CMSA AGM	Burton/Clark		**Banquet**	
	Penguins			