PCC 2009

20th Postgraduate Combinatorial Conference

22 – 24 June 2009

Royal Holloway, University of London

Welcome to the Postgraduate Combinatorial Conference 2009 at the Royal Holloway, University of London!

We are very pleased to see so many of you here, and hope that everyone will have an interesting and enjoyable time at the conference. We are particularly delighted to welcome our invited speakers Prof. Andrew G. Thomason, Prof. Dave Cohen, Dr. Anders Yeo, Prof. Derek Smith and Dr. Angela Koller. All of us organisers will be happy to help you with any queries. Best wishes for the conference and beyond,

Arezou, EunJung and Sian.

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General Information

Invited Speakers

Prof. Andrew G. Thomason. Department of Pure Mathematics and Mathematical Statistics, University of Cambridge, Cambridge, England

Prof. Derek Smith. Faculty of Advanced Technology, University of Glamorgan, Pontypridd, Wales.

Prof. Dave Cohen. Department of Computer Science, Royal Holloway University of London, England

Dr. Anders Yeo. Department of Computer Science, Royal Holloway University of London, England.

Dr. Angela Koller. Speaker from industry.

Sponsors

We are immensely grateful for the very generous support from our sponsors:

- The London Mathematical Society (LMS): `www.lms.ac.uk`
- The British Combinatorial Committee (BCC): `www.maths.qmul.ac.uk/~pjc/bcc`

Their financial contributions reduced the registration fees we have had to charge considerably.

Talks

All talks will be held in the Management Annexe lecture theatre MX01 (13 on the map, page 6). A computer, a data projector, an overhead projector, a whiteboard and pens will be provided.

Accommodation

Delegate accommodation is provided in Runnymede (43 on the map, page 6), check-in with Customer Services at the Hub, from Monday 22 July until the morning of Wednesday 24 July. Checkout before 10:00am on Wednesday 24 July.

Catering

- Breakfast will be served on Tuesday and Wednesday in The Athlone HUB (number 41 on the map, page 6) 07:30 - 08:59.
- Morning and afternoon tea & coffee breaks will take place in the Moore Annexe (13 on the map, page 6).
- Lunch on Monday and Tuesday will be served in the Moore Annexe 12:00 - 14:00.
- The evening meal on Monday and the Conference Dinner on Tuesday will be served in the SCR 18:00 to 20:00 (1 on the map, page 6).

Internet Access

Connect to the wireless network **CampusNet** using the following details:
First Name: **Combinatorial**
Last Name: **Conference**
Password: **RHUL**

PCC 2010

This is the 20th Postgraduate Combinatorial Conference (PCC). In previous years the conference was held at the following universities:

- PCC 2008 at the University of Warwick,
- PCC 2007 at the University of St Andrews,
- PCC 2006 at the University of Glamorgan,
- PCC 2005 at the University of Oxford,
- PCC 2004 at Queen Mary, University of London,
- PCC 2003 at the University of Nottingham.

Why don't you organise next year's PCC? Feel free to speak to any of this year's organisers about what's involved.

Organising Committee

Arezou Soleimanfallah , Royal Holloway, University of London
EunJung Kim, Royal Holloway, University of London
Sian Jones, University of Glamorgan

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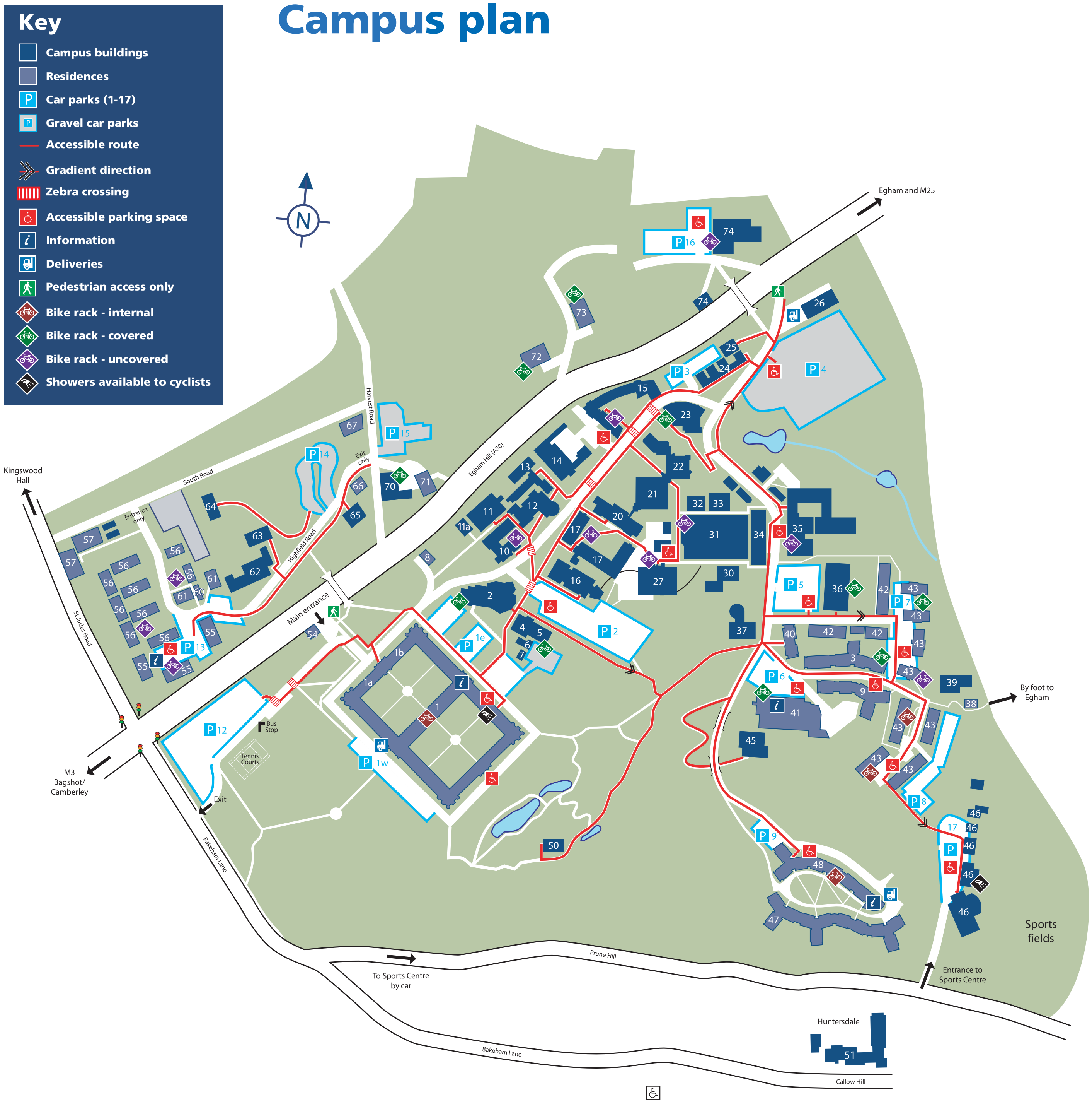
URL: `www.cs.rhul.ac.uk/PCC2009/`

Campus plan



A more detailed guide to the practical nature of the College's accessible routes for the mobility impaired is available through the Educational Support Office (based in the Founder's Building)

Academic departments and centres

Archive and Bedford Centre	1	Founder's Building
Biological Sciences	31, 34	Bourne & Wolfson Laboratories
Classics	1	Founder's Building (west ground floor)
Computer Science	17	McCrea Building
Drama & Theatre	74	Sutherland House and Lodge ☒
	25, 14	Handa Noh Theatre, Boilerhouse
Earth Sciences	35, 36	Queen's Building & Annexe
Economics	20	Horton Building ☒ (upper floor)
English	15	International Building
European Studies	1	Founder's Building (west first floor)
Geography	35, 36	Queen's Building & Annexe
Health & Social Care	16	Arts Building ☒ (upper floors)
Hellenic Institute	15	International Building
History	17	McCrea Building
Management	12, 13, 1	Moore Building ☒, Annexe & Founder's Building (east first floor)
Mathematics	17	McCrea Building
Media Arts	11	Williams Building ☒ & Arts Building (ground floor)
Modern Languages	15	International Building
French	15	International Building
German	15	International Building
Hispanic Studies	15	International Building
Italian	15	International Building
Music	62, 65	Wetton's Terrace ☒, Woodlands ☒
Physics	21, 22	Tolansky & Wilson Laboratories
Politics & International Relations	1	Founder's Building (west first floor)
Psychology	34, 30	Wolfson Laboratory, Bourne Annexe
Royal Holloway International	15	International Building

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☒ Non-accessible Buildings

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Programme

Monday 22 June

11:00 – 12:15	*Check-in with Customer Services at the Hub*
12:15 – 12:45	*Meet at Moore Annex*
12:45 – 13:30	*Lunch at the Moore Annex*

Session 1	*Chair: EunJung Kim*
13.30 – 13.35	**Welcome by Dr Adrian Johnstone**
13.35 – 14.35	**Dr. Anders Yeo**: Transversals in Hypergraphs, Total Domination in Graphs and Other Related Problems
14.40 – 15.00	**Arezou Soleimanfallah**: A new kernel of size $2k - c$ for the Vertex Cover Problem
15.00 – 15.30	*Tea & coffee*

Session 2	*Chair: Ryan Davies*
15.30 – 15.50	**Linzy Phillips**: Encoding Information in a Sudoku Grid
15.50 – 16.10	**Sian Jones**: Unavoidable Sets in Sudoku and Quasi-Magic Sudoku Grids
16.10 – 16.30	**Niema Aboluion**: Construction of DNA codes

Session 3	*Chair: Emil Vaughan*
16.45 – 17.45	**Prof. Andrew G. Thomason**: 2-Coloured Graphs, Multigraphs and Hereditary Properties
18.00 –	*Dinner & drinks at the Founder's Building - SCR*

Tuesday 23 June

07.30 – 08.59	*Breakfast at The Hub*
Session 4	*Chair: Matthew White*
09.30 – 10.30	**Prof. Dave Cohen**: Arrow's Theorem Showing That There is No Fair Voting System
10.30 – 11.00	*Tea & coffee*
Session 5	*Chair: Manuela Heurer*
11.10 – 11.30	**Tony Forbes**: Eleven billion STS(19)s
11.30 – 11.50	**Costas Psomas**: Biembeddings of Steiner triple systems using the Bose construction
11.50 – 12.10	**Matthew White**: 2-Factors in Hamiltonian Graphs
12.15 – 12.45	*Photos*
12.45 – 13.30	*Lunch at the Moore Annex*
Session 6	*Chair: Sian Jones*
13.50 – 14.50	**Prof. Derek Smith**: Old and New Problems in Coding Theory
15.00 – 16.30	*Tea & coffee*
Session 7	*Chair: Linzy Phillips*
16.45 – 17.05	**EunJung Kim**: Algorithm for Finding k-Vertex Out-trees and its Application to k-Internal Out-branching Problem
17.05 – 17.25	**Daniel Karapetyan**: A Memetic Algorithm for the Multidimensional Assignment Problem
17.25 – 17.45	**John Faben**: Reducing Graphs by Involutions
19.00 –	*Conference dinner at the Founder's Building - SCR*

Wednesday 24 June

07.30 – 08.59	*Breakfast at The Hub*
Session 8	*Chair: Arezou Soleimanfallah*
09.05 – 10.05	**Dr. Angela Koller**: Graph Theory in Industry
10.05 – 11.00	*Goodbye Tea & coffee*

Abstracts of Invited Talks

Transversals in hypergraphs, total domination in graphs and other related problems

Anders Yeo
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(joint work with Michael Henning, Arezou Soleimanfallah and Stephan Thomasse)

A set S of vertices in a graph G is a total dominating set of G if every vertex of G is adjacent to some vertex in S. The minimum cardinality of a total dominating set is called the *total domination number*.

A *hypergraph*, H, contains a vertex set denoted by $V(H)$ and an edge set denoted by $E(H)$. Every hyper-edge in H is a subset of the vertices. For graphs these sets all have size tw0, but for hypergraphs they can have any size. A *transversal* (also called a *hitting set*) in a hypergraph, H, is a set of vertices $T \subseteq V(H)$, such that every hyper-edge in $E(H)$ contains at least one vertex from T.

We will both give bounds on the size of transversals in several kind of hypergraphs and show how these bounds can be used to obtain many different kind of bounds for the total domination number of a graph with properties such as *(i) minimum degree 3 or 4*, *(ii)* 2*-connected*, *(iii) minimum degree 2, containing no induced* 6*-cycles* and *(iv) minimum degree 3, containing no* 4*-cycle*.

The area of *fixed parameter tractable algorithms* is new, interesting and growing rapidly. As finding transversals in 3-uniform hypergraphs (i.e. all edges contain 3 vertices) has many application, we will mention a fixed parameter tractable algorithm for this problem. This algorithm can immediately be used in areas such as computational biology (related to phylogenetic trees) and tournaments (finding a minimum feedback vertex set). The time complexity of our algorithm beats all previously know algorithms.

We finally mention several open problems and conjectures.

Keywords: Hitting Set, Transversal, Hypergraph, Total Domination.

2-coloured graphs, multigraphs and hereditary properties

Andrew Thomason
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(joint work with Ed Marchant)

Several different lines of study, such as those of Ramsey games, the probability of hereditary graph properties, and the computational complexity of graph testing, all lead to the following extremal problem for 2-coloured graphs.

A 2-coloured graph is a graph whose edges are coloured red, blue or green. A 2-coloured graph H is contained in another one G if H is a subgraph of G in a way that respects the colours, except that green is a wildcard, meaning that a green edge of G can represent an edge of H of any colour. The weight of the graph G is the sum of its edge weights, these being p, q or $1 = p + q$ according as the edge is red, blue or green. The extremal problem is to find the maximum weight of a graph G that does not contain some forbidden graph H.

It is possible to prove quite a lot about the broad structure of the extremal configurations, which makes it possible to find the maximum weight for many graphs H, so yielding progress in the applications mentioned. But many questions remain unresolved.

MSC2000: 05C35.

Keywords: hereditary graph properties, Szemerédi's regularity lemma, Ramsey games.

Arrow's Theorem Showing That There is No Fair Voting System

Dave Cohen
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Back in 1953 an economist, Ken Arrow, proved a key result concerning social welfare. The problem he addressed was how individual preferences can be aggregated to derivea social preference.

Of course this is a problem in combinatorics. The existence of a function from a collection of individual quasi-orderings to a single quasi-ordering which satisfiescertain properties. Arrow proved that, under very natural conditions, such a function does not exist.

This has had implications on social and economic theory ever since and many economists have come back to the problem.The original proof, which was notparticularly illuminating, has been considerably simplified since Arrow's time and many systems for avoiding the impossibility have been proposed.Papers on the subject are still being published in 2009.

In this talk we will consider such social welfare functions.We will give twoproofs of the impossibility result: one simple and direct, the other using-interesting combinatorics and appealing to well-known results.We will also explain a subsequent issue - the liberal paradox - which has tested thinkers both on theright and the left of socio-economic thinking.

Old and new problems in coding theory

Derek H. Smith
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This talk describes some problems in coding theory arising from areas as diverse as data compression, genetics and interference mitigation in code-division multiple-access (CDMA) radio systems.

Huffman codes are variable length codes designed for data compression. Although better data compression techniques are available, they still find a role in combination with these techniques. In common with most data compression methods they can potentially suffer from massive error propagation. Alternative codes such as HE-codes and T-codes have been proposed, but do not always exist. Codes known as OT-codes exist for all required length vectors and resynchronize more quickly. It is suggested that OT-codes should always be used in preference to Huffman codes. An important problem that remains concerning OT-codes is outlined.

Coding theory is beginning to find significant application in Biology. Some of these applications are outlined, in particular to the design of synthetic DNA strands.

In synchronous or quasi-synchronous CDMA systems the rows of Hadamard matrices form codewords or are used in the construction of codewords. The fact that the inner product of rows is zero is exploited to avoid interference. If more codewords are required several Hadamard matrices can be used, but the inner product of rows will no longer be zero and interference will be greater. It is shown that it is possible to select four Hadamard matrices and assign the rows to a tessellation of hexagonal cells in such a way that rows assigned to the same cell or to adjacent cells have zero inner product. The extension of the idea to asynchronous CDMA is discussed.

MSC2000: 94A29, 92D20, 05B20.

Keywords: Variable length codes, DNA codes, CDMA, Hadamard matrices.

Angela Koller
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In this session we will hear how a PhD in Graph Theory can be useful in the Insurance Industry. Angela will briefly talk about her background, how she found her current job in the city and what areas in General Insurance she is working on. She will then focus on a few particularly interesting problems, where using optimisation, general mathematical knowledge and transferrable skills all played an important role.

Keywords: General Insurance, Industry, Optimisation, Geometry.

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Abstracts of Contributed Talks

Session 2

A new kernel of size $2k - c$ for the Vertex Cover Problem

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(joint work with Anders Yeo)

Given a graph $G = (V, E)$, a vertex cover is a set $VC \subset V(G)$ such that for every edge $uv \in E(G)$, we have $\{u, v\} \cap VC \neq \emptyset$. The Parameterised Vertex Cover is defined as: given a graph $G = (V, E)$ and a positive integer k, does there exist a vertex cover VC in G such that $|VC| \leq k$? This problem belongs to the class of FPT problems. Vertex Cover is amongst the well-studied problems of graph theory. Amongst the motivations for studying this problem lies its application in real life. For example in computational biology, the "Gene Conflict Resolution" problem is solved using the classic Vertex Cover by constructing a graph $G = (V, E)$ and associating vertices with genes and edges with conflicting pairs. The problem asks if there is a way of finding a minimum size set of genes such that if deleted all inconsistencies will be removed. The solution to the Vertex Cover problem in G will then answer this question. Here we introduce a kernel of size $2k - c$ for this problem. We, in particular, show that for every positive integer c, there exists a polynomial algorithm that either given an instance (G, k) for the Vertex Cover, constructs another instance (G', k'), where the graph G' contains at most $2k' - c$ vertices such that $k' \leq k$ and the graph G has a vertex cover of size k if and only if the graph G' has a vertex cover of size k'. Or the algorithm returns the answer to the Vertex Cover problem. Our result is an improvement over the best known kernel of size $2k$ introduced by Chen et. al. in 2001.

MSC2000: 05B40,30C10.

Keywords: vertex cover, kernel, FPT.

Session 2

Encoding Information in a Sudoku Grid

Linzy A. Phillips
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(joint work with Stephanie Perkins, Paul A. Roach, Derek H. Smith)

Recently Sudoku, and related structures, have attracted attention for their potential applications to fields such as erasure correction. Sudoku supports the requirements of an erasure-correcting code, as both are concerned with the deduction or recovery of data from partial, given information. One problem that arises is how the information to be transmitted should best be encoded in the Sudoku grid. An initial candidate is the use of the minigrids on the leading diagonal, although it would be desirable to extend this encoding if possible. It can be shown computationally that data suitably written in these minigrids can always be extended to a valid grid, but a theoretical proof would be preferable. In this talk, such a proof is given for the simpler Rudoku puzzle, and extensions are discussed.

MSC2000: 05B30.

Keywords: Sudoku, Rudoku, Erasure-Correcting Codes.

Unavoidable Sets in Sudoku and Quasi-Magic Sudoku Grids

Sian K. Jones
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A Sudoku grid is a 9×9 Latin Square further subdivided so that nine 3×3 'mini-grids' also contain the numbers $1, \ldots, 9$. A Quasi-Magic Sudoku has the further constraint that every row, column and diagonal of each mini-grid sums to 15 ± 2.

A discussion will be given here of how unavoidable sets in Sudoku puzzles and Quasi-Magic Sudoku puzzles affect the uniqueness of their solution.

MSC2000: 05B15.

Keywords: Latin Squares, Sudoku, Intercalates.

Construction of DNA codes

Niema Ali Aboluion
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Coding theory has several application in genetics. In this talk we concentrate on a specific application from Computational Biology. This concerns the construction of DNA codes using an alphabet of four symbols. These are used in DNA computing, as bar codes in molecular libraries and in microarray technologies. DNA codes constructed satisfy a GC-content constraint and a minimum Hamming distance constraint. They are derived from linear codes over $GF(4)$ and Z_4, additive codes over $GF(4)$, and their cosets. The software system Magma is used for the implementation. Previous approaches to the construction of these codes are extended in several ways. The codes found include many new bests, and longer codes are constructed than are available in the literature. Future work, which includes the addition of a reverse complement constraint, is outlined.

MSC2000: 94B05, 94B15, 92D20.

Keywords: DNA codes, Linear codes, Cyclic codes.

Session 5

Eleven billion STS(19)s

Tony Forbes
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(joint work with Terry Griggs)

A *Steiner triple system* of order $v > 0$, also known as an STS(v), is a type of block design consisting of a v-element set of *points*, V, together with a set, $\mathcal{B}$, of 3-element subsets of V called *blocks* (or triples or lines) such that every pair of points appears in precisely one block of $\mathcal{B}$. Steiner triple systems exist for every $v \equiv 1$ or 3 (mod 6) and the size of the block set is $v(v-1)/6$.

Up to isomorphism the numbers of STS(v)s for $v = 1, 3, 7, 9, 13$ and 15 are 1, 1, 1, 1, 2 and 80 respectively, and for the block sets of typical representatives of the first four, we have {}, {012}, {012, 034, 135, 236, 146, 245, 056} and {012, 345, 678, 036, 147, 258, 057, 138, 246, 048, 156, 237}. The STS(7) is the familiar projective plane of order 2 and the STS(9) is the affine plane of order 3.

When $v = 19$ the number is somewhat larger. Last year the STS(19)s were enumerated by Kaski, Östergård, Pottonen & Kiviluto, repeating an earlier computation by Kaski & Östergård in 2000. This time, however, the actual systems were recorded in addition to being counted and are currently available in compressed format to any interested researcher. I received my copy for Christmas 2008, and I shall be talking about some of the things I and others have been doing with this huge finite set of designs. The exact number is 11,084,874,829.

MSC2000: 05B07.

Keywords: Steiner triple system.

Biembeddings of Steiner triple systems using the Bose construction

Costas Psomas
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(joint work with Prof Jozef Širáň & Prof Terry Griggs)

A face two-colourable triangulation of a complete graph on a surface gives rise to a biembedding of two Steiner triple systems. I will explain how such biembeddings in both orientable and nonorientable surfaces can be constructed starting from the well-known Bose construction.

MSC2000: 05B07, 05C10.

Keywords: Steiner Triple System, Complete Graph, Topological Graph Theory, Embedding.

2-Factors in Hamiltonian Graphs

Matthew White
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A well-known theorem of Dirac states that a graph with minimal degree at least $\frac{n}{2}$ is hamiltonian, this result was extended by Brandt *et al* to show that a graph with minimal degree at least $\frac{n}{2}$ has a 2-factor with k components for $4k \leq n$. Both results are tight, as shown by the complete bipartite graph with classes of order $\frac{n-1}{2}$ and $\frac{n+1}{2}$ for n odd. However, this graph has no 2-factors at all, and so a natural question is what minimal degree is required in a hamiltonian graph to guarantee a 2-factor with k components. This talk will look at this problem, with particular empathisis on the case $k = 2$.

MSC2000: 05C38, 05C45.

Keywords: Hamilton cycle, 2-factor, minimal degree.

Session 7

Algorithm for Finding k-Vertex Out-trees and its Application to k-Internal Out-branching Problem

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(joint work with N. Cohen, F. V. Fomin, G. Gutin, S. Saurabh and A. Yeo)

An *out-tree* is an oriented tree with only one vertex of in-degree zero called the *root*. The k-OUT-TREE problem is the problem of deciding for a given parameter k, whether an input digraph contains a given out-tree with $k \geq 2$ vertices. In their seminal work on Color Coding Alon, Yuster, and Zwick provided fixed-parameter tractable (FPT) randomized and deterministic algorithms for k-OUT-TREE. While Alon, Yuster, and Zwick only stated that their algorithms are of runtime $O(2^{O(k)}n)$, however, it is easy to see that their randomized and deterministic algorithms are of complexity $O^*((4e)^k)$ and $O^*(c^k)$, where $c \geq 4e$.

The main results of Alon, Yuster, and Zwick, however, were a new algorithmic approach called Color Coding and a randomized $O^*((2e)^k)$ algorithm for deciding whether a digraph contains a path with k vertices (the k-PATH problem). Recently Chen et al. and Kneis et al. developed an approach, called Divide-and-Color, that allowed them to design a randomized $O^*(4^k)$-time algorithm for k-PATH. Divide-and-Color in Kneis et al. (and essentially in Chen et al.) is 'symmetric', i.e., both colors play similar role and the probability of coloring each vertex in one of the colors is 0.5. We further develop Divide-and-Color by making it asymmetric, i.e., the two colors play different roles and the probability of coloring each vertex in one of the colors depends on the color. As a result, we refine the result of Alon, Yuster, and Zwick by obtaining randomized and deterministic algorithms for k-OUT-TREE of runtime $O^*(5.7^k)$ and $O^*(5.7^{k+o(k)})$ respectively.

We apply the above deterministic algorithm to obtain a deterministic algorithm of runtime $O^*(c^k)$, where c is a constant, for deciding whether an input digraph contains a spanning out-tree with at least k internal vertices. This answers in affirmative a question of Gutin, Razgon and Kim (Proc. AAIM'08).

MSC2000: 05C85.

Keywords: subgraph isomorphism, algorithm, tree.

A Memetic Algorithm for the Multidimensional Assignment Problem

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(joint work with Gregory Gutin)

The Multidimensional Assignment Problem (MAP or s-AP in the case of s dimensions) is an extension of the well-known assignment problem. The most studied case of MAP is 3-AP, though the problems with larger values of s have also a number of applications. In this paper we propose a memetic algorithm for MAP that is a combination of a genetic algorithm with a local search procedure. The main contribution of the paper is an idea of dynamically adjusted generation size that yields an outstanding flexibility of the algorithm to perform well for both small and large fixed running times. To evaluate the effect of the proposed approach, a number of computational experiments for several instance families were conducted.

MSC2000: 90C27, 90C59.

Keywords: Multidimensional Assignment Problem, Metaheuristic, Genetic Algorithm, Memetic Algorithm.

Reducing Graphs by Involutions

John Faben
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I will give you a graph, and ask you to pick an involution, any involution. Now delete from the original graph all vertices which are not fixed by this involution. You then pick any involution of your new graph, delete all but its fixed points and repeat the process until you have a graph which is involution-free. Now just by looking at the original graph, I will tell you which graph you are now thinking of.

This is not magic: the choice of involutions, and the order in which they are chosen, is irrelevant. The final graph is uniquely determined by the original. We prove this fact using the theory of confluent reduction systems introduced by Newman in 1942. We also discuss the complexity of determining where this process will end given only the original graph.

MSC2000: 05C60,68Q25.

Keywords: graphs,automorphisms,complexity.

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