Abstracts of the

8th Slovenian Conference on Graph Theory

Kranjska Gora, Slovenia, June 21 – 27, 2015

Institute of Mathematics, Physics and Mechanics
June 2015

Welcome

We thank all of you for coming to the 8th Slovenian conference on Graph Theory and wish you a pleasant and successful meeting in Kranjska Gora.

This conference has come a long way from its first meeting in Dubrovnik (now in Croatia) in 1985. The second meeting of the series *Slovenian Conference on Graph Theory* was held at Lake Bled in 1991, following by the subsequent meetings at the same location in 1995, 1999, 2003, 2007, and 2011. The growth of the conference was stable, from 30 participants at the 1991 meeting to almost 300 participants at the present *8th Slovenian Conference on Graph Theory*. We must admit that it was not an easy decision to move the "Bled conference" to the new location in Kranjska Gora. The number of participants at the present meeting tells us that the decision was right.

There are 9 keynote speakers, 13 invited speakers who have organized 13 minisymposia, and a general session. This booklet contains a total of 247 abstracts from our conference.

Satellite events have made our meeting even more attractive to the mathematical community. The conference *Algorithmic Graph Theory on the Adriatic Coast* took place in Koper from June 16 till June 19, while the *11th Meeting of the International Academy of Mathematical Chemistry* took place in Kranjska Gora from June 18 till June 21. During the week after the conference, the *PhD Summer School in Discrete Mathematics* will take place on Rogla. A meeting of the Editorial and Advisory Boards of the journal *Ars Mathematica Contemporanea* is also planned during the conference.

In last few decades, the growth of the Slovenian graph theory conference was accompanied by a similar growth, both in numbers as well as quality, of the Slovenian graph theory community. This would not have been possible without the help of our friends abroad. At the occasions of their round birthdays, we would like to thank in particular to Tom Tucker (70), Marston Conder, Egon Schulte, and Paul Terwilliger (60).

The organization of this meeting would not have been possible without financial and technical support from the Institute of Mathematics, Physics and Mechanics, Ljubljana (IMFM); University of Ljubljana, Faculty of Mathematics and Physics (UL FMF), and Faculty of Education (UL PeF); University of Maribor, Faculty of Natural Sciences and Mathematics (UM FNM); University of Primorska, Faculty of Mathematics, Natural Sciences and Information Technologies (UP FAMNIT), and Andrej Marušič Institute (UP IAM). We also thank Abelium d.o.o. for their superb technical support.

Sandi Klavžar
Dragan Marušič
Bojan Mohar
Tomaž Pisanski

Kranjska Gora, June 21, 2015

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General Information

KG'15 – 8th Slovenian International Conference on Graph Theory
Kranjska Gora, Slovenia, June 21 – 27, 2015

Organized by:
IMFM (*Institute of Mathematics, Physics and Mechanics*)

In Collaboration with:
UL FMF (*University of Ljubljana, Faculty of Mathematics and Physics*),
UL PeF (*University of Ljubljana, Faculty of Education*),
UM FNM (*University of Maribor, Faculty of Natural Sciences and Mathematics*),
UP FAMNIT (*University of Primorska, Faculty of Mathematics, Natural Sciences and Information Technologies*),
UP IAM (*University of Primorska, Andrej Marušič Institute*),
Abelium d.o.o.

Scientific Committee:
Sandi Klavžar (chair), Dragan Marušič, Bojan Mohar, Tomaž Pisanski

Organizing Committee:
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Local Organizing Committee:
Katja Berčič, Tanja Gologranc, Marko Jakovac, Aleksander Kelenc, Tilen Marc, Polona Repolusk

Conference Venues:
Ramada resort, Borovška cesta 99, SI-4280, Kranjska Gora, Slovenia
Hotel Kompas, Borovška cesta 100, SI-4280, Kranjska Gora, Slovenia

Conference Website:
kg15.imfm.si

Conference Information:
kranjska.gora2015@gmail.com

Plenary speakers:
Michael Giudici, *The University of Western Australia, Perth, Australia*
Michael Henning, *University of Johannesburg, South Africa*
Brendan D. McKay, *Australian National University, Canberra, Australia*
Alexander Mednykh, *Sobolev Institute of Mathematics, Novosibirsk, Russia*
Joy Morris, *University of Lethbridge, Canada*
Gábor Tardos, *Hungarian Academy of Sciences, Budapest, Hungary*
Carsten Thomassen, *Technical University of Denmark, Lyngby, Denmark*
Thomas Tucker, *Colgate University, Hamilton, USA*
Douglas West, *Zhejiang Normal University, Jinhua, China, and University of Illinois, USA*

Invited speakers:
Paul Dorbec, *Université de Bordeaux, LaBRI, France*
Ismael González Yero, *Universidad de Cádiz, Spain*
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Richard Hammack, *Virginia Commonwealth University, Richmond, USA*
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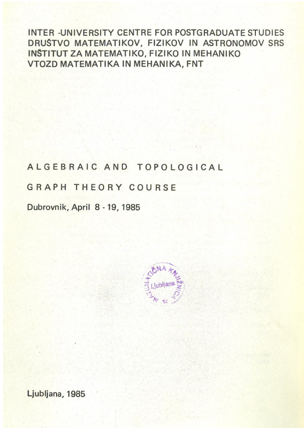
Matjaž Konvalinka, *University of Ljubljana, Slovenia*
Xueliang Li, *Nankai University, Tianjin, China*
Christopher Parker, *University of Birmingham, UK*
Ilya Ponomarenko, *Saint Petersburg Department of V. A. Steklov Institute of Mathematics, Russia*
Ingo Schiermeyer, *Technische Universität Bergakademie Freiberg, Germany*
Egon Schulte, *Northeastern University, Boston, USA*
Dragan Stevanović, *Serbian Academy of Science and Arts, Belgrade, Serbia and University of Primorska, Koper, Slovenia*
Tamás Szőnyi, *Eötvös Loránd University, Budapest, Hungary*

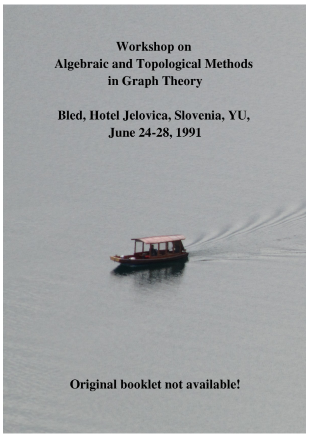
Minisymposia and Minisymposia Organizers:
Applications of Groups in Graph Theory (*Christopher Parker*)
Association Schemes (*Ilya Ponomarenko*)
Chemical Graph Theory (*Xueliang Li*)
Combinatorics (*Matjaž Konvalinka*)
Finite Geometry (*Tamás Szőnyi*)
Graph Imbeddings and Map Symmetries (*Jonathan L. Gross*)
Graph Products (*Richard Hammack*)
Metric Dimension and Related Parameters (*Ismael González Yero*)
Polytopes and Graphs (*Egon Schulte*)
Spectral Graph Theory (*Dragan Stevanović*)
Vertex Colourings and Forbidden Subgraphs (*Ingo Schiermeyer*)
Graph Domination (*Paul Dorbec*)
Structure and Properties of Vertex-Transitive Graphs (*Robert Jajcay*)

Past Conferences



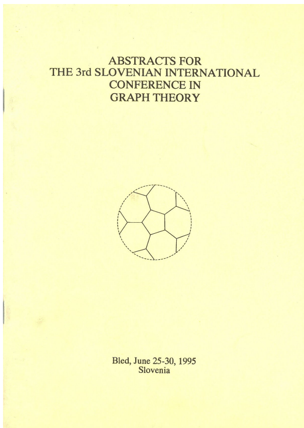
1st Slovenian International Conference on Graph Theory

a. k. a. Algebraic and Topological Graph Theory Course. Dubrovnik (now Croatia), April 8–19, 1985. 47 participants, 10 invited speakers, 37 talks. Scientific Committee: W. Imrich, T. D. Parsons, T. Pisanski.



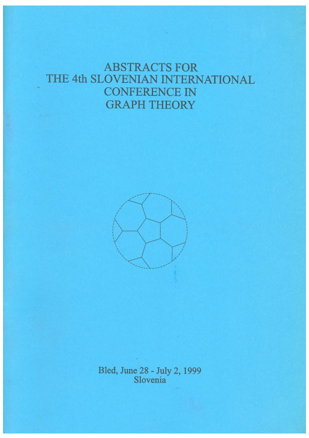
2nd Slovenian International Conference on Graph Theory

a. k. a. Workshop on Algebraic and Topological Methods in Graph Theory. Bled, Slovenia, YU, June 24–28, 1991. Around 30 participants, 7 invited speakers. The meeting started in FLR Yugoslavia and ended in independent Slovenia. Scientific Committee: V. Batagelj, D. Marušič, B. Mohar and T. Pisanski. Conference proceedings printed in a special issue of Discrete Math, Vol 134 (1994).



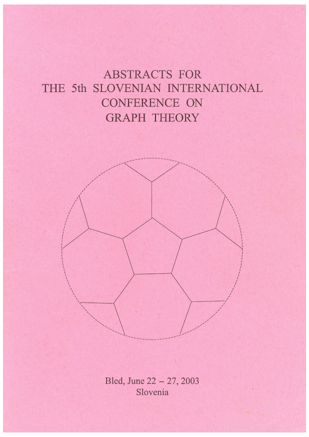
3rd Slovenian International Conference on Graph Theory

Bled, June 25–30, 1995. 8 invited speakers, 79 talks, general session and 6 special sessions. Scientific Committee: D. Marušič and B. Mohar. Conference proceedings printed in a special issue of Discrete Math, Vol 182 (1998).



4th Slovenian International Conference on Graph Theory

Bled, June 28–July 2, 1999. 18 invited speakers, 92 talks. Scientific Committee: S. Klavžar, D. Marušič and B. Mohar. Proceedings in a special issue of Discrete Math, Vol. 244 (2002).



5th Slovenian International Conference on Graph Theory

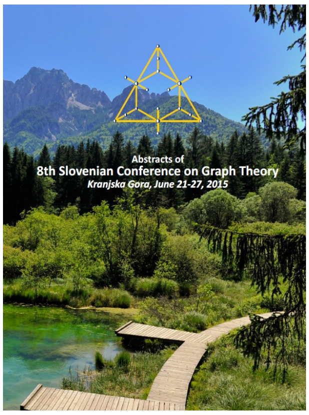
Bled, June 22–27, 2003. 87 participants, 13 invited speakers, 72 talks. Scientific Committee: B. Brešar, M. Juvan, S. Klavžar, D. Marušič, A. Malnič, B. Mohar, T. Pisanski. Conference proceedings printed in a special issue of Discrete Math, Vol. 307 (2007).

6th Slovenian International Conference on Graph Theory

Bled, June 24–30, 2007. 15 invited speakers, 189 registered contributions, general session, 14 minisymposia and 2 satellite conferences. Scientific Committee: S. Klavžar, D. Marušič, B. Mohar, T. Pisanski. Conference proceedings printed in special issues of Discrete Math, Vol. 310 (2010) and Ars Mathematica Contemporanea, Vol. 1 (2008).

7th Slovenian International Conference on Graph Theory

Bled, June 19–25, 2011. 10 keynote speakers, 222 registered contributions, general session, 17 minisymposia and 4 satellite events. Scientific Committee: S. Klavžar, D. Marušič, B. Mohar, T. Pisanski. Conference proceedings printed in special issue of Ars Mathematica Contemporanea, Vol. 6 (2013).



8th Slovenian Conference on Graph Theory

Kranjska Gora, June 21–27, 2015. 9 plenary speakers, 247 registered contributions, general session, 13 minisymposia and 3 satellite events. Scientific Committee: S. Klavžar, D. Marušič, B. Mohar, T. Pisanski.

Plenary Talks

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Thomas Tucker, *Colgate University*

Coloring, Sparseness, and Girth
Douglas West, *Zhejiang Normal University and University of Illinois (China and USA)*

Bounding the number of automorphisms of a graph

Michael Giudici, michael.giudici@uwa.edu.au
The University of Western Australia

Given a finite graph Γ with n vertices, can we obtain useful bounds on the number of automorphisms of Γ? If Γ is vertex transitive then $|\mathrm{Aut}(\Gamma)| = n|G_v|$ and so the question becomes one about $|G_v|$. When Γ is a cubic arc-transitive graph then Tutte showed that $|G_v|$ divides 48. Weiss conjectured that if the graph is locally primitive of valency d then there is some function f such that $|G_v| \leqslant f(d)$. Verret recently proposed that the correct way to view the result of Tutte and the conjecture of Weiss is in terms of graph-restrictive permutation groups. This subsequently lead to the Potočnik-Spiga-Verret Conjecture. I will outline this viewpoint and discuss some recent results towards the conjecture.

Transversals and Independence in Hypergraphs with Applications

Michael Henning, mahenning@uj.ac.za
University of Johannesburg

Coauthors: Christian Löwenstein, Anders Yeo

The transversal number, $\tau(H)$, of a hypergraph H is the minimum cardinality of a subset of vertices in H that has a nonempty intersection with every edge of H. A hypergraph is k-uniform if every edge has size k. We present several bounds on the transversal number of uniform hypergraphs and discuss several conjectured bounds. Let H be a hypergraph on n vertices and m edges. We discuss the Chvátal-McDiarmid bound which states that for $k \geq 2$, if H is a k-uniform hypergraph, then $\tau(H) \leq (n+\left\lfloor \frac{k}{2} \right\rfloor m)/\left\lfloor \frac{3k}{2} \right\rfloor$. We characterize the connected hypergraphs that achieve equality in this bound. We present recent results on the conjecture that for all $k \geq 2$, if H is a k-uniform hypergraph with maximum degree 3, then $\tau(H) \leq n/k + m/6$. Motivated by the Thomassé-Yeo conjecture that every 5-uniform hypergraph has a transversal of size at most $\frac{4}{11}n$, we prove an upper bound of strictly less than $(\frac{4}{11} + \frac{1}{72})n$ on the transversal number. We investigate upper bounds on the transversal number of linear hypergraphs, where a hypergraph is linear if every two edges intersect in at most one vertex. We also present results on independence and strong independence in hypergraphs. Applications of transversals in hypergraphs to, among others, colorings in hypergraphs, and domination and total domination in hypergraphs are given. The interplay with transversals in hypergraphs and total domination in graphs is explored.

Graph generation

Brendan Mc Kay, bdm@cs.anu.edu.au
Australian National University

We give a brief overview of the art of generating graph classes on the computer, with particular attention to avoidance of isomorphs. Our examples will include two recent projects. One is to generate fullerenes without adjacent pentagons (joint with Jan Goedgebeur) and the other is to catalogue all small Turan graphs for collections of short cycles (joint with Narjess Afzaly). In both cases we manage to considerably improve on earlier results.

Branched coverings of graphs and harmonic action of groups

Alexander Mednykh, smedn@mail.ru
Sobolev Institute of Mathematics, Novosibirsk State University,
Laboratory of Quantum Topology, Chelyabinsk State University

In this lecture we give a short survey of old and new results about branched coverings of graphs. This notion was introduced independently by T. D. Parsons, T. Pisanski, P. Jackson (1980), H. Urakawa (2000), B. Baker, S. Norine (2009) and others. The branched covering of graphs are also known as harmonic maps or vertically holomorphic maps of graphs. The main idea of the present talk to is create a parallel between classical results on branched covering of Riemann surfaces and those for graphs. We introduce the notion of harmonic action on a graph and discuss the Hurwitz type theorems for the groups acting harmonically. These results can be regarded as discrete analogues of the well known theorems by Hurwitz and Accola–Maclachlan. They, respectively, give sharp upper and lower bounds for the order of an automorphism group acting on a Riemann surface.

We present discrete versions of theorems by Wiman (1895), Oikawa (1956) and Arakawa (2000), which sharpen the Hurwitz' upper bound for various classes of groups acting on a Riemann surface of given genus.

Then we define a hyperelliptic graph as two fold branched covering of a tree and a γ-hyperelliptic graph as two fold branched covering of a graph of genus γ. A few discrete versions of the well-known results on γ-hyperelliptic Riemann surface will be given.

Colour-permuting and colour-preserving automorphisms

Joy Morris, joy.morris@uleth.ca
University of Lethbridge, Canada
Coauthors: Ademir Hujdurovic, Klavdija Kutnar, Dave Witte Morris

A Cayley graph $\mathrm{Cay}(G;S)$ on a group G with connection set $S = S^{-1}$ is the graph whose vertices are the elements of G, with $g \sim h$ if and only if $g^{-1}h \in S$. If we assign a colour $c(s)$ to each $s \in S$ so that $c(s) = c(s^{-1})$ and $c(s) \neq c(s')$ when $s' \neq s, s^{-1}$, this is a natural (but not proper) edge-colouring of the Cayley graph.

The most natural automorphisms of any Cayley graph are those that come directly from the group structure: left-multiplication by any element of G; and group automorphisms of G that fix S setwise. It is easy to see that these graph automorphisms either preserve or permute the colours in the natural edge-colouring defined above. Conversely, we can ask: if a graph automorphism preserves or permutes the colours in this natural edge colouring, need it come from the group structure in one of these ways?

We show that in general, the answer to this question is no. We explore the answer to this question for a variety of families of groups and of Cayley graphs on these groups. I will touch on work by other authors that explores similar questions coming from closely-related colourings.

Homomorphism duality pairs and regular families of forests

Gábor Tardos, tardos@renyi.hu
Rényi Institute, Budapest
Coauthors: Péter L. Erdős, Dömötör Pálvölgyi, Claude Tardif

Homomorphism duality pairs play a crucial role in the theory of relational structures and in the Constraint Satisfaction Problem. In this talk we concentrate on infinite-finite duality pairs of directed graphs. We find a characterization of infinite antichains that allow for a finite dual. The characterization resembles the Myhill-Nerode characterization of regular languages, so we call these families ragular.

Orientations of graphs

Carsten Thomassen, ctho@dtu.dk
Technical University of Denmark

Let Γ be an abelian group and F a set of elements of Γ. We consider the following general problem: Given a graph G, is it possible to give every edge a direction and an element from F such that, at every vertex, the in-sum equals the out-sum. Tutte's flow conjectures and the $(2+\epsilon)$-flow conjecture are instances of this problem. We discuss other instances as well and show when sufficiently large edge-connectivity guarantees an F-flow.

The Riemann-Hurwitz Equation

Thomas Tucker, ttucker@colgate.edu
Colgate University

The Riemann-Hurwitz equation for a finite group acting on a closed surface S with isolated fixed points is just a simple application of inclusion-exclusion, but it plays the leading role in all study of surface symmetry and, through a remarkable series of coincidences, in my own research. Those instances include, in chronological order, the classification of group actions on the sphere and torus, the groups of (White) genus one, the Hurwitz bound for the genus of a group, the group of genus two, the symmetric genus of a group, the classification of regular maps of genus $p+1$ for p prime, Kulkarni's theorem, and the symmetry of closed surfaces immersed in euclidean 3-space.

Coloring, Sparseness, and Girth

Douglas West, dwest@math.uiuc.edu
Zhejiang Normal University and University of Illinois (China and USA)

A *proper coloring* of a graph G assigns colors to its vertices so that adjacent vertices receive distinct colors. The *chromatic number* of G is the least k such that G has a proper coloring from a set of k colors. A *list assignment* L on G assigns a list $L(v)$ of available colors to each vertex v. An *L-coloring* is a proper coloring with the color on each vertex chosen from its list. A graph is *k-choosable* if it is L-colorable whenever each list in the assignment L has size at least k. The lists could be identical, so the least k such that G is k-choosable is at least the chromatic number.

We construct existence and sharpness examples for several questions in coloring and list coloring, using sparse graphs constructed from very tall trees. An *r-augmented tree* consists of a rooted tree plus edges added from each leaf to r ancestors. For $d, g, r \in \mathbb{N}$, we construct a bipartite r-augmented complete d-ary tree having girth at least g. The height of such trees must grow extremely rapidly in terms of the girth.

Applications of this construction involve expanding the leaves of an r-augmented tree into special graphs. We use it for the following: (1) A new simple construction of graphs (and uniform hypergraphs) with large girth and chromatic number. (2) Construction of bipartite graphs with large girth that are not k-choosable even though all proper subgraphs have average degree at most $2(k-1)$ (maximum average degree at most $2(k-1)$ makes a bipartite graph k-choosable). (3) Construction of a bipartite graph with large girth having a k-uniform list assignment L from which no proper coloring can be chosen even though the lists at adjacent vertices have only one common element (having two common elements guarantees L-colorability). (4) Enhancement of (2) so that the union of the lists has size $2k-1$ (size at most $2k-2$ guarantees L-colorability).

These results are joint work with Noga Alon, Alexandr V. Kostochka, Benjamin Reiniger, and Xuding Zhu.

Invited Talks

How does the game domination number behave by atomic changes on the graph?
Paul Dorbec, *LaBRI, Univ. Bordeaux - CNRS*

From the identification of vertices in a graph to non-identification: a short story
Ismael Gonzalez Yero, *University of Cadiz*

Calculating Genus Polynomials via String Operations and Matrices, Part I
Jonathan Gross, *Columbia University*

Automorphism groups of bipartite direct products
Richard Hammack, *Virginia Commonwealth University*

Structure and Properties of Vertex-Transitive Graphs
Robert Jajcay, *Comenius University, Bratislava, and University of Primorska*

Untangling the parabola: two problems in double coset enumeration
Matjaž Konvalinka, *FMF, University of Ljubljana*

Indices, polynomials and matrices–A unified viewpoint
Xueliang Li, *Center for Combinatorics, Nankai University*

New directions in the classification of finite simple groups
Chris Parker, *University of Birmingham, UK*

On Schur 2-groups
Ilya Ponomarenko, *St. Petersburg Department of V.A. Steklov Institute of Mathematics of the Russian Academy of Sciences*

Chromatic number of P_5-free graphs: χ-bounding functions
Ingo Schiermeyer, *Technische Universität Bergakademie Freiberg*

Skeletal Polyhedral Geometry and Symmetry
Egon Schulte, *Northeastern University*

On ± 1-eigenvectors of graphs
Dragan Stevanović, *Mathematical Institute, Serbian Academy of Sciences and Arts and University of Primorska, Slovenia*

Zarankiewicz' problem and finite geometries
Tamás Szőnyi, *ELTE Budapest*

How does the game domination number behave by atomic changes on the graph?

Paul Dorbec, paul.dorbec@u-bordeaux.fr
LaBRI, Univ. Bordeaux - CNRS

In the domination game, two players alternate turns marking a vertex in a graph. When it is marked, a vertex must dominate at least one new vertex, either itself or one of its neighbours. When the set of marked vertices forms a dominating set (not necessarily minimal), the game comes to an end and the score of the game is the order of this set. One player, Dominator, tries to minimize this score while the other player, Staller, tries to maximize it. The domination game number $\gamma_g(G)$ is the score when both players play optimally and Dominator starts, $\gamma'_g(G)$ denoting the score when Staller starts.

During this talk, we survey some recent results on the domination game, focusing on how the domination game number changes when the graph is subject to small changes such as deletion, addition or contraction of edges/vertices. We in particular show that these parameters show heredity only for edge contraction, but that bounds can be proved in most other cases. The results presented come from joint works with B. Brešar, T. James, S. Klavžar, G. Košmrlj, G. Renault, and A. Vijayakumar.

From the identification of vertices in a graph to non-identification: a short story

Ismael Gonzalez Yero, ismael.gonzalez@uca.es
University of Cadiz

Graph structures may be used to model computer networks. Each vertex in a graph is a possible location for an intruder (fault in a computer network, spoiled device). So, a correct surveillance of each vertex of the graph to control such a possible intruder would be worthwhile. In this sense, Slater (1975) brought in the notion of locating sets in graphs. Also, Harary and Melter (1976) introduced independently the same concept, but using the name of resolving sets. Moreover, the terminology of metric generators was recently introduced.

A metric generator is an ordered subset S of vertices in a graph G, such that every vertex of G is uniquely determined by its vector of distances to the vertices in S. The cardinality of a minimum metric generator for G is called the metric dimension of G. A generalization of this concept to k-metric generators is due to Estrada-Moreno et al. (2013). Let $G = (V, E)$ be a simple and connected graph. A set $S \subseteq V$ is said to be a *k-metric generator* for G if any pair of vertices of G is distinguished by at least k elements of S. The minimum cardinality of any k-metric generator is the *k-metric dimension* of G.

At this point of the story we are able to propose a new problem in Graph Theory: the k-metric antidimension, that resembles to the aforementioned k-metric dimension. The fact is that not always is desirable to uniquely recognize each vertex of the graph, instead, it is very frequently desirable to have some privacy features. In this sense, a principal motivation of the new concept arises from a connection with some privacy preserving problem lying along the borderline between computer science and social sciences.

Let $d_G(u,v)$ be the length of the shortest path between the vertices u and v in G. For an ordered set $S = \{u_1, \cdots, u_t\}$ of vertices in V and a vertex v, we call $r(v|S) = (d_G(v,u_1),\ldots,d_G(v,u_t))$ the *metric representation* of v with respect to S. The set S is a *k-antiresolving set* for G, if k is the largest positive integer such that for every $v \in V - S$ there exist at least $k-1$ different vertices $v_1,\ldots,v_{k-1} \in V - S$ with $r(v|S) = r(v_1|S) = \cdots = r(v_{k-1}|S)$. The *$k$-metric antidimension* of a simple connected graph $G = (V,E)$ is the minimum cardinality of any k-antiresolving set in G.

Intuitively, if S is a k-antiresolving set, then it cannot uniquely re-identify other nodes in the network with probability higher than $1/k$. However, it might exist other subset of vertices in G that forms a k'-antiresolving set where $k' < k$. This is, indeed, considered in the next privacy measure. It is said that a graph G meets *(k,ℓ)-anonymity* with respect to active attacks if k is the smallest positive integer such that the k-metric antidimension of G is lower or equal than ℓ.

According to the facts above, in this talk the "evolution" of the metric dimension in graphs is described, beginning at its primary usefulness as a model of navigation of robots in networks and finishing as a privacy measure for social graphs.

Calculating Genus Polynomials via String Operations and Matrices, Part I

Jonathan Gross, gross@cs.columbia.edu
Columbia University

Coauthors: Imran Khan, Toufik Mansour, Thomas Tucker

In calculations of genus polynomials for a recursively specifiable sequence of graphs, the imbeddings of each of the graphs are partitioned into *imbedding-types*. The effects of a recursively applied graph operation τ on each imbedding-type are represented by a *production matrix*. We demonstrate herein how representing the operation τ by *string operations* enables us to automate the calculation of the production matrices, a task requiring time proportional to the square of the number of imbedding-types. It also allows us to reduce the number of imbedding-types, which lets us calculate some genus polynomials that were heretofore computationally infeasible.

Automorphism groups of bipartite direct products

Richard Hammack, rhammack@vcu.edu
Virginia Commonwealth University

We are concerned with automorphism groups of thin direct products. (A graph is *thin* if no two vertices have the same neighborhood.) It is known that if φ is an automorphism of a connected non-bipartite thin graph G that factors (uniquely) into primes as $G = G_1 \times G_2 \times \cdots \times G_k$, then there is a permutation π of $\{1,2,\ldots,k\}$, together with isomorphisms $\varphi_i : G_{\pi(i)} \to G_i$, such that

$$\varphi(x_1,x_2,\ldots,x_k) = \Big(\varphi_1(x_{\pi(1)}), \varphi_2(x_{\pi(2)}), \ldots, \varphi_k(x_{\pi(k)})\Big).$$

This talk explores an analogous result for *bipartite* graphs G. Unlike the non-bipartite case, such graphs do not factor uniquely into primes. But if $G = A \times B$, where B is prime and bipartite, then B is unique up to isomorphism, though the non-bipartite factor A is not uniquely determined. We codify the structure of automorphisms of thin connected bipartite products $A \times B$, where B is prime and bipartite.

Structure and Properties of Vertex-Transitive Graphs

Robert Jajcay, robert.jajcay@famnit.upr.si
Comenius University, Bratislava, and University of Primorska

Vertex-transitive graphs have many regularity properties, and look the same in the neighborhoods of all of their vertices. Consequently, the number of any small induced subgraphs, such as cycles or cliques, containing any fixed vertex of a vertex-transitive graph must be the same for each vertex of the graph. While this observation can be used for a quick criterion to show that a graph is not vertex-transitive, it can also be used for argueing the non-existence of certain vertex-transitive graphs. We demonstrate such techniques for two well-known problems from extremal graph theory restricted to the class of vertex-transitive graphs, namely the Cage Problem and the Degree/Diameter Problem. We also dicuss some recent methods for constructing vertex-transitive graphs with prescribed degree, girth, or diameter, and address the problem of the cycle length distribution of vertex-transitive graphs.

Untangling the parabola: two problems in double coset enumeration

Matjaž Konvalinka, matjaz.konvalinka@fmf.uni-lj.si
FMF, University of Ljubljana

In this talk, I will present two recent results on the enumeration of double cosets in the symmetric group.

Tanglegrams are a special class of graphs appearing in applications concerning cospeciation and coevolution in biology and computer science. They are formed by identifying the leaves of two rooted binary trees, and can be viewed as a double coset of the symmetric group with respect to the action of the groups of symmetries of the two trees. We give an explicit formula for the number of distinct (asymmetric) binary rooted tanglegrams with n matched vertices, along with a simple asymptotic formula and an algorithm for choosing a tanglegram uniformly at random.

A *parabolic double coset* of the symmetric group is a double coset with respect to the action of two parabolic subgroups (one on each side). I will present a formula for enumerating all parabolic double cosets with a given minimal element, along with extensions to arbitrary Coxeter groups and a conjectured asymptotic formula for the total number of parabolic double cosets.

Indices, polynomials and matrices–A unified viewpoint

Xueliang Li, lxl@nankai.edu.cn
Center for Combinatorics, Nankai University

In this talk we will give a unified viewpoint on indices, polynomials and matrices of graphs. Starting from a graph with weights on edges or vertices, one can get various kinds of graph indices, graph polynomials, and graph matrices. Then, we can see that a lot of new and interesting objects can be taken into account for further studies.

New directions in the classification of finite simple groups

Chris Parker, c.w.parker@bham.ac.uk
University of Birmingham, UK

I will report of recent work with Gernot Stroth and others focussed on the classification of finite simple groups of local characteristic p.

On Schur 2-groups

Ilya Ponomarenko, inp@pdmi.ras.ru
St. Petersburg Department of V.A. Steklov Institute of Mathematics of the Russian Academy of Sciences
Coauthor: Misha Muzychuk

A finite group G is called a Schur group, if any Schur ring over G is the transitivity module of a point stabilizer in a subgroup of $\mathrm{Sym}(G)$ that contains all right translations. We complete a classification of abelian 2-groups by proving that the group $Z_2 \times Z_{2^n}$ is Schur. We also prove that any non-abelian Schur 2-group of order larger than 32 is dihedral (the Schur 2-groups of smaller orders are known). Finally, in the dihedral case, we study Schur rings of rank at most 5, and show that the unique obstacle here is a hypothetical S-ring of rank 5 associated with a divisible difference set.

Chromatic number of P_5-free graphs: χ-bounding functions

Ingo Schiermeyer, Ingo.Schiermeyer@tu-freiberg.de
Technische Universität Bergakademie Freiberg

In this talk we study the chromatic number of P_5-free graphs. Gyárfas has shown

Theorem Let G be a P_k-free graph for $k \geq 4$ with clique number $\omega(G) \geq 2$. Then $\chi(G) \leq (k-1)^{\omega(G)-1}$.

and has posed the following question:

Question Is there a polynomial (χ-bounding) function f_k for $k \geq 5$ such that every P_k-free graph G satisfies $\chi(G) \leq f_k(\omega(G))$?

We will show that there is a polynomial χ-bounding function for several subclasses of P_5-free graphs. Our main result is the following.

Theorem Let G be a connected P_5-free graph of order n and clique number $\omega(G)$. If G is
(i) $Claw$-free or (ii) Paw-free or (iii) $Diamond$-free or (iv) $Dart$-free or (v) Gem^+-free or (vi) $Cricket$-free,
then $\chi(G) \leq \omega^2(G)$.

Here Gem^+ denotes the graph $(K_1 + (K_1 \cup P_4))$.

Skeletal Polyhedral Geometry and Symmetry

Egon Schulte, schulte@neu.edu
Northeastern University

Highly symmetric polyhedra-like structures in ordinary euclidean 3-space have a long history of study tracing back to the early days of geometry. With the passage of time, various notions of polyhedra have brought to light new exciting figures intimately related to finite or infinite groups of isometries. In the 1970's, a new "skeletal" approach to polyhedra was pioneered by Grünbaum building on Coxeter's work.

We survey the present state of the classification of discrete skeletal structures by distinguished transitivity properties of their symmetry groups. These figures are finite, or infinite periodic, geometric edge graphs equipped with additional polyhedra-like structure determined by the collection of faces (simply closed planar or skew polygons, zig-zag polygons, or helical polygons). Particularly interesting classes of skeletal structures include the regular, chiral, or uniform skeletal polyhedra, as well as the regular polygonal complexes.

On ±1-eigenvectors of graphs

Dragan Stevanović, dragance106@yahoo.com
Mathematical Institute, Serbian Academy of Sciences and Arts and University of Primorska, Slovenia

While discussing his spectral bound on the independence number of a graph, Herbert Wilf asked back in 1986 what kind of a graph can have an eigenvector consisting solely of ±1 entries? This question reappeared independently more than twenty years later while we were studying Jerry Ray Dias' question on the existence of graphs with square roots of positive integers as their eigenvalues.

We show that to answer Wilf's problem it is enough to be able to answer whether a graph has a ±1 eigenvector corresponding to the eigenvalue 0. The latter problem, however, turns out to be NP-complete. In addition, Wilf's problem has different answers for the triangular graph $L(K_8)$ and the three Chang graphs cospectral to it, leaving little hope for a simple answer in general. Nevertheless, the set of graphs with a ±1 eigenvector corresponding to the eigenvalue 0 turns out to be very rich, being closed under a number of different graph compositions.

Zarankiewicz' problem and finite geometries

Tamás Szőnyi, szonyi@cs.elte.hu
ELTE Budapest

Coauthors: Tamás Héger, Gabor Damasdi

Zarankiewicz asked for the minimum number of 1s in an $m \times n$ 0-1 matrix that assures the existence of an $s \times t$ submatrix containing only 1s. We consider the following, equivalent formulation. A bipartite graph $G = (A, B; E)$ is *$K_{s,t}$-free* if it does not contain s nodes in A and t nodes in B that span a subgraph isomorphic to $K_{s,t}$. The maximum number of edges a $K_{s,t}$-free bipartite graph with $|A| = m$, $|B| = n$ may have is denoted by $Z_{s,t}(m,n)$, and is called a *Zarankiewicz number*. Note that a $K_{s,t}$-free bipartite graph is not necessarily $K_{t,s}$-free if $s \neq t$.

An old result, due to Reiman establishes a connection between Zarankiewicz' problem and incidence graphs of block designs (in particular, projective planes). In this talk, based on joint work with G. Damásdi and T. Héger, we present upper and lower bounds on Zarankiewicz numbers, some giving exact values. We put emphasis on the case $s = t = 2$, which has strong connections with finite geometries. Some of the results can be regarded as stability results for incidence graphs.

Minisymposium

Applications Of Groups In Graph Theory

Organized by Christopher Parker, *University of Birmingham, UK*

Spectrum of the Power Graph of Finite Groups, *Ali Reza Ashrafi*
Computing automorphism group of some cage graphs, *Modjtaba Ghorbani*
Recent advances on the bipartite divisor graph of a finite group, *Roghayeh Hafezieh*
On a Theorem of Halin, *Wilfried Imrich*
On the CI-property for balanced configurations, *Sergio Hiroki Koike Quintanar*
Groups with many self-centralizing subgroups, *Primož Moravec*
Vertex-stabilisers in locally-transitive graphs, *Luke Morgan*
Point-primitive generalised polygons, *Tomasz Popiel*
On the order of arc-stabilisers in arc-transitive graphs with prescribed local group, *Primož Potočnik*
Direct sum of CI-groups, *Gábor Somlai*
A weak version of the Erdos-Ko-Rado theorem for 2-transitive groups., *Pablo Spiga*
2-arc-transitive graphs of order kp^n, *Gabriel Verret*
Progress on the GFR Problem, *Mark E. Watkins*

Spectrum of the Power Graph of Finite Groups

Ali Reza Ashrafi, ashrafi@kashanu.ac.ir
University of Kashan, Kashan, I R Iran
Coauthors: Ahmad Gholami, Zeinab Mehranian

The power graph $\mathcal{P}(G)$ of a group G is the graph with group elements as vertex set and two elements are adjacent if one is a power of the other [1,3]. Chattopadhyay and Panigrahi [2] studied the Laplacian spectrum of the power graph of cyclic group Z_n and the dihedral group D_{2n}, $n \geq 2$ is positive integer. They proved that the Laplacian spectrum of $\mathcal{P}(D_{2n})$ is the union of that of $\mathcal{P}(Z_n)$ and $\{2n, 1\}$. The aim of this paper is to report our recent results on the spectrum of the power graph of some finite groups.

Keywords: Power graph, graph spectrum, generalized quaternion, semi-dihedral group.

AMS Subject Classification Number: $05C25$, $05C50$.

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Computing automorphism group of some cage graphs

Modjtaba Ghorbani, mghorbani@srttu.edu
Department of Mathematics, Faculty of Science, Shahid Rajaee Teacher Training University, Tehran, 16785-136, I. R. Iran.
Coauthor: Mahin Songhori

A fullerene is a three connected cubic planar graph whose faces are squares, pentagons, hexagons or heptagons. In this paper, for given fullerene graph F, we compute the order of automorphism group Aut(F).

Recent advances on the bipartite divisor graph of a finite group

Roghayeh Hafezieh, roghayeh@gyte.edu.tr
Gebze Technical University

Let X be a finite set of positive integers. Let P(X) be the set of all primes dividing the elements of X and X* be the set of all elements of X different from 1. The bipartite divisor graph of X, which is denoted by B(X), has the disjoint union of P(X) with X* as its vertex set and one vertex like p from the first part (P(X)) is joined to a vertex like x in the second part (X*) if and only if p divides x. For any finite group G, there are two important sets of positive integers which are the set of conjugacy class sizes and the set of irreducible character degrees of G. In this talk we will discuss the recent advances on the bipartite divisor graph of a finite group G for these two sets of positive integers.

On a Theorem of Halin

Wilfried Imrich, imrich@unileoben.ac.at
Montanuniversität Leoben, Leoben, Austria
Coauthor: Simon Smith

The talk begins with a new, concise proof of a generalization of a theorem of Halin about locally finite, infinite graphs to graphs with unbounded degrees. Then it investigates when such graphs have finite set of vertices whose stabilizer is the identity automorphism. A bound on the size of such sets, which are called distinguishing, is also provided.

To put the theorem of Halin and its generalization into perspective, several related non-elementary, independent results and their methods of proof are also discussed.

On the CI-property for balanced configurations

Sergio Hiroki Koike Quintanar, hiroki.koike@iam.upr.si
University of Primorska
Coauthors: István Kovács, Dragan Marušič, Misha Muzychuk

Let G be a finite group. A Cayley object is a relational structure with underlying set G which is invariant under all right translations $x \mapsto xg$, $x, g \in G$. Given a class $\mathcal{K}$ of Cayley objects of G, the group G is said to satisfy the CI-property for $\mathcal{K}$ if for any two isomorphic Cayley objects in $\mathcal{K}$, there is an isomorphism between them, which is at the same time an automorphism of the group G. The question whether a given group G satisfies the CI-property for a given class $\mathcal{K}$ of Cayley objects has been studied under various choices of G and $\mathcal{K}$. In this talk, we focus our attention to the class of balanced configurations where we show that every cyclic group satisfy the CI-property.

Groups with many self-centralizing subgroups

Primož Moravec, primoz.moravec@fmf.uni-lj.si
University of Ljubljana

Coauthors: Costantino Delizia, Heiko Dietrich, Urban Jezernik, Chiara Nicotera, Chris Parker

A subgroup H of a group G is called self-centralizing if $C_G(H)$ is contained in H. In this talk we describe finite groups in which every non-cyclic subgroup is self-centralizing, and apply this information to certain classes of infinite groups with the same property. We also consider groups in which every non-abelian subgroup is self-centralizing, and address the problem of classification of finite p-groups with this property that was posed by Berkovich.

Vertex-stabilisers in locally-transitive graphs

Luke Morgan, luke.morgan@uwa.edu.au
The University of Western Australia

A graph Γ is G-locally-transitive, for $G \leqslant \mathrm{Aut}(\Gamma)$, if for each vertex x of Γ the vertex-stabiliser G_x acts transitively on the neighbours of x in Γ. Additionally, Γ is weakly locally projective if for each vertex x the stabiliser G_x induces on the set of vertices adjacent to x a doubly transitive action with socle the projective group $L_{n_x}(q_x)$ for an integer n_x and a prime power q_x.

The Mathieu group M_{24} and the Held group He are known to arise as automorphism groups of rank three geometries. In turn, these geometries give rise to weakly locally projective graphs. In this talk I will report on joint work with Michael Giudici, Alexander Ivanov and Cheryl Praeger in which we have begun a program characterising some of the remarkable examples of locally-transitive graphs. We begin by characterising the amalgams arising from the weakly locally projective graphs obtained from M_{24} and He. This reveals a new amalgam with the alternating group A_{16} as a completion. We are also able to demonstrate how these amalgams form part of a natural infinite family.

Point-primitive generalised polygons

Tomasz Popiel, tomasz.popiel@uwa.edu.au
University of Western Australia

We present some recent results about generalised polygons with collineation groups that act primitively on points. In particular, a group acting point-primitively on a generalised hexagon or octagon must be almost simple of Lie type.

On the order of arc-stabilisers in arc-transitive graphs with prescribed local group

Primož Potočnik, primoz.potocnik@fmf.uni-lj.si
Univerza v Ljubljani

Given a finite connected graph Γ and a group G acting transitively on the arcs of Γ, one defines the *local group* $G_v^{\Gamma(v)}$ as the permutation group induced by the action of the stabiliser G_v on the neighbourhood $\Gamma(v)$ of a vertex v. I will address the following question: To what extent does (the isomorphism class of) $G_v^{\Gamma(v)}$ bound the order of G_v?

More precisely, I will present some examples of local groups $G_v^{\Gamma(v)}$ for which one can bound the order of G_v by a polynomial function (but not constant!) of the order of the graph, and some examples where this is not possible.

To put this in a historical context, the celebrated Tutte's result shows that for $G_v^{\Gamma(v)} \cong \mathrm{Sym}(3)$ one can bound $|G_v|$ by the constant function $f(n) = 48$.

Most of the original results presented in this talk have appeared in the paper by Gabriel Verret, Pablo Spiga and myself published last year in volume 366 of the Transactions of AMS under the same title as this talk.

Direct sum of CI-groups

Gábor Somlai, zsomlei@gmail.com
Ben Gurion University of Negev
Coauthor: Misha Muzychuk

The investigation of CI-groups started with the conjecture of Ádám. Using the terminology later introduced by Babai, he conjectured that every cyclic group is a CI-group. A group G is called a CI-group when two Cayley graphs of G are isomorphic only if there is an automorphism of the group G which induces an isomorphism between the two Cayley graphs. It was proved by Babai and Frankl that a CI-group, which is also a p-group can only be elementary abelian p-group, quaternion group or cyclic group of small order. Several authors contributed to the description of CI-groups and a fairly short list of possible CI-groups was described by Li, Lu and Pálfy. Most of the candidates are abelian groups. Kovács and Muzychuk conjectured that the direct sum of CI-groups of relative prime order is a CI-group. The list provided by Li, Lu and Pálfy shows that this is one of the main questions in this area.

We contribute towards this conjecture by proving that if H is an abelian CI-group, q is a prime which does not divide $|H|$, then $H \times \mathbb{Z}_q$ is a CI-group. The proof relies on two different approaches. One of them uses elementary permutation theory tools worked out in a previous paper about CI-groups of order p^3q but the most important technique is the theory of Schur rings used by Kovács and Muzychuk.
Joint work with Mikhail Muzychuk.

A weak version of the Erdos-Ko-Rado theorem for 2-transitive groups.

Pablo Spiga, pablo.spiga@unimib.it
University of Milano-Bicocca

The celebrated Erdos-Ko-Rado theorem determines the cardinality and also describes the structure of a set of maximal size of intersecting k-subsets from a set of size n. Analogous results hold for many other combinatorial objects and in this talk we are concerned with a weak extension of the Erdos-Ko-Rado theorem to permutation groups.

2-arc-transitive graphs of order kp^n

Gabriel Verret, gabriel.verret@uwa.edu.au
The University of Western Australia

Over the past few years, there has been an explosion of results classifying arc-transitive (or 2-arc-transitive, arc-regular, etc...) graphs of valency d and order kp^n, where d,k,n are fixed integers and p is a prime that is allowed to vary.

These results are often proved by standard methods and thus there has been some recent efforts to unify the results by proving more general ones. For example, a recent theorem of Conder, Li and Potočnik shows that, for *every* fixed k and $d \geq 3$, there exists only finitely many 2-arc-transitive graphs of valency d and order kp, for p a prime. They also prove something similar for graphs of order kp^2.

Recently, we have proved an analog of their result for $n \geq 3$. More precisely, we have shown that there exists a function g such that there are only finitely many d-valent 2-arc-transitive graphs of order kp^n with $d > g(n)$ and p a prime.

This is joint work with Luke Morgan and Eric Swartz.

Progress on the GFR Problem

Mark E. Watkins, mewatkin@syr.edu
Syracuse University

Coauthors: Marston Conder, John Kevin Doyle, Thomas Tucker

We describe our progress during the past year on the so-called “GFR problem.” A *GFR*, or *graphical Frobenius representation*, is a graph whose automorphism group acts as a Frobenius permutation group, that is, it acts vertex-transitively but not regularly and only the identity automorphism fixes more than one vertex. We ask, which abstract groups can be isomorphic to the automorphism group of a GFR? Group theoretical conditions are surprisingly not less, but more restrictive than in the GRR problem (solved over the period between 1958 and 1982) which succeeded in characterizing the finitely generated abstract groups G admitting a graphical regular representation (GRR), namely a graph Γ whose automorphism group is isomorphic to G and acts as a regular permutation group on the vertex set of Γ. In both problems, the graph Γ under consideration must be a Cayley graph: of the given group G in the GRR problem, while of the Frobenius kernel of G in the GFR problem.

Graphical requirements for "GFR-hood" are also more restrictive. For example, while almost all Cayley graphs of an odd-order nilpotent group are GRRs without categorically forbidden valences (Babai & Godsil, 1982), we now know that there exists no p-valent GFR if p is a prime such that 2 is a primitive element of $\mathbb{Z}_p$. No group of odd order < 1029 admits a GFR, but we have found this bound to be sharp by constructing an 18-valent GFR on 343 vertices and vertex-stabilizers of order 3. We have also constructed infinite GFRs, both 1-ended and infinitely-ended, and of every even valence ≥ 6.

Minisymposium

Association Schemes

Organized by Ilya Ponomarenko, *Saint Petersburg Department of V. A. Steklov Institute of Mathematics, Russia*

Schemes for extending the theory of scheme extensions, *Christopher French*

New characterizations of Leonard pairs, *Edward Hanson*

Calculating Fusions of Association Schemes , *Allen Herman*

The number of ideals of $\mathbb{Z}[x]$ containing $x(x-\alpha)(x-\beta)$ with given index, *Mitsugu Hirasaka*

Commutative Schur rings over symmetric groups, *Stephen Humphries*

Association schemes and S-rings coming from loops and quasigroups, *Kenneth Johnson*

Q-polynomial distance-regular graphs and nonsymmetric Askey-Wilson polynomials, *Jae Ho Lee*

On small strongly regular graphs with an automorphism of order 3, *Martin Mačaj*

Bipartite distance-regular graphs with exactly two irreducible T-modules with endpoint 2, both thin, *Štefko Miklavič*

On Coherent Terwilliger Algebras and Wreath Products, *Misha Muzychuk*

On bipartite Q-polynomial distance-regular graphs with $c_2 \leq 2$, *Safet Penjić*

On abelian Schur 3-groups, *Grigory Ryabov*

Association schemes related to Hadamard matrices, *Sho Suda*

Lowering-Raising Triples of Linear Transformations, *Paul Terwilliger*

Directed strongly walk-regular graphs and their eigenvalues, *Edwin van Dam*

Schemes with the base of size 2, *Andrey Vasilév*

Hypergroups - Association Schemes - Buildings, *Paul Hermann Zieschang*

Schemes for extending the theory of scheme extensions

Christopher French, frenchc@grinnell.edu
Grinnell College

We say a group K is an extension of G by N if K contains a normal subgroup isomorphic to N with quotient isomorphic to G; such an extension then determines a “twisting" homomorphism $\phi : G \to \mathrm{Aut}(N)$. If, on the other hand, we are given groups N and G, and a homomorphism $\phi : G \to \mathrm{Aut}(N)$, the obstruction to finding an associated extension K is an element in a third cohomology group. When the obstruction vanishes, a second cohomology group then parametrizes the family of such extensions, up to isomorphism.

In full generality, the theory of extensions of association schemes seems much harder. Some work has been done to develop a cohomological approach to restricted versions of this problem, most notably by Bang and Hirasaka. In this talk, I build on this work, presenting some ideas for classifying extensions of schemes in greater generality.

New characterizations of Leonard pairs

Edward Hanson, hansone@newpaltz.edu
SUNY New Paltz

Roughly speaking, a Leonard pair can be thought of as an algebraic generalization of a Q-polynomial distance-regular graph. Because of this connection, there are sequences of parameters associated with Leonard pairs that generalize the intersection numbers of a distance-regular graph. In this talk, we will discuss two new characterizations of Leonard pairs using these parameter sequences.

Calculating Fusions of Association Schemes

Allen Herman, Allen.Herman@uregina.ca
University of Regina

Given two finite association schemes (X,T) and (X,S) of the same order, we say that T is a fusion of S if every relation in T is a union of relations in S. This talk will discuss two computer algorithms for detecting the fusions of a given association scheme. The first directly calculates fusions of (X,S) arising from partitions of S, which works reasonably well for partitions that are relatively small or large compared to the size of S. The second detects the possibility that T is a fusion of S by comparing automorphism groups, and verifies actual fusions using an explicit embedding of $Aut(S)$ into $Aut(T)$. This second method can effectively determine a fusion relationship between schemes of higher rank in situations where the first method would not be conclusive. In joint work with Sourav Sikdar, we have used our GAP implementation of these methods to produce an almost complete list of fusions among schemes of order up to 30 that appear in Hanaki and Miyamoto’s classification of small association schemes.

The number of ideals of $\mathbb{Z}[x]$ containing $x(x-\alpha)(x-\beta)$ with given index

Mitsugu Hirasaka, hirasaka@pusan.ac.kr
Pusan National University
Coauthor: Semin Oh

Let A denote an integral square matrix and R the subring of the full matrix ring generated by A. Then R is a free $\mathbb{Z}$-module of finite rank, which guarantees that there are only finitely many ideals of R with given finite index. Thus, the formal Dirichlet series $\zeta_A(s) = \sum_{n\geq 1} a_n n^{-s}$ is well-defined where a_n is the number of ideals of R with index n. In this talk we aim to find an explicit form of $\zeta_A(s)$ when A is the adjacency matrix of a graph whose eigenvalues consists of exactly three integers. which are integral.

Commutative Schur rings over symmetric groups

Stephen Humphries, steve@mathematics.byu.edu
Brigham Young University, Provo, Ut, USA

We study commutative Schur rings over the symmetric group S_n that contain the sum of the transpositions in S_n, by determining the possibilities for the partition of the class of transpositions that such a Schur ring gives. We note a connection with Gallai colorings of complete graphs.

Association schemes and S-rings coming from loops and quasigroups

Kenneth Johnson, kwj1@hotmail.com
Penn State University

Given any finite quasigroup Q an association scheme can be automatically constructed from the "class algebra". Moreover if Q is a loop (i.e there is an identity element) the association scheme may be regarded as an S-ring over Q (with suitable modifications to the definition). Recently Humphries and I have been examining commutative fissions of S-rings over groups and it is a natural extension of the work to look at S-rings over loops. The family of Moufang loops retain some of the properties of groups and provide interesting examples. There is a connection between this work and the theory of random walks on the corresponding objects.

Q-polynomial distance-regular graphs and nonsymmetric Askey-Wilson polynomials

Jae Ho Lee, jhlee@ims.is.tohoku.ac.jp
Tohoku University

Nonsymmetric Askey-Wilson polynomials were defined by Sahi in 1999. Roughly speaking, they are the eigenfunctions of the Cherednik-Dunkl operator and form a linear basis of the space of the Laurent polynomials in one variable. In my thesis (2013), we found a relationship between Q-polynomial distance-regular graphs and a double affine Hekce algebra of rank one. In this talk, using this relationship we will define some nonsymmetric Laurent polynomials and discuss how these polynomials are related with Sahi's nonsymmetric Askey-Wilson polynomials.

On small strongly regular graphs with an automorphism of order 3

Martin Mačaj, martin.macaj@fmph.uniba.sk
Comenius University
Coauthor: Anton Koval

A graph is a strongly regular graph with parameters (n,k,λ,μ) if it is a k-regular graph of order n such that each pair of adjacent vertices has in G exactly λ common neighbors and each pair of non-adjacent vertices has in G exactly μ common neighbors.

There exist several necessary conditions for parameter sets (n,k,λ,μ) to admit an existence of a strongly regular graph. Parameter sets which satisfy all such conditions are called feasible. Although the existence of a strongly regular graph is solved for all feasible parameter sets with $n \leq 50$, the complete classification is still open for parameter sets $(37,18,8,9)$, $(41,20,9,10)$, $(45,22,10,11)$, $(49,24,11,12)$, $(49,18,7,6)$ and $(50,21,8,9)$.

By exhaustive computer search we obtain the full list of strongly regular graphs on up to 50 vertices with an automorphism of order 3. Further, for parameter sets $(37,18,8,9)$, $(41,20,9,10)$, $(45,22,10,11)$, $(49,24,11,12)$, $(49,18,7,6)$ and $(50,21,8,9)$ we determine a class of strongly regular graphs which contains all the Z_3 graphs and is closed under particular instances of partial switching defined by Godsil-McKay and Behbahani-Lam-Ostergaard, respectively. As a corollary, we significantly extend list of known regular two-graphs on at most 50 vertices.

(Recall that a two-graph is a set of (unordered) triples chosen from a finite vertex set X, such that every (unordered) quadruple from X contains an even number of triples of the two-graph. A regular two-graph has the property that every pair of vertices lies in the same number of triples of the two-graph.)

Bipartite distance-regular graphs with exactly two irreducible T-modules with endpoint 2, both thin

Štefko Miklavič, stefko.miklavic@upr.si
University of Primorska
Coauthor: Mark MacLean

Let Γ denote a bipartite distance-regular graph with diameter $D \geq 4$ and valency $k \geq 3$. Let X denote the vertex set of Γ. Fix $x \in X$ and let $T = T(x)$ denote the corresponding Terwilliger algebra of Γ. In this talk we consider the situation where, up to isomorphism, Γ has exactly two irreducible T-modules with endpoint 2, and they are both thin. Our main result is a combinatorial characterization of this situation.

On Coherent Terwilliger Algebras and Wreath Products

Misha Muzychuk, misha.muzychuk@gmail.com
Netanya Academic College
Coauthor: Bangteng Xu

Let $\mathcal{A} \subseteq M_\Omega[\mathbb{F}]$ be a coherent algebra. It's Terwilliger algebra $\mathcal{T}_\omega(\mathcal{A})$ is called *coherent* if $\mathcal{T}_\omega$ is closed with respect to Schur-Hadamard product. In our talk we'll present some properties of coherent Terwilliger algebra.

We also present a theorem which provides a complete description of T-algebra of a wreath product of association schemes. Using this result we prove that if both factors of the wreath product have coherent T-algebras, then the wreath product has a coherent T-algebra too.

On bipartite Q-polynomial distance-regular graphs with $c_2 \leq 2$

Safet Penjić, safet.penjic@iam.upr.si
University of Primorska
Coauthor: Štefko Miklavič

Let Γ denote a Q-polynomial bipartite distance-regular graph with diameter D, valency $k \geq 3$ and intersection number $c_2 \leq 2$. In this talk we show the following two results:

(1) If $D \geq 6$, then Γ is either the D-dimensional hypercube, or the antipodal quotient of the $2D$-dimensional hypercube.

(2) If $D = 4$ then Γ is either the 4-dimensional hypercube, or the antipodal quotient of the 8-dimensional hypercube.

We show (1) using results of Caughman. To show (2) we first introduce certain equitable partition of the vertex-set of Γ. Then we use this equitable partition to prove (2).

On abelian Schur 3-groups

Grigory Ryabov, gric2ryabov@gmail.com
Novosibirsk State University

Let G be a finite group. If Γ is a permutation group with $G_{right} \leq \Gamma \leq Sym(G)$ and $\mathcal{S}$ is the set of orbits of the stabilizer of the identity e in Γ, then the $\mathbb{Z}$-submodule $\mathcal{A}(\Gamma, G) = Span_{\mathbb{Z}}\{\underline{X} : X \in \mathcal{S}\}$ of the group ring $\mathbb{Z}G$ is an S-ring as it was observed by Schur. Following Pöschel an S-ring $\mathcal{A}$ over G is said to be *schurian* if there exists a suitable permutation group Γ such that $\mathcal{A} = \mathcal{A}(\Gamma, G)$. A finite group G is called a *Schur group* if every S-ring over G is schurian. We prove that the groups $\mathbb{Z}_3 \times \mathbb{Z}_{3^n}$, where $n \geq 1$, are Schur. Modulo previously obtained results, it follows that every non-cyclic Schur p-group is isomorphic to $\mathbb{Z}_3 \times \mathbb{Z}_3 \times \mathbb{Z}_3$ or $\mathbb{Z}_3 \times \mathbb{Z}_{3^n}$, $n \geq 1$, whenever p is an odd prime.

Association schemes related to Hadamard matrices

Sho Suda, suda@auecc.aichi-edu.ac.jp
Aichi University of Education

Coauthor: Hadi Kharaghani

Hadamard matrices have been widely studied from the view point of design theory, coding theory, quantum information theory. Algebraic combinatorics also contributes the study for Hadamard matrices. For example, it was shown that Hadamard matrices have a structure of a distance regular graph of diameter 4. In this talk we pursue the study of Hadamard matrices along this line and show that some association schemes are obtained from Hadamard matrices with some mutually orthogonal Latin squares. This is joint work with Hadi Kharaghani.

Lowering-Raising Triples of Linear Transformations

Paul Terwilliger, terwilli@math.wisc.edu
University of Wisconsin Math Department

Fix a nonnegative integer d. Let $\mathbb{F}$ denote a field, and let V denote a vector space over $\mathbb{F}$ with dimension $d+1$. By a decomposition of V we mean a sequence $\{V_i\}_{i=0}^d$ of one-dimensional subspaces whose direct sum is V. Let $\{V_i\}_{i=0}^d$ denote a decomposition of V. A linear transformation $A \in \mathrm{End}(V)$ is said to lower $\{V_i\}_{i=0}^d$ whenever $AV_i = V_{i-1}$ for $1 \leq i \leq d$ and $AV_0 = 0$. The map A is said to raise $\{V_i\}_{i=0}^d$ whenever $AV_i = V_{i+1}$ for $0 \leq i \leq d-1$ and $AV_d = 0$. A pair of elements A, B in $\mathrm{End}(V)$ is called lowering-raising (or LR) whenever there exists a decomposition of V that is lowered by A and raised by B. A triple of elements A, B, C in $\mathrm{End}(V)$ is called LR whenever any two of A, B, C form an LR pair. We show how to normalize an LR triple, and classify up to isomorphism the normalized LR triples. There are nine infinite families of solutions. We show that each solution A, B, C satisfies some relations that resemble the defining relations for $U_q(\mathfrak{sl}_2)$ in the equitable presentation.

Directed strongly walk-regular graphs and their eigenvalues

Edwin van Dam, edwin.vandam@uvt.nl
Tilburg University
Coauthor: Gholamreza Omidi

A directed graph is called strongly ℓ-walk regular if the number of walks of length ℓ from one vertex to another depends only on whether the two vertices are the same, adjacent, or not adjacent. This generalizes the concept of directed strongly regular graphs and a problem introduced by Hoffman. It also generalizes the same concept for undirected graphs, which was studied by the authors in earlier work (JCTA 120 (2013), 803-810. arXiv:1208.3067). Here we present several results and constructions of directed strongly ℓ-walk-regular graphs. Eigenvalue methods play a crucial role in obtaining these results.

Schemes with the base of size 2

Andrey Vasilév, vdr256@gmail.com
Sobolev Institute of Mathematics, Novosibirsk, Russia
Coauthor: Ilya Ponomarenko

A sufficient condition for a homogeneous coherent configuration (or simply a scheme) to have the (combinatorial) base of size 2 is proved. This result is applied to the Cartan scheme of a finite simple group G with BN-pair; by definition, it is the coherent configuration associated with the action of G on the right cosets of the Cartan subgroup $H = B \cap N$ by the right multiplications.

Hypergroups - Association Schemes - Buildings

Paul Hermann Zieschang, zieschang@utb.edu
Depatment of Mathematics, University of Texas, Brownsville, TX 78520

Let S be a set, and let μ be a map from $S \times S$ to the power set of S. For any two elements p and q of S, we write pq instead of $\mu(p,q)$ and assume that pq is not empty. For any two non-empty subsets P and Q of S, we define the *complex product* PQ to be the union of the sets pq with $p \in P$ and $q \in Q$. If one of the two factors in a complex product consists of a single element, say s, we write s instead of $\{s\}$ in that product.

Following (and generalizing) Frédéric Marty's terminology (1934) we call S a *hypergroup* (with respect to μ) if the following three conditions hold.

1. $\forall\, p, q, r \in S$: $p(qr) = (pq)r$.
2. $\exists\, e \in S\ \forall\, s \in S$: $se = \{s\}$.
3. $\forall\, s \in S\ \exists\, s^* \in S\ \forall\, p, q, r \in S$: $p \in q^*r^* \Rightarrow q \in r^*p^*$ and $r \in p^*q^*$.

Each association scheme satisfies the above three conditions with respect to its complex multiplication. Thus, hypergroups generalize association schemes.

I will explain how association schemes may take advantage of the structure theory of hypergroups. Special attention will be given to the embedding of the theory of buildings (also the definition of a building will be given in my talk) into scheme theory.

Minisymposium

Chemical Graph Theory

Organized by Xueliang Li, *Nankai University, Tianjin, China*

Perforated patches, iterated altans and their properties, *Nino Bašić*
Counting maximal matchings in some classes of graphs, *Tomislav Došlić*
Desgning enzyme catalysed reaction networks, *Christoph Flamm*
On structure sensitivity of topological indices, *Boris Furtula*
The Clar and Fries Structures of a Fullerene, *Elizabeth Hartung*
On the Terminal Wiener and Edge-Wiener Indices of an Infinite Family of Dendrimers, *Ali Iranmanesh*
Homfly polynomials of DNA double crossover polyhedral links, *Xian'an Jin*
On the Hausdorff Distance between Some Families of Chemical Graphs, *Aleksander Kelenc*
Using Hypergraphs for Chemical Synthesis Design, *Rojin Kianian*
A congruence relation for the Wiener index of graphs with a special structure, *Martin Knor*
On the Wiener inverse interval problem, *Matjaž Krnc*
On the anti-Kekule number of cubic graphs, *Qiuli Li*
The permanental polynomials of graphs and matrices, *Wei Li*
Composition of Chemical Graph Grammar Rules, *Daniel Merkle*
Molecules with Analogous Conducting Connections, *Irene Sciriha*
Edge Realizability of Connected Simple Graphs, *Cherif Sellal*
Mathematical aspects of Wiener index, *Riste Škrekovski*
An inequality between the edge-Wiener index and the Wiener index of a graph, *Aleksandra Tepeh*
Automatically Inferring Atom to Atom Mappings of Chemical Reactions, *Uffe Thorsen*
Carbon nanotubes and their resonance graphs, *Niko Tratnik*
Regular coronoids and 4-tilings, *Aleksander Vesel*
A lower bound for the first Zagreb index and its application, *Jianfeng Wang*
Binary Hamming Graphs in Archimedean Tilings, *Fuji Zhang*
On the Anti-Forcing Number of Fullerene Graphs, *Heping Zhang*
Equivalence of Zhang-Zhang polynomial and cube polynomial for carbon nanotubes, *Petra Žigert Pleteršek*

Perforated patches, iterated altans and their properties

Nino Bašić, nino.basic@fmf.uni-lj.si
University of Ljubljana
Coauthors: Tomaž Pisanski, Patrick W Fowler

Recently a class of molecular graphs, called *altans*, became a focus of attention of several theoretical chemists and mathematicians. In this talk I will present iterated altans and show, among other things, their connections with nanotubes and nanocaps. Using a result of Gutman we are able to enumerate Kekulé structures of nanocaps of arbitrary length, and hence comment on the predicted magnetic response properties (ring currents) of the corresponding carbon frameworks. In addition, the iterated altan operation will be used on a class of planar graphs called *perforated patches* where it generates multi-tube structures.

Counting maximal matchings in some classes of graphs

Tomislav Došlić, doslic@grad.hr
University of Zagreb

A matching M in a graph G is maximal if it cannot be extended to a larger matching in G. We show how several chemical and technical problems can be successfully modeled in terms of maximal matchings. Then we enumerate maximal matchings in several classes of graphs made by a linear or cyclic concatenation of basic building blocs. We also count maximal matchings in joins and corona products of some classes of graphs.

Desgning enzyme catalysed reaction networks

Christoph Flamm, xtof@tbi.univie.ac.at
University of Vienna
Coauthors: Daniel Merkle, Jakob Andersen, Peter F. Stadler

Various measures e.g. atom economy or number of used reactions are frequently used in Organic Synthesis to evaluate and compare different total synthesis'. These measures shape the strategies how organic chemists design a synthesis to a target molecule. Metabolic engineering, a sub-field of Synthetic Biology, investigates the de-novo construction and design of enzyme catalysed reaction networks for in vitro and/or in vivo production of commodity chemicals. Since for many target molecules no natural pathways are known, recombination of enzyme functionality under optimality criteria becomes important to guide the design efforts. But what does "optimal" mean in a biological context? I will present a computational framework which allows to explore and rank the entire network design space spanned by a set of enzymes, starting compounds, and some measure of optimality.

On structure sensitivity of topological indices

Boris Furtula, furtula@kg.ac.rs
Faculty of Science, University of Kragujevac

A number of topological indices (TIs) was increasing rapidly in the past decade. However, their applications do not follow such trend. This fact significantly decreases the reputation of chemical graph theory in scientific community.

As a remedy for such problem, stringent criteria for the introducing a "new" topological index must be applied.

In nineties, Randić has gathered a set of properties that some newly proposed TI must have in order to be further considered in researches. One of these qualities will be discussed here.

The Clar and Fries Structures of a Fullerene

Elizabeth Hartung, lizhartung@gmail.com
Massachusetts College of Liberal Arts
Coauthor: Jack Graver

The Fries and Clar number of a fullerene are two parameters related to the stability of the molecule. We introduce “Fries chains," a decomposition of the edges of a Kekule structure (or perfect matching) of a fullerene. Chains allow us to better understand the structure of these graphs and to find the Fries number for classes of fullerenes. The relationship to the Clar number and Clar chains will be discussed, and we will give a class of fullerenes with the property that the set of benzene rings (alternating hexagons) of its Clar structure and the set of benzene rings of its Fries structure are practically disjoint.

On the Terminal Wiener and Edge-Wiener Indices of an Infinite Family of Dendrimers

Ali Iranmanesh, iranmanesh@modares.ac.ir
Faculty of Mathematical Sciences, Tarbiat Modares University, Tehran, Iran
Coauthor: Mahdieh Azari

Let G be a simple connected n-vertex graph with the vertex set $V(G) = \{v_1, v_2, ..., v_n\}$ and let $\mathrm{P} = (p_1, p_2, ..., p_n)$ be an n-tuple of nonnegative integers. The thorn graph G_P is the graph obtained by attaching p_i pendent vertices to the vertex v_i of G, for $i = 1, 2, ..., n$. The concept of thorn graphs was first introduced by Gutman [1] and eventually found a variety of chemical applications. The terminal Wiener index $TW(G)$ of G [2] is defined as the sum of distances between all pairs of pendent vertices of G and the edge-Wiener index $W_e(G)$ of G [2-4] is defined as the sum of distances between all pairs of its edges. Two possible distances $d_0(e, f|G)$ and $d_4(e, f|G)$ between the edges e and f of G can be considered and according to them, the first edge-Wiener index $W_{e_0}(G)$ and the second one $W_{e_4}(G)$ are introduced. In this paper, we present exact formulae for computing the terminal Wiener index, the first and the second edge-Wiener indices of an infinite family of dendrimers by considering them as the thorn graphs of simpler dendrimers.

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Homfly polynomials of DNA double crossover polyhedral links

Xian'an Jin, xajin@xmu.edu.cn

Xiamen University

In this talk, we first give a relation between the Homfly polynomal and the weighted Tutte polynomial. Then we discuss applications of the relation to DNA double crossover polyhedra.

On the Hausdorff Distance between Some Families of Chemical Graphs

Aleksander Kelenc, aleksander.kelenc@um.si

Faculty of Natural Sciences and Mathematics, University of Maribor

Coauthor: Andrej Taranenko

In chemistry, the problem known as similarity searching involves finding a set of molecules that are similar to a given sample molecule. The problem is tackled using graph theory and related algorithmic approaches involving some kind of measure of similarity of two graphs. In this talk we present some results about a recently introduced Hausdorff distance between some families of graphs that often appear in chemical graph theory. Next to a few results for general graphs, we determine formulae for the distance between paths and cycles. For trees some bounds are proved. Also, an exact (exponential time) algorithm for determining the distance between two arbitrary trees is presented. We give examples emphasizing the difference between this new measure and some other known approaches, also reasons why some well-known algorithms for trees may not suffice to determine the Hausdorff distance of two trees are shown.

Using Hypergraphs for Chemical Synthesis Design

Rojin Kianian, rojin@imada.sdu.dk
Department of Mathematics and Computer Science, University of Southern Denmark
Coauthors: Rolf Fagerberg, Christoph Flamm, Daniel Merkle, Peter F. Stadler

Sophisticated tools have been developed in order to create new compounds. However, despite the fact that computer-assisted organic synthesis design has been an active research topic for decades, many well-established approaches from theoretical computer science are nearly unused in this context. For instance, algorithmic approaches to find optimal synthesis plans are often limited to revolve around the question of determining optimal bond sets. Noting that each bond set represents a possibly very large set of different synthesis plans for the target compound, there is a need for methods for choosing among these. We attack this problem by modeling synthesis plans as hyperpaths in a hypergraph. As a consequence, a polynomial time algorithm to find the K shortest hyperpaths can be adapted to compute the K best synthesis plans. Since any modeling and cost measure definition necessarily leaves out many real-world details, finding a (small) set of good plans – as oppose to merely one – allows a chemist to choose a good plan based on additional chemical knowledge and actual wet-lab feasibility. We discuss classical objective functions for synthesis plans, such as convergence of a plan and the total weight of starting materials.

A congruence relation for the Wiener index of graphs with a special structure

Martin Knor, knor@math.sk
Slovak University of Technology in Bratislava
Coauthors: Katarína Hriňáková, Riste Škrekovski, Aleksandra Tepeh

Wiener index, the sum of all distances in a graph, is probably the most important topological descriptor. There are several papers establishing congruence relations for the Wiener index in various classes of graphs. We generalized the results of Lin and we obtained congruence relations for large families of graphs with a tree-like structure.

On the Wiener inverse interval problem

Matjaž Krnc, matjaz.krnc@gmail.com
Institute of Mathematics, Physics and Mechanics
Coauthor: Riste Škrekovski

The well studied Wiener index $W(G)$ of a graph G is equal to the sum of distances between all pairs of vertices of G. Denote by $\mathrm{Im}(n)$ the set of all values of the Wiener Index over all connected graphs on n vertices. Also, let $\mathcal{I}_n$ be the largest interval which is fully contained in $\mathrm{Im}(n)$. In the minisymposium I will outline our results on the cardinality of $\mathcal{I}_n$ and $\mathrm{Im}(n)$. In particular, I will show that $\mathcal{I}_n$ and $\mathrm{Im}(n)$ are of cardinality $\frac{1}{6}n^3 + O\left(n^2\right)$, and that they both start at $\binom{n}{2}$. We will also discuss other properties of $\mathrm{Im}(n)$ and $\mathcal{I}_n$ and state some open problems.

On the anti-Kekule number of cubic graphs

Qiuli Li, qlli@lzu.edu.cn
Lanzhou University
Coauthors: Wai Chee Shiu, Pak Kiu Sun, Dong Ye

The anti-Kekulé number of a connected graph G is the smallest number of edges to be removed to create a connected subgraph without perfect matchings. In this article, we show that the anti-Kekulé number of a 2-connected cubic graph is either 3 or 4, and the anti-Kekulé number of a connected cubic bipartite graph is always equal to 4. Moreover, direct application of these results show that the anti-Kekulé number of a boron-nitrogen fullerene is 4 and the anti-Kekulé number of a (3,6)-fullerene is 3.

The permanental polynomials of graphs and matrices

Wei Li, liw@nwpu.edu.cn
Northwestern Polytechnical University
Coauthor: Heping Zhang

Pólya's problem concerns the conversion of the permanent and determinant of a matrix. As a generalization of this problem, this topic focus on the conversion of the permanental polynomial and the characteristic polynomial. Firstly, we provide a sufficient and necessary condition for converting the computation of the permanental polynomial of a graph into the computation of the characteristic polynomial of an orientation graph. Then we characterize those matrices whose permanental polynomials can computed by the characteristic polynomials of some matrices.

Composition of Chemical Graph Grammar Rules

Daniel Merkle, daniel@imada.sdu.dk
University of Southern Denmark
Coauthors: Jakob Andersen, Christoph Flamm, Peter F. Stadler

Graph rewriting has been applied successfully to model chemical and biological systems at different levels of abstraction. To this end chemical reactions are modelled as graph transformations and in a generative fashion a hypergraph is expanded that allows for subsequent network flow analysis. A particularly powerful feature of rule-based models that are rigorously grounded in category theory, is, that they admit a well-defined notion of rule composition, hence, provide their users with an intrinsic mechanism for compressing trajectories and coarse grained representations of dynamical aspects. The same formal framework, however, also allows the detailed analysis of transitions in which the final and initial states are known, but the detailed step-wise mechanism remains hidden. To demonstrate the general principle we consider how rule composition is used to determine accurate atom maps for complex enzyme reactions. This problem not only exemplifies the paradigm but is also of considerable practical importance for many down-stream analyses of metabolic networks and it is

a necessary prerequisite for predicting atom traces for the analysis of isotope labelling experiments.

Molecules with Analogous Conducting Connections

Irene Sciriha, isci1@um.edu.mt
University of Malta

According to the Source and Sink Potential (SSP) model, for a chosen two–vertex–connection, a molecule is a conductor or an insulator, at the Fermi—level. Of particular interest are two classes of graphs that have analogous vertex pairs, that is the molecule shows the same behaviour for any two–vertex–connection. The first consists of the uniform—core graphs, corresponding to insulation at the Fermi-–level for all two–vertex–connections and the second class, the nuciferous graphs, which are Fermi-–level conducting devices with no non–bonding orbital, independent of the two–vertex–connection. The latter class has the additional property that the graphs are insulators for all one vertex connections. The criteria depend solely on the nullity of the adjacency matrix of the graph and of its vertex–deleted subgraphs. A graph G in the first class reaches the minimum allowed value for the nullity relative to that of G when the connecting vertices are deleted, for all pairs of distinct connecting vertices of G. In the second, the nullity reaches one, the maximum possible, when any vertex is deleted.

Edge Realizability of Connected Simple Graphs

Cherif Sellal, cherif.sellal@gerad.ca
Polytechnique de Montréal

Coauthors: Mustapha Aouchiche, Gilles Caporossi, Pierre Hansen, Damir Vukičević

We study necessary and sufficient conditions for existence of a simple graph G, and for a simple and connected graph G' with given numbers m_{ij} of edges with end-degrees i, j for $i \leq j \in \{1, 2, ..., \Delta\}$ where Δ denotes the maximum degree of G or G'. Applications in Mathematical Chemical are to optimization of bound additive topological indices. Algorithms for drawing these graphs are also provided

Mathematical aspects of Wiener index

Riste Škrekovski, skrekovski@gmail.com
FMF, FIS, FAMNIT, IMFM,

The Wiener index (i.e., the total distance or the transmission number), defined as the sum of distances between all unordered pairs of vertices in a graph, is one of the most popular molecular descriptors. In this talk, I will summarize some results, conjectures, and problems on this molecular descriptor, with emphasis on the work of me and my coauthors.

An inequality between the edge-Wiener index and the Wiener index of a graph

Aleksandra Tepeh, aleksandra.tepeh@gmail.com
FEECS, University of Maribor and FIŠ, Novo mesto
Coauthors: Martin Knor, Riste Škrekovski

The Wiener index $W(G)$ of a connected graph G is defined to be the sum $\sum_{u,v} d(u,v)$ of distances between all unordered pairs of vertices in G. Similarly, the edge-Wiener index $W_e(G)$ of G is defined to be the sum $\sum_{e,f} d(e,f)$ of distances between all unordered pairs of edges in G, or equivalently, the Wiener index of the line graph $L(G)$. Wu showed that $W_e(G) \geq W(G)$ for graphs of minimum degree 2, where equality holds only when G is a cycle. Similarly, Knor, Potočnik, Škrekovski showed that $W_e(G) \geq \frac{\delta^2-1}{4} W(G)$ where δ denotes the minimum degree in G. In this talk, we extend/improve these two results by showing that $W_e(G) \geq \frac{\delta^2}{4} W(G)$ with equality satisfied only if G is a path on 3 vertices or a cycle. In addition, we show that among graphs G on n vertices $\frac{W_e(G)}{W(G)}$ attains its minimum for the star.

Automatically Inferring Atom to Atom Mappings of Chemical Reactions

Uffe Thorsen, uthorsen@imada.sdu.dk
University of Southern Denmark
Coauthors: Daniel Merkle, Christoph Flamm, Peter F. Stadler

By modeling molecules as graphs it is possible to infer atom to atom mappings of chemical reactions by solving the minimum edge edit distance problem. This can among other things be used to generate graph grammar rules for use in generative chemistry. Another application is to complete chemical or biological networks by automatically inferring hypotheses for missing chemical reactions missing in the networks.

Chemically inspired methods for solving the minimum edge edit distance, both a constructive and a declarative, will be introduced. Included is a discussion on the challenges of and techniques for distinguishing mathematically optimal atom to atom mappings from chemically valid ones.

Carbon nanotubes and their resonance graphs

Niko Tratnik, niko.tratnik1@um.si
FNM UM
Coauthor: Petra Žigert Pleteršek

Carbon nanotubes are chemical compounds made of carbon which possess a cylindrical structure. Open-ended single-walled carbon nanotubes are called tubulenes. The resonance graph of a tubulene reflects the interference among its Kekulé structures. First we will present some basic properties of tubulenes and their resonance graphs. Then we will describe the structure and the length of a shortest path in the hexagonal lattice. This result is then used to give a condition under which the resonance graph of a tubulene is not connected. Furthermore, we will mention that every connected component of the resonance graph of a tubulene is either a path or a graph of girth 4. We will also provide a condition for a tubulene under which every connected component of its resonance graph different from a path without vertices of degree one is 2-connected.

Regular coronoids and 4-tilings

Aleksander Vesel, aleksander.vesel@um.si
University of Maribor, IMFM

A benzenoid graph is a finite connected plane graph with no cut-vertices in which every interior region is bounded by a regular hexagon of a side length one. A coronoid G is a connected subgraph of a benzenoid graph such that every edge lies in a hexagon of G and G contains at least one non-hexagon interior face (called corona hole), which should have a size of at least two hexagons. A polyhex is either a benzenoid or a coronoid. Regular coronoids can be generated from a single hexagon by a series of normal additions plus corona condensations of modes L_2 or A_2. The vertices of the inner dual of a polyhex G, denoted by $I(G)$, are the centers of all hexagons of G, two vertices being adjacent if and only if the corresponding hexagons share an edge in G. Let S denote a subset of internal edges of $E(I(G))$. If $I_S(G) := I(G) \setminus S$ is the graph where for every triple of pairwise adjacent hexagons h_1, h_2, h_3 of $V(I(G))$ there exists a hexagon h_4 of $V(I(G))$ such that h_1, h_2, h_3, h_4 induce a 4-cycle of $I_S(G)$, then S is a 4-tiling of G. We show that a coronoid G admits a 4-tiling if and only if G is regular. Moreover, we prove that a coronoid G is regular if and only if G can be generated from a single hexagon by a series of normal additions plus corona condensations of mode A_2. This confirms Conjecture 6 stated in [H. Zhang, Regular coronoids and ear decompositions of plane elementary bipartite graphs, *CJCDGCGT'05 Proceedings of the 7th China-Japan conference on Discrete geometry, combinatorics and graph theory* (2007) 259–271].

A lower bound for the first Zagreb index and its application

Jianfeng Wang, jfwang@aliyun.com
Qinghai Normal University, Nankai University,China

Coauthor: Francesco Belardo

In this report, we will introduce a new lower bound for the first Zagreb index and determine all the extreme graphs. These results not only contain many previous ones but are helpful to find new graphs determined by the Laplacian spectra.

Binary Hamming Graphs in Archimedean Tilings

Fuji Zhang, fjzhang@xmu.edu.cn
Xiamen University

In this paper, we find all binary Hamming tilings (i.e. the tilings corresponding to binary Hamming graphs) in Archimedean tilings and show the only four such tilings are (4; 4; 4; 4),(6; 6; 6),(4; 8; 8) and (4; 6; 12). Then we compute the Wiener number of some plane connected subgraphs of binary Hamming tilings and consider their asymptotic behavior

On the Anti-Forcing Number of Fullerene Graphs

Heping Zhang, zhanghp@lzu.edu.cn
Lanzhou University

The anti-forcing number of a connected graph G is the smallest number of edges such that the remaining graph obtained by deleting these edges has a unique perfect matching. In this paper, we show that the anti-forcing number of every fullerene has at least four. We give a procedure to construct all fullerenes whose anti-forcing numbers achieve the lower bound four. Furthermore, we show that, for every even $n \geq 20$ ($n \neq 22, 26$), there exists a fullerene with n vertices that has the anti-forcing number four, and the fullerene with 26 vertices has the anti-forcing number five.

Equivalence of Zhang-Zhang polynomial and cube polynomial for carbon nanotubes

Petra Žigert Pleteršek, petra.zigert@um.si
UM FKKT, UM FNM

Coauthors: Niko Tratnik, Martina Berlič

Benzenoid systems or hexagonal systems are subgraphs of a hexagonal lattice. Open-ended carbon nanotubes alias tubulenes can be seen as an embedding of a benzenoid system to a surface of a cylinder with some perimeter edges being joined. Carbon nanotubes are interesting materials with some unusual properties and have therefore been of great interest for researchers in the last 30 years.

Zhang-Zhang polynomial (also called Clar covering polynomial) of a spherical benzenoid system is a counting polynomial of resonant structures called Clar covers. Cube polynomial is a counting polynomial of induced hypercubes in a graph. In 2013 Zhang et al. established the one-to-one correspondence between Clar covers of a benzenoid system G and hypercubes of its resonance graph $R(G)$. We will extend the equality of these two polynomials to tubulenes.

Minisymposium

Combinatorics

Organized by Matjaž Konvalinka, *University of Ljubljana, Slovenia*

Trees with minimum number of infima closed sets, *Eric Andriantiana*
Combinatorial study of r-Whitney and r-Dowling numbers, *Eszter Gyimesi*
Generalization of enumeration polynomials for graphs, *Gábor Nyul*
On the enumeration of planar Eulerian orientations, *Claire Pennarun*
A Gluing Scheme for Maximal-Girth Tree-Decomposed Graphs, *Daniel Pinto*
Group divisible designs $GDD(n, n, n, 2; \lambda_1, \lambda_2)$, *Atthakorn Sakda*
Recent results on subtrees of trees, *Stephan Wagner*
Ryser's conjecture for multipartite hypergraphs, *Ian Wanless*
Special cases of de Bruijn Objects and its applications, *Rafał Witkowski*
Order congruence lattices are EL-shellable, *Russ Woodroofe*

Trees with minimum number of infima closed sets

Eric Andriantiana, e.andriantiana@ru.ac.za
Rhodes University
Coauthor: Stephan Wagner

A subset X of $V(T)$ is called an infima closed set of a rooted tree T if for any $u, v \in X$ the merging vertex of the paths joining the root of T to u and v is also in X. We determine the trees with minimum number of infima closed sets among all rooted trees of fixed order. It is observed that minimal trees can be obtained from a complete binary trees by attaching more leaves to selected vertices that has at most one non-leaf neighbour.

Combinatorial study of r-Whitney and r-Dowling numbers

Eszter Gyimesi, gyimesie@science.unideb.hu
Institute of Mathematics, University of Debrecen
Coauthor: Gábor Nyul

T. A. Dowling introduced Whitney numbers of the first and second kind concerning the so-called Dowling lattices of finite groups. It turned out that they are generalizations of Stirling numbers. Later, I. Mező defined r-Whitney numbers as a common generalization of Whitney numbers and r-Stirling numbers.

By summation of r-Whitney numbers of the second kind, we obtain r-Dowling numbers which are therefore the generalizations of Bell numbers.

In our talk, we present a new combinatorial interpretation of r-Whitney and r-Dowling numbers. This allows us to explain their properties in a purely combinatorial manner, as well as derive some new identities.

Generalization of enumeration polynomials for graphs

Gábor Nyul, gnyul@science.unideb.hu
Institute of Mathematics, University of Debrecen
Coauthor: Zsófia Kereskényi-Balogh

B. Duncan and R. Peele were the first who studied enumeration of independent partitions of graphs from a combinatorial point of view, and introduced Stirling numbers of the second kind and Bell numbers for graphs.

In our talk, we present properties of these numbers and values for special graphs, as well as their ordered relatives, the so-called Fubini numbers for graphs. In connection with these numbers, we introduce and study some enumeration polynomials for graphs.

These results give us an alternative way to investigate several purely combinatorial variants of these numbers and polynomials, for instance, the ordinary, nonconsecutive and r-generalized variants.

On the enumeration of planar Eulerian orientations

Claire Pennarun, claire.pennarun@labri.fr
University of Bordeaux
Coauthors: Nicolas Bonichon, Mireille Bousquet-Mélou, Paul Dorbec

Eulerian planar maps are planar maps with all vertices of even degree. The number of Eulerian planar maps with a fixed number of edges m is well known, and they are in bijection with many combinatorial families, such as balanced Eulerian trees or bicubic maps. Planar Eulerian orientations are directed planar maps in which the in- and out-degrees of every vertex are equal. We first count the number of planar Eulerian orientations for $m \leq 12$ (m is the number of edges) thanks to an encoding based on bilateral Dyck words. The values found (2, 10, 66, 504, 4216, 37548...) do not match with any known series from the OEIS. We then present a sequence of algebraic series giving lower and upper bounds of the growth rate of planar Eulerian orientations. We show in particular that the growth rate of planar Eulerian orientations is between 10.69^m and 12.94^m.

A Gluing Scheme for Maximal-Girth Tree-Decomposed Graphs

Daniel Pinto, dpinto@mat.uc.pt
University of Coimbra
Coauthor: Ethan Cotterill

If we take three perfect binary trees of the same height we can build a trivalent graph, that we will call *quasi-binary tree*, by adding an edge from each one of the three root vertices of the original trees to a new vertex. We will show that, for all $n \in \mathbb{N}$, there is a way of gluing three quasi-binary trees of the same height n such that the girth of the connected graph, that results from identification of the leaves, has the maximal possible value, that is: $2n+2$.

Group divisible designs $\mathrm{GDD}(n,n,n,2;\lambda_1,\lambda_2)$

Atthakorn Sakda, atthakorn1974@hotmail.com
Chulalongkorn University
Coauthor: Chariya Uiyyasathian

A *group divisible design* $\mathrm{GDD}(g = g_1 + g_2 + \cdots + g_s, s, k; \lambda_1, \lambda_2)$ is an ordered pair $(G, \mathcal{B})$ where G is a g-set of treatments which is partitioned into s sets (called *groups*) of sizes $g_1, g_2, \ldots, g_s$, and $\mathcal{B}$ is a collection of k-subsets of G called *blocks* such that each pair of elements from the same group appear together in λ_1 blocks and each pair of elements from distinct groups appear together in λ_2 blocks. In this talk, for each tuple of integers $(n, \lambda_1, \lambda_2)$ we give a complete solution for the existence problem of $\mathrm{GDD}(g = n+n+n+2, 4, 3; \lambda_1, \lambda_2)$.

Recent results on subtrees of trees

Stephan Wagner, swagner@sun.ac.za
Stellenbosch University

This talk reviews some recent results on the number of subtrees of a tree and related tree invariants. Specifically, we will be looking at extremal trees (maximising or minimising the number of subtrees) under various conditions, bounds on the average subtree order (average size of a randomly chosen subtree of a tree) that settle some conjectures of Jamison from the 1980s, the distribution of the subtree orders in "large" trees, and the number of nonisomorphic subtrees of a tree.

Ryser's conjecture for multipartite hypergraphs

Ian Wanless, ian.wanless@monash.edu
Monash University

An *r-partite hypergraph* has a partition of the vertices into disjoint sets $V_1,\dots,V_r$ and every edge includes exactly one vertex from each V_i. A *matching* in a hypergraph H is a set of disjoint edges. The largest size of a matching in H is denoted $\nu(H)$. A *cover* in a hypergraph is a set of vertices which meets every edge. The size of the largest cover in H is denoted $\tau(H)$. Ryser conjectured that $\tau(H) \le (r-1)\nu(H)$ for r-partite hypergraphs.

Define $f(r)$ to be the smallest number of edges in an r-partite hypergraph H with $\nu(H) = 1$ and $\tau(H) \ge r-1$ (if such an H exists!).

I will discuss work from two recent papers in which we

- Prove the special case of Ryser's conjecture where $r \le 9$ and H is linear (meaning each pair of edges meets at a unique vertex).
- Disprove a strengthened version of Ryser's conjecture proposed by Aharoni.
- Find the values of $f(6)$ and $f(7)$ and improve the general lower bound on $f(r)$.

Special cases of de Bruijn Objects and its applications

Rafał Witkowski, rmiw@amu.edu.pl
Adam Mickiewicz University

A k-ary De Bruijn sequence $B(n,k)$ of order n, is a sequence of a given alphabet A with size k for which every subsequence of length n in A appears as a sequence of consecutive characters exactly once. De Bruijn matrix is an array of symbols from an alphabet A of size k that contains every m-by-n matrix exactly once. Our goal is to maximize size of the matrix. We will define rotation resistant De Bruijn matrix as a matrix where $k = 4$ and each symbol can be rotated: $1 \to 2, 2 \to 3, 3 \to 4, 4 \to 1$. We will try to give an answer how big can be such a matrix. We will consider, if there exist upper bound for the size of regular de Bruijn matrix.

Order congruence lattices are EL-shellable

Russ Woodroofe, rw1003@msstate.edu
Mississippi State University
Coauthor: Jay Schweig

The lattice of order congruences of a poset P is the subposet O(P) of the lattice of partitions of P, consisting of all partitions that satisfy a certain order-convexity property. The partition lattice is both semi-modular and supersolvable, but Körtesi, Radelecki and Szilágyi gave examples of order congruence lattices that are not semi-modular, and we find examples that are not supersolvable.

We show that the order congruence lattices satisfy a recursive condition on the existence of modular elements, which we call lm-decomposability. Lm-decomposability generalizes both supersolvability and semimodularity. We show that any lm-decomposable lattice is EL-shellable. This result simultaneously improves a weaker result of Jenča and Sarkoci, and also exposes inclusion-exclusion information (Möbius numbers).

This project is joint with Jay Schweig.

Minisymposium

Finite Geometry

Organized by Tamás Szőnyi, *Eötvös Loránd University, Budapest, Hungary*

Pseudoachromatic and connected-pseudoachromatic indices of the complete graph, *Gabriela Araujo Pardo*

Resolving sets in Affine planes, *Daniele Bartoli*

Strongly regular graphs and substructures of finite classical polar spaces, *Jan De Beule*

Linear codes from Hermitian curves , *Gabor Korchmaros*

On Ovoids, Cores, and Preserver Problems, *Marko Orel*

Forbidden subgraphs in the norm graph, *Valentina Pepe*

Integral automorphisms of higher dimensional affine spaces over finite fields $GF(p)$, *János Ruff*

Binary codes of the symplectic generalized quadrangle of even order, *Binod Kumar Sahoo*

Large Cayley graphs of given degree and diameter from finite geometries, *Jozef Širáň*

Pseudoachromatic and connected-pseudoachromatic indices of the complete graph

Gabriela Araujo Pardo, garaujo@math.unam.mx
Mathematics Institute, National University of Mexico
Coauthor: Christian Rubio

In this paper we study these two parameters for the complete graph K_n. First, we prove that, when q is a power of 2 and $n = q^2 + q + 1$, the pseudoachromatic index $\psi'(K_n)$ of the complete graph K_n is at least $q^3 + 2q - 3$; which improves the bound $q^3 + q$ given by Araujo, Montellano and Strausz [J Graph Theory 66 (2011), 89–97]. Our main contribution is to improve the linear lower bound for the connected pseudoachromatic index given by Abrams and Berman [Australas J Combin 60 (2014), 314–324] and provide an upper bound, these two bounds prove that for any integer $n \geq 8$ the order of $\psi'_c(K_n)$ is $n^{3/2}$.

Remark: The colorations that induce the lower bounds are given using the structure of Projectives Planes.

Resolving sets in Affine planes

Daniele Bartoli, dbartoli@cage.ugent.be
Department of Mathematics, Ghent University
Coauthors: Tamás Héger, György Kiss, Marcella Takáts

Let $\Gamma = (V, E)$ be a graph. A vertex $v \in V$ is resolved by a vertex-set $S = \{v_1, \ldots, v_n\}$ if its (ordered) distance list $(d(v, v_1), \ldots, d(v, v_n))$ with respect to S is unique. S is a resolving set in Γ if every vertex $v \in V$ is resolved by S. The metric dimension of Γ is the size of the smallest resolving set in it.

In a recent work Héger and Takáts (*Resolving sets and semi-resolving sets in finite projective planes*, Electron. J. Combin. **19** #P30, 2012) showed that the metric dimension of the incidence graph of a finite projective plane of order $q \geq 23$ is $4q - 4$ and they classified all the resolving sets of that size.

We analyze the problem in the affine case and we prove that the metric dimension of $AG(2, q)$ is at most $3q - 4$. The main differences in the approach rely on the non-applicability of the duality principle, due to the presence of parallel lines.

Strongly regular graphs and substructures of finite classical polar spaces

Jan De Beule, jdebeule@cage.ugent.be
Ghent University

Let Γ be a strongly regular graph with parameters (n,k,λ,μ). Let A be its adjacency matrix. if $0<k<n-1$, then it is well known that, under certain conditions,

- the matrix A has three eigenvalues k, e^+ and e^-;
- the eigenvalue k has multiplicity 1 and its eigenspace is generated by the all-one vector $\mathbf{j}$;
- let V^+, V^- respectively, be the eigenspace corresponding to the eigenvalue e^+, e^- respectively, then $\mathbb{C}^n = \langle \mathbf{j} \rangle \perp V^+ \perp V^-$.

A finite classical polar space is the geometry of totally isotropic sub vector spaces with relation to a sesquilinear or quadratic form on a vector space. Such a geometry is embedded in a projective space and contains points, lines, planes, etc. The point graph of a finite classical polar space is the graph with vertex set the set of points, and two vertices are adjacent if and only if the two points are collinear in the polar space. This graph Γ will be strongly regular and its parameters are well known. A *weighted intriguing set* is a vector orthogonal to either V^- or V^+. In the polar space, such a vector represents a generalization of the geometrical concepts *ovoid* and *tight* sets.

In the talk we report on some recent results on substructures of finite classical polar spaces that were obtained by studying them in a graph theoretical context. These results include: recent results (jointly with J. Bamberg and F. Ihringer) on the non-existence of ovoids of certain finite classical polar spaces, recent results (jointly with J. Demeyer, K. Metsch, and M. Rodgers) on the construction of certain tight sets of the quadric of Klein.

Linear codes from Hermitian curves

Gabor Korchmaros, gabor.korchmaros@unibas.it
Department of Mathematics, Informatics and Economy of University of Basilicata
Coauthor: Pietro Speziali

We deal with some problems in Finite geometry arising from current research on AG (algebraic-geometry) codes defined over the Hermitian curve.

In $PG(2,q^2)$, let $\mathcal{H}$ be the Hermitian curve. For a fixed positive integer d, let $\mathbf{S}_d$ be the family of all degree d plane algebraic curves (possibly singular or reducible) defined over $\mathbf{F}_{q^2}$ which do not have $\mathcal{H}$ as a component. A natural question in Finite geometry is to ask for the maximum number $N(d)$ of common points in $PG(2,q^2)$ of $\mathcal{H}$ with $\mathcal{S}$ where $\mathcal{S}$ ranges over $\mathbf{S}_d$. From Bézout's theorem, $N(d) \le d(q+1)$. The problem of finding better upper bounds on $N(d)$ for certain families of curves $\mathbf{S}$ is motivated by the "minimum distance problem" for AG-codes.

A family of curves which play role in the study of Hermitian codes is defined as follows:

Let β be a Baer involution of $PG(2,q^2)$ which preserves $\mathcal{H}$. The set of points of $\mathcal{H}$ which are fixed by β has size $q+1$ and it is the complete intersection $\mathcal{H}\cap\mathcal{C}^2$ of $\mathcal{H}$ with an irreducible conic $\mathcal{C}^2$. For a positive integer m less than $q+1$, define D to be the set of all points of $\mathcal{H}$ other than those in U, together with the divisor (formal sum) G of points on $\mathcal{H}$:

$$\mathsf{G} := m \sum_{\mathcal{H}\cap\mathcal{C}^2} P.$$

The functional AG-code $C_L(\mathsf{G}, D)$ is obtained taking the rational functions with pole numbers at most m at any point in $\mathcal{H}\cap\mathcal{C}^2$ and evaluating them at the points of D.

For m even, the minimum distance problem for $C_L(D,G)$ is equivalent to the problem of determining the maximum number of points on $\mathcal{H}\cap\mathcal{S}$ with $\mathcal{S}\in\mathbf{S}_m$.

For m odd, let $\mathbf{T}_{m+1}$ be the subfamily of $\mathbf{S}_d$ consisting of all curves $\mathcal{T}$ of degree $m+1$ which contain all points in D. The minimum distance problem for $C_L(D,G)$ is equivalent to the problem of determining the maximum number of points on $\mathcal{H}\cap\mathcal{T}$ with $\mathcal{T}\in\mathbf{T}_{m+1}$.

The automorphism group of $C_L(D,G)$ contains a subgroup $G\cong P\Gamma L(2,q)$. Is it true that this subgroup is the full automorphism group?

We address the above problems using tools from Finite geometry.

On Ovoids, Cores, and Preserver Problems

Marko Orel, marko.orel@upr.si

University of Primorska; Institute of Mathematics, Physics, and Mechanics

I will present two results from matrix theory (two preserver problems), which are closely related to (non)existence of ovoids in certain classical polar spaces. While in the first problem, the nonexistence of ovoids or spreads in polar spaces is just applied to deal with one of the key steps in the proof, the second problem is essentially equivalent to the (non)existence of ovoids. In both results several tools from graph theory that involves graph spectra, chromatic number of a graph, etc, are applied as well.

Forbidden subgraphs in the norm graph

Valentina Pepe, valepepe@sbai.uniroma1.it

Sapienza University of Rome

Coauthor: Simeon Ball

Let H be a fixed graph. The *Turán number* of H, denoted $ex(n,H)$, is the maximum number of edges that a graph with n vertices and not containing a copy of H can have. When H is bipartite, in many cases, even the question of determining the right order of magnitude for $ex(n,H)$ is not known. We have the following bounds:

$$cn^{2-1/t} \leq ex(n,K_{t,s}) \leq \frac{1}{2}(s-1)^{\frac{1}{t}}n^{2-\frac{1}{t}} + \frac{1}{2}(t-1)n$$

where the lower one is probabilistic. In [1], the authors construct the so called *norm graph* $\Gamma(t)$, proving that the upper bound is asymptotically sharp for $K_{t,s}, s > (t-1)!$. We prove that $\Gamma(t)$ also contains no copy of $K_{t+1,s}, s \geq (t-1)! - 1$, improving the known lower bound for $t = 4$ and showing that $\Gamma(t)$ is the best determinist construction for $(t-1)! - 1 \leq s \leq t!$, $t \geq 4$.

References:

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[2] S. Ball and V. Pepe, Asymptotic improvements to the lower bound of certain bipartite Turán numbers, *Combin. Probab. Comput.*, **21** (2012) 323–329.

[3] S. Ball and V. Pepe, New forbidden graphs in the norm graph, arXiv: http://arxiv.org/abs/1502.01502.

Integral automorphisms of higher dimensional affine spaces over finite fields $GF(p)$

János Ruff, ruffjanos@gmail.com

University of Pécs

Coauthors: István Kovács, Klavdija Kutnar, Tamás Szőnyi

A permutation of the affine space $AG(n,q)$ is called an integral automorphism if it preserves the integral distance defined among the points. The integral automorphisms which are also semiaffine transformations were determined by Kurz and Meyer (2009). In this talk, we show that there is no additional integral automorphism for the affine spaces $AG(n,p)$ and $AG(3,p^2)$, where $n \geq 3$ and p is an odd prime. Joint work with István Kovács, Klavdija Kutnar and Tamás Szőnyi.

Binary codes of the symplectic generalized quadrangle of even order

Binod Kumar Sahoo, bksahoo@niser.ac.in

National Institute of Science Education and Research, Bhubaneswar, India

Coauthor: N. S. Narasimha Sastry

Let q be a prime power and $W(q)$ be the symplectic generalized quadrangle of order q. For q even, let $\mathcal{O}$ (respectively, $\mathcal{E}$, $\mathcal{T}$) be the binary linear code spanned by the ovoids (respectively, elliptic ovoids, Tits ovoids) of $W(q)$ and Γ be the graph defined on the set of ovoids of $W(q)$ in which two ovoids are adjacent if they intersect at one point. For $\mathcal{A} \in \{\mathcal{E}, \mathcal{T}, \mathcal{O}\}$, we describe the codewords of minimum and maximum weights in $\mathcal{A}$ and its dual $\mathcal{A}^\perp$, and show that $\mathcal{A}$ is a one-step completely orthogonalizable code. We prove that, for $q > 2$, any blocking set of $PG(3,q)$ with respect to the hyperbolic lines of $W(q)$ contains at least $q^2 + q + 1$ points and equality holds if and only if it is a hyperplane of $PG(3,q)$. We deduce that a clique in Γ has size at most q.

Large Cayley graphs of given degree and diameter from finite geometries

Jozef Širáň, siran@math.sk

Slovak University of Technology, Bratislava, Slovakia

Coauthors: Jana Šiagiová, Martin Bachratý

It has been known that for diameters $k \in \{2, 3, 5\}$, graphs of diameter k and maximum degree $q + 1$ for infinite sets of prime powers q and with orders asymptotically approaching the corresponding Moore bounds can be obtained from generalised triangles, quadrangles and hexagons. These graphs, however, are not vertex-transitive, as they are not even regular. We will show how to use finite geometries to construct *Cayley* graphs with the above properties for $k = 2$ and 3; the case $k = 5$ still remains open.

Minisymposium

Graph Domination

Organized by Paul Dorbec, *Université de Bordeaux, LaBRI, France*

General upper bound on the game domination number, *Csilla Bujtás*

Monitoring a Network with Watchers and Listeners, *Bert Hartnell*

Uniform hypergraphs and vertex dominating sets of graphs, *Mercè Mora*

Broadcast Domination and Irredundance, *Kieka Mynhardt*

On the rainbow domination number of graphs, *Polona Repolusk*

Gamburgers and Graphs with Small Domination Number , *Simon Schmidt*

Distance domination in vertex-partitioned graphs, *Zsolt Tuza*

On the Robustness of the Vertex Independence Number of a Forest with respect to Multiple Edge Removals, *Jan Van Vuuren*

Edgeless graphs are the only universal fixers, *Kirsti Wash*

General upper bound on the game domination number

Csilla Bujtás, bujtas@dcs.uni-pannon.hu
University of Pannonia, Veszprém

In the domination game, Dominator and Staller alternately choose a vertex of a graph G and take it into a set D. The number of vertices dominated by the set D must increase with each move and the game ends when D becomes a dominating set of G. Dominator aims to minimize while Staller aims to maximize the number of turns. Assuming that Dominator starts and both players play optimally, the number of turns is called the game domination number $\gamma_g(G)$ of G.

It was conjectured that the game domination number $\gamma_g(G)$ of an n-vertex isolate-free graph G cannot be greater than $3n/5$. Here we prove that $\gamma_g(G) < 0.6395n$ always holds. This improves the earlier upper bound $2n/3$.

Monitoring a Network with Watchers and Listeners

Bert Hartnell, Bert.Hartnell@smu.ca
Saint Mary's University

Rather than guarding a network with a minimum dominating set, consider having two types of monitors available, cameras (can see adjacent nodes) and listeners (can detect the distance to an intruder). Preliminary results for finding the minimum number of such monitors for trees will be outlined.

Uniform hypergraphs and vertex dominating sets of graphs

Mercè Mora, merce.mora@upc.edu
Universitat Politècnica de Catalunya
Coauthors: Jaume Martí-Farré, José Luis Ruiz

The collection of the minimal dominating sets of a graph is a hypergraph. However, there are hypergraphs H that are not the collection of the vertex dominating sets of any graph. We say that a hypergraph H is a *domination hypergraph* if there is at least a graph G such that the collection of minimal dominating sets of G is equal to H. Given a hypergraph, we are interested in determining if it is a domination hypergraph, otherwise we want to find domination hypergraphs "close" to it. To solve this problem, we define the *domination completions* of a hypergraph. Moreover, we prove that it is possible to recover a hypergraph from suitable domination completions. Here we will focus on the case of uniform hypergraphs, that is, hypergraphs whose elements are all the subsets with the same cardinality. Concretely, we characterize all the uniform hypergraphs that are domination hypergraphs and, in some other cases, we give those domination completions that allow us to recover the hypergraph.

Broadcast Domination and Irredundance

Kieka Mynhardt, kieka@uvic.ca
University of Victoria

A *broadcast* on a nontrivial connected graph $G = (V, E)$ is a function $f : V \to \{0, 1, \ldots, \operatorname{diam} G\}$ such that $f(v) \le e(v)$ (the eccentricity of v) for all $v \in V$. The *cost* of f is $\sigma(f) = \sum_{v \in V} f(v)$. A broadcast f is a *dominating broadcast* if every vertex of G is within distance $f(v)$ from a vertex v with $f(v) > 0$. A dominating broadcast f is a *minimal dominating broadcast* if no broadcast $g \neq f$ such that $g(v) \le f(v)$ for each $v \in V$ is dominating. The *lower and upper broadcast numbers* of G are defined by

$$\gamma_b(G) = \min\{\sigma(f) : f \text{ is a dominating broadcast of } G\} \text{ and}$$

$$\Gamma_b(G) = \max\{\sigma(f) : f \text{ is a minimal dominating broadcast of } G\}.$$

A dominating broadcast is minimal dominating if and only if it satisfies

$\mathbf{P}_{\min}$: For each v such that $f(v) > 0$ there exists $u \in V$ that is not dominated by the broadcast $f' = (f - \{(v, f(v))\}) \cup \{(v, f(v) - 1)\}$.

A broadcast that satisfies $\mathbf{P}_{\min}$ is an *irredundant broadcast*, and may or may not also be dominating. An irredundant broadcast f is *maximal irredundant* if no broadcast $g \neq f$ such that $g(v) \ge f(v)$ for each $v \in V$ is irredundant. The *lower and upper broadcast irredundant numbers* of G are

$$\mathrm{ir}_b(G) = \min\{\sigma(f) : f \text{ is a maximal irredundant broadcast of } G\} \text{ and}$$

$$\mathrm{IR}_b(G) = \max\{\sigma(f) : f \text{ is an irredundant broadcast of } G\}.$$

We discuss properties of these concepts and the relationships between their associated parameters.

On the rainbow domination number of graphs

Polona Repolusk, polona.repolusk@um.si
University of Maribor, Faculty of Natural Sciences and Mathematics
Coauthors: Janez Žerovnik, Zehui Shao, Meilian Liang, Chuang Yin, Xiaodong Xu

Given a graph G and a set of t colors $\{1, 2, \ldots, t\}$, assume that we assign an arbitrary subset of these colors to each vertex of G. If we require that each vertex to which an empty set is assigned has in its neighborhood all t colors, then this assignment is called a t-rainbow dominating function of the graph G. The corresponding invariant $\gamma_{rt}(G)$, which is the minimum sum of numbers of assigned colors over all vertices of G, is called the t-rainbow domination number of G. In this talk, bounds for the t-rainbow domination number of an arbitrary graph will be presented. For a special case of the 3-rainbow domination numbers, bounds or exact values will be presented for several classes of graphs including paths, cycles and the generalized Petersen graphs $P(n, k)$.

Gamburgers and Graphs with Small Domination Number

Simon Schmidt, simon.schmidt@ujf-grenoble.fr
Joseph Fourier's University Grenoble
Coauthors: Sandi Klavžar, Gašper Košmrlj

The domination game is played on a graph G by Dominator and Staller. The two players are taking turns choosing a vertex from G such that at least one previously undominated vertex becomes dominated. Dominator wants to finish the game as fast as possible, while Staller wants to prolong it. The game is called D-game, when Dominator starts and S-game otherwise. The game domination number $\gamma_g(G)$ of G is the number of moves played in D-game when both players play optimally. Similarly, $\gamma'_g(G)$ is the number of moves played in S-Game.

In this talk, graphs G with $\gamma_g(G) = 2$ and graphs with $\gamma'_g(G) = 2$, as well as graphs extremal with respect to the diameter among these graphs are characterized. In particular, $\gamma'_g(G) = 2$ and $\mathrm{diam}(G) = 3$ hold for a graph G if and only if G is a so-called gamburger. The classes of graphs with $\gamma_g = 3$ or $\gamma'_g = 3$ turn to be much richer. Though, we are able to characterize graphs G with $\gamma_g(G) = 3$ and $\mathrm{diam}(G) = 6$, as well as graphs G with $\gamma'_g(G) = 3$ and $\mathrm{diam}(G) = 5$. The latter can be described as the so-called double-gamburgers.

Distance domination in vertex-partitioned graphs

Zsolt Tuza, tuza@dcs.uni-pannon.hu
MTA Rényi Institute & University of Pannonia

We consider a variation of the graph domination problem, which involves two positive integer parameters k and d. Given a connected graph G and a partition $(V_1, \dots, V_k)$ of its vertex set $V(G)$, the task is to find subsets $D_1, \dots, D_k$ of $V(G)$ such that for each $v \in V_i$ there is a vertex $v' \in D_i$ whose distance from v is at most d. One of the problems is to determine a general upper bound of the form $|D_1| + \ldots + |D_k| \le c \cdot |V(G)|$.

This is joint work with Allan Frendrup and Preben Dahl Vestergaard.

On the Robustness of the Vertex Independence Number of a Forest with respect to Multiple Edge Removals

Jan Van Vuuren, vuuren@sun.ac.za
Stellenbosch University

A vertex subset $X \subseteq V$ of a graph $G = (V, E)$ is an *independent set* of G if no two vertices in X are adjacent in G. The cardinality of a largest independent set of G is called the (vertex) *independence number* of G. A nonempty graph G is *p-stable* if p is the largest number of *arbitrary* edges of G whose removal from G *necessarily* results in a graph with independence number equal to that of G, and *q-critical* if q is the smallest number of *arbitrary* edges of G whose removal from G *necessarily* results in a graph with independence number larger than that of G. The classes of p-stable and q-critical forests of order n are characterised in this paper for all admissible combinations of values of p, q and n.

Edgeless graphs are the only universal fixers

Kirsti Wash, kirsti.wash@trincoll.edu
Trinity College

Given two disjoint copies of a graph G, denoted G^1 and G^2, and a permutation π of $V(G)$, the graph πG is constructed by joining $u \in V(G^1)$ to $\pi(u) \in V(G^2)$ for all $u \in V(G^1)$. G is said to be a universal fixer if the domination number of πG is equal to the domination number of G for all π of $V(G)$. In 1999, Gu conjectured that the only universal fixers are the edgeless graphs. Over the next decade, several classes of connected graphs were identified as not containing any universal fixers. In this talk, we show explicitly how to partition a graph G and define a permutation on $V(G)$ to guarantee that edgeless graphs are the only universal fixers.

Minisymposium

Graph Imbeddings And Map Symmetries

Organized by Jonathan L. Gross, *Columbia University, New York, USA*

Symmetric and self-dual spherical embeddings with all vertices of degrees 3, 4 and 5

Lowell Abrams, labrams@gwu.edu
George Washington University
Coauthor: Daniel Slilaty

We describe an approach to constructing spherical graph embeddings in which all vertices are of degrees 3, 4, and 5 and all faces are quadrangular, in terms of regions of expansion and contraction. Of particular interest is a useful "diagonal metric." We describe these constructions more explicitly for the cases when there are exactly two vertices of degree 5 and some requirement of cellular symmetry.

Cyclic complements and skew morphisms of groups

Marston Conder, m.conder@auckland.ac.nz
University of Auckland

A skew morphism of a group is a variant of an automorphism, which arises in the study of regular Cayley maps (regular embeddings of Cayley graphs on surfaces, with the property that the ambient group induces a vertex-regular group of automorphisms of the embedding). More generally, skew morphisms arise in the context of any group expressible as a product AB of subgroups A and B with B cyclic and $A \cap B = \{1\}$. Specifically, a skew morphism of a group A is a bijection $\varphi\colon A \to A$ fixing the identity element of A and having the property that $\varphi(xy) = \varphi(x)\varphi^{\pi(x)}(y)$ for all $x, y \in A$, where $\pi(x)$ depends only on x. The kernel of φ is the subgroup of all $x \in A$ for which $\pi(x) = 1$. In this talk I will present some of the theory of skew morphisms, including some new theorems: two about the order and kernel of a skew morphism of a finite group, and a complete determination of the finite abelian groups for which every skew morphism is an automorphism.

Much of this is joint work with Robert Jajcay and Tom Tucker.

Complete minors in orientable surfaces

Gašper Fijavž, gasper.fijavz@fri.uni-lj.si
IMFM and University of Ljubljana

Assume that a graph G embeds in a surface Σ. A theorem of Robertson and Seymour states that there exists a constant c_Σ, so that every graph which embeds in Σ with face-width $\geq c_\Sigma$ contains G as a minor.

Let Σ be an arbitrary *orientable* surface of genus ≥ 1. We prove that there exists an absolute constant c (independent on the choice of Σ), so that:

- if G embeds in Σ with face-width $\geq c$, then G contains a K_7 minor, and
- if G is not bipartite and embeds in Σ with face-width $\geq c$ while having all faces of even length, then G contains an *odd* K_5 minor.

This is in part joint work with Atsuhiro Nakamoto.

Orientably-regular maps on the group $M(q^2)$

Katarína Hriňáková, hrinakova@math.sk
Slovak University of Technology in Bratislava, Slovakia
Coauthors: Grahame Erskine, Jozef Širáň

In this talk we will present an enumeration of orientably-regular maps with automorphism group isomorphic to the twisted linear fractional group $M(q^2)$ for any odd prime power q.

Conjugacy classes of reflections of maps

Gareth Jones, G.A.Jones@maths.soton.ac.uk
University of Southampton

I shall consider how many conjugacy classes of reflections a map can have, under various transitivity conditions. For vertex- and for face-transitive maps there are no restrictions on their number or size, whereas edge-transitive maps can have at most four classes of reflections. This upper bound is attained only by certain maps of type 3 in the Graver-Watkins taxonomy of edge-transitive maps. (These are the just-edge-transitive maps, those which are edge- but neither vertex- nor face-transitive.) Examples are constructed, using topology, covering spaces and group theory, to show that various distributions of reflections can be achieved.

Genus of circular amalgamations of graphs

Michal Kotrbčik, kotrbcik@fi.muni.cz
Masaryk University

The talk is concerned with genus of ring-like graphs obtained by repeatedly amalgamating complete or complete bipartite graphs over one vertex in a path-like manner, and then identifying two vertices, one from each graph at the end of the path. A theorem of Decker, Glover, and Huneke easily yields that the genus of the resulting graph is either the sum of the genera of the involved graphs, or the sum minus 1. However, to determine the genus exactly seems to be a rather difficult problem, which requires revising several classical results of topological graph theory. In the talk I will discuss these results and their interplay, and indicate what would be sufficient to obtain a complete solution of the problem.

Some regular Cayley maps on dihedral groups and corresponding skew-morphisms

Young Soo Kwon, ysookwon@ynu.ac.kr
Yeungnam University
Coauthor: István Kovács

In this talk, we will consider some regular Cayley maps on dihedral groups and their corresponding skew-morphisms. Especially, reflexible regular Cayley maps, reglar Cayley maps having minimum kernel, some properties of skew-morphisms of dihedral groups and some recent related progress will be dealt with.

Genera of Cayley maps

Jian Bing Liu, jbliu010@gmail.com
Beijing Jiaotong University
Coauthor: Jin Ho Kwak

The genus distribution of a graph G is defined to be the sequence g_m, where g_m is the number of different embeddings of G in the closed orientable surface of genus m. In this paper, we examine the genus distribution of Cayley maps for several Cayley graphs. It will be shown that the genus distribution of Cayley maps has many different properties from its usual genus distribution.

Diagonal flips in plane graphs with triangular and quadrangular faces

Atsuhiro Nakamoto, nakamoto@ynu.ac.jp
Yokohama National University
Coauthor: Naoki Matsumoto

Wagner proved that any two plane *triangulations* with $n > 3$ vertices can be transformed into each other by diagonal flips. His proof gives us an algorithm to transform them by $O(n^2)$ diagonal flips. However, Komuro has given an algorithm with $O(n)$ diagonal flips, and proved that the order is best possible.

For plane *quadrangulations* with $n > 3$ vertices, there is a similar research using a kind of diagonal flips, and an $O(n)$ algorithm is also known for this class.

In our talk, we focus on a plane *mosaic*, that is, a simple plane graph each of whose faces is triangular or quadrangular. We prove that any two mosaics with n vertices can be transformed into each other by $O(n)$ diagonal flips if they have the same number of triangular faces. This improves the estimation for the number of diagonal flips given by Aichholzer et al.

Grünbaum colorings of locally planar Fisk triangulations

Kenta Noguchi, knoguchi@comb.math.keio.ac.jp
Keio University

A Grünbaum coloring of a triangulation T of a surface F^2 is a 3-edge-coloring of T such that every face of T receives all the three colors. A Grünbaum coloring of T 1-to-1 corresponds to a proper 3-edge-coloring of the dual T^* of T. Robertson conjectured that every locally planar triangulation T of a non-spherical surface has a Grünbaum coloring. Thomassen showed that every locally planar triangulation is 5-colorable. It is not difficult to see that there exists a Grünbaum coloring of T if T is 4-colorable. The only two families are known as 5-chromatic locally planar triangulations; One is a subset of Eulerian triangulations and the other is a set of Fisk triangulations. It is known that every locally planar Eulerian triangulation has a Grünbaum coloring. In this talk, we show that every locally planar Fisk triangulation has a Grünbaum coloring.

Book-embeddings of graphs on the projective plane or the torus

Kenta Ozeki, ozeki@nii.ac.jp
National Institute of Informatics / JST, ERATO, Kawarabayashi Large Graph Project
Coauthors: Atsuhiro Nakamoto, Takayuki Nozawa

A *book embedding* of a graph G is to put the vertices along the *spine* (a segment) and each edge of G on a single *page* (a half-plane with the spine as its boundary) so that no two edges intersect transversely in the same page. We say that a graph G is *k-page embeddable* if G has a book embedding with at most k pages. The *pagenumber* (or sometimes called *stack number* or *book thickness*) of a graph G is the minimum of k such that G is k-page embeddable.

Yannakakis obtained the sharp upper bound: every planar graph has the pagenumber at most four. Then it is natural to ask what about graphs on other surfaces. Nakamoto and Nozawa proved that every graph on the projective plane or on the torus is 9-page embeddable, and Endo proved that every graph on the torus is 7-page embeddable. In this talk, we improve those results.

Odin: An Artistic Case Study between Circle Packing and Medial

Tomaž Pisanski, Tomaz.Pisanski@fmf.uni-lj.si
University of Primorska and University of Ljubljana
Coauthors: DeWitt Godfrey, Thomas Tucker

Odin, a magnificent 13 ton steel sculpture is used as a case study of mathematical analysis of art. In particular, it shows the connection between geometry (circle packing) and topological graph theory (medial of a map). Recently a Symposium on Odin has been hosted by the Colgate University (https://www.youtube.com/watch?v=Wp-oVIdbyfA).

Imbedding Types for Linear Families, Markov Chains, and Smoothing

Thomas Tucker, ttucker@colgate.edu
Colgate University
Coauthors: Jonathan Gross, Toufik Mansour

e genus polynomial $g_G(z) = \Sigma a_i z^i$ of graph G is the generating function where a_i is the number of imbeddings of G in the surface of genus i. A genus polynomial is always *interpolating*, that is the nonzero coefficients form an interval. Little else is known; for example the number of imbeddings of K_7 is $(6!)^7$ and its genus polynomial has not been computed. On the other hand, for any "linear family' of graphs G_n, one can partition into imbedding types and compute a "production" (recursion) matrix $M(z)$ with polynomial entries (with non-negative integer coefficients) such that the vector $v_n(z)$ of genus polynomials partitioned by imbedding types satisfies $v_n(z) = M^n(z)v_0(z)$. The matrix $M(1)$ has constant column sum s, so $(1/s)M(1)$ is the matrix of a Markov chain. We conjecture that it is regular, that is $M^n(1)$ has all positive entries for some n. We also conjecture that multiplication by $M^n(z)$ is a form of smoothing analogous to multiplication of any polynomial (with nonnegative coefficients) by $(1+z)^n$, which is eventually interpolating and log-concave.

Minisymposium

Graph Products

Organized by Richard Hammack, *Virginia Commonwealth University, Richmond, USA*

Determining and Distinguishing within the Cartesian Product, *Debra Boutin*

Rainbow Connection Number of Graph Powers and Graph Products, *Sunil Chandran Leela*

Steiner convex sets of grids, *Tanja Gologranc*

A first step towards determining biological traits from phenotypespaces: The strong product of di-graphs, *Marc Hellmuth*

Vertex covers in rooted product graphs, *Marko Jakovac*

Another approach to the linear algorithm for the prime factor decomposition of Cartesian product, *Iztok Peterin*

On Cartesian products having a minimum dominating set that is a box or a stairway, *Douglas Rall*

Distance two labeling for the strong product of two infinite paths, *Yoomi Rho*

The k-independence number of direct products of graphs, *Simon Špacapan*

Optimal Pebbling on Grids, *Carl Yerger*

Determining and Distinguishing within the Cartesian Product

Debra Boutin, dboutin@hamilton.edu
Hamilton College

A *determining set* S is a set of vertices with the property that each automorphism of the graph is uniquely identified by its action on S. The *distinguishing number* is the smallest number of colors necessary to color the vertices so that no nontrivial automorphism preserves the color classes. If a graph can be distinguished with two colors, the *distinguishing cost* is the smallest possible size of the smaller color class. We will examine each of these parameters for Cartesian products and powers of graphs.

Rainbow Connection Number of Graph Powers and Graph Products

Sunil Chandran Leela, sunil.cl@gmail.com
Indian Institute of Science, Bangalore, India.

Coauthors: Manu Basavaraju, Deepak Rajendraprasad, Arunselvan Ramaswamy

Rainbow connection number, $rc(G)$, of a connected graph G is the minimum number of colors needed to color its edges so that every pair of vertices is connected by at least one path in which no two edges are colored the same (note that the coloring need not be proper). In this paper we study the rainbow connection number with respect to three important graph product operations (namely the Cartesian product, the lexicographic product and the strong product) and the operation of taking the power of a graph. In this direction, we show that if G is a graph obtained by applying any of the operations mentioned above on non-trivial graphs, then $rc(G) \leq 2r(G) + c$, where $r(G)$ denotes the radius of G and $c \in \{0, 1, 2\}$. In general the rainbow connection number of a bridgeless graph can be as high as the square of its radius. This is an attempt to identify some graph classes which have rainbow connection number very close to the obvious lower bound of diameter (and thus the radius). The bounds reported are tight up to additive constants. The proofs are constructive and hence yield polynomial time $(2 + 2/r(G))$ -factor approximation algorithms.

Steiner convex sets of grids

Tanja Gologranc, tanja.gologranc@um.si
Faculty of Natural Sciences and Mathematics, University of Maribor

The Steiner tree of a (multi)set of vertices $R = \{u_1, \ldots, u_k\} \subseteq V(G)$ is the smallest tree in G that contains all vertices of R. The Steiner distance $d(R)$ of a set R is the number of edges in a Steiner tree T for R. The k-Steiner interval of a set $R \subseteq V(G)$, $I(R)$, consists of all vertices in G that lie on some Steiner tree for R. A set S of vertices is k-Steiner convex, if the Steiner interval $I(R)$ of every (multi)set R on k vertices is contained in S. We say that a set S is Steiner convex if it is k-Steiner convex, for every $k \geq 2$. In this talk the characterization of Steiner convex sets of grids will be presented.

A first step towards determining biological traits from phenotypespaces: The strong product of di-graphs

Marc Hellmuth, mhellmuth@mailbox.org

University of Greifswald

Coauthors: Peter F. Stadler, Tilen Marc

Product graphs and product-like structures play a central role in theoretical biology. To determine traits that can vary independently through evolution one can equivalently ask for the (local) prime factors of the underlying phenotypespace. The topology of the phenotypespace corresponds (at least locally) to the direct product of di-graphs. Hence, of immediate interest for biologists are algorithms that determine or approximate the prime factors of the phenotypespace w.r.t. the direct product.

Here we consider a special case of the direct product of di-graphs, namely the strong product, and show that the respective prime factors can be determined in polynomial time. The factorization algorithm depends on the construction of the Cartesian skeleton, which we introduce here for di-graphs as a generalization of the well-known Cartesian skeleton of undirected graphs. Finally, we discuss open problems and challenges that we are dealing with when we want to find approximate factors of a "real-world" phenotypespace.

Vertex covers in rooted product graphs

Marko Jakovac, marko.jakovac@um.si

Faculty of Natural Sciences and Mathematics, University of Maribor

A subset S of vertices of a graph G is called a k-path vertex cover if every path of order k in G contains at least one vertex from S. Denote by $\psi_k(G)$ the minimum cardinality of a k-path vertex cover in G. A lower and an upper bound for ψ_k of the rooted product graphs are presented. Two characterizations are given when those bounds are attained. Moreover, ψ_2 and ψ_3 are exactly determined.

Another approach to the linear algorithm for the prime factor decomposition of Cartesian product

Iztok Peterin, iztok.peterin@um.si

FEECS, University of Maribor and IMFM Ljubljana

In [Discrete Math. 307 (2007) 472–483] a linear algorithm for the prime factor decomposition of a graph with respect to Cartesian product is presented. Hence the paper establishes the best possible complexity for this important fundamental problem. Unfortunately this algorithm has a big constant and its linearity become visible only for very big graphs. This fact is due to generating lines of adjacency matrix during edge labeling procedure of the algorithm. We present a variant of this algorithm where we can completely avoid adjacency matrix. This is possible by changing the order of vertices that are scanned, which is not a BFS order anymore as in [Discrete Math. 307

(2007) 472–483].

It seems that this approach will have some influence in recognizing approximate Cartesian products as well as to find a fast prime factor decomposition of a graph with respect to the strong product.

On Cartesian products having a minimum dominating set that is a box or a stairway

Douglas Rall, doug.rall@furman.edu
Furman University
Coauthor: Boštjan Brešar

Combining a lower bound due to El-Zahar and Pareek with an upper bound of Vizing we get that for any pair of graphs G and H,

$$\min\{|V(G)|,|V(H)|\} \leq \gamma(G \Box H) \leq \min\{\gamma(G)|V(H)|, \gamma(H)|V(G)|\}.$$

We give a complete characterization of the pairs that achieve the lower bound and give some necessary and some sufficient conditions for pairs of graphs that meet the upper bound.

Distance two labeling for the strong product of two infinite paths

Yoomi Rho, rho@incheon.ac.kr
Incheon National university
Coauthors: Byeong Kim, Byung Song

An $L(h,k)$-labeling of a graph $G = (V,E)$ is a function f on V such that $|f(u) - f(v)| \geq h$ if $\mathrm{dist}(u,v) = 1$ and $|f(u) - f(v)| \geq k$ if $\mathrm{dist}(u,v) = 2$. The span of f is the difference between the maximum and the minimum of f. The $L(h,k)$-labeling number $\lambda_{h,k}(G)$ of G is the minimum span over all $L(h,k)$-labelings of G.

Let G be the strong product of two infinite paths. Calamoneri found lower bounds and upper bounds of $\lambda_{h,k}(G)$ for all h and k when $h \geq k$. Recently Kim et al. found a refined upper bound $3h+6k$ when $h \geq 4k$ and showed that it is the exact value when $h \geq 6k$.

In this paper, we obtain lower bounds and upper bounds when $h < k$. Also we improve the result of Calamoneri when $k \leq h \leq 2k$.

The k-independence number of direct products of graphs

Simon Špacapan, simon.spacapan@um.si
FME, UM

The k-independence number of G, denoted as $\alpha_k(G)$, is the size of a largest k-colorable subgraph of G. We conjecture that for any graphs G and H,

$$\alpha_k(G \times H) \leq \alpha_k(G)|V(H)| + \alpha_k(H)|V(G)| - \alpha_k(G)\alpha_k(H).$$

The conjecture is stronger than the Hedetniemi's conjecture, and it was proved for $k = 1, 2$. For $k = 3$ the conjecture implies the result of El-Zahar and Sauer that the direct product of 4-chromatic graphs is 4-chromatic. Under some additional conditions the conjecture is also true for $k = 3$, and in this talk we discuss these conditions.

Optimal Pebbling on Grids

Carl Yerger, cryerger@gmail.com
Davidson College
Coauthor: Chenxiao Xue

Given a distribution of pebbles on the vertices of a connected graph G, a *pebbling move* is defined as the removal of two pebbles from some vertex and the placement of one of these on an adjacent vertex. The *pebbling number* of a graph G is the smallest integer k such that for each vertex v and each distribution of k pebbles on G there is a sequence of pebbling moves that places at least one pebble on v. We say such a distribution is *solvable*. The *optimal pebbling number* of G, denoted $\Pi_{OPT}(G)$, is the least k such that some particular distribution of k pebbles is solvable. In this talk, we describe a strengthening of a result of Bunde et al relating to the optimal pebbling number of the 2 by n square grid by describing all possible optimal configurations. We find the optimal pebbling number for the 3 by n square grid and related structures. Finally, we describe a bound for the analogue of this question for the infinite square grid and suggest related open questions.

Minisymposium

Metric Dimension And Related Parameters

Organized by Ismael González Yero, *Universidad de Cádiz, Spain*

Metric dimension of imprimitive distance-regular graphs

Robert Bailey, rbailey@grenfell.mun.ca
Grenfell Campus, Memorial University

The metric dimension of a graph Γ is the least size of a set of vertices $\{v_1, \ldots, v_m\}$ with the property that, for any vertex w, the list of distances from w to each of $v_1, \ldots, v_m$ uniquely identifies w.

In this talk, we consider the metric dimension of imprimitive distance-regular graphs, which are either bipartite or antipodal (i.e. being at distance 0 or d is an equivalence relation on the vertices, where d is the diameter). We use a theorem of Alfuraidan and Hall, along with the operations of "halving" and "folding", to reduce the problem to primitive graphs, where known results of Babai apply, except when the diameter is between 3 and 6. In this case, especially when the diameter is 3, we see that unexpected things start to happen.

On optimal approximability results for computing the strong metric dimension

Bhaskar DasGupta, bdasgup@uic.edu
University of Illinois at Chicago
Coauthor: Nasim Mobasheri

We show that the problem of computing the strong metric dimension of a graph can be reduced to the problem of computing a minimum node cover of a transformed graph within an additive logarithmic factor. This implies both a 2-approximation algorithm and a $(2-\varepsilon)$-inapproximability for the problem of computing the strong metric dimension of a graph.

Locating-dominating sets in twin-free graphs

Florent Foucaud, florent.foucaud@gmail.com
Université Blaise Pascal, Clermont-Ferrand (France)
Coauthors: Michael Henning, Christian Löwenstein, Thomas Sasse

A locating-dominating set of a graph is a dominating set such that each vertex not in the set has a unique neighbourhood within the set. In 2014, Garijo, González and Márquez conjectured that any twin-free graph without isolated vertices admits a locating-dominating set of size at most half the order. We discuss this beautiful conjecture and present proofs of it for the special cases of split graphs, cobipartite graphs, cubic graphs, and line graphs. We also discuss the set of graphs having location-domination number exactly half the order.

Doubly resolvability, location and domination in graphs.

Antonio González, gonzalezh@us.es
University of Seville
Coauthors: Carmen Hernando, Mercè Mora

In this talk, we discuss several relationships among some special sets of vertices of graphs such as metric-locating-dominating sets, locating-dominating sets and doubly resolving sets. First, we extend a result of Henning and Oellermann (2004) by proving that the location-domination number of a graph is not bounded above by any polynomial function on its metric-location-domination number. However, we show that this is possible when the graph does not contain the cycles C_4 and C_6 as a subgraph. Finally, we provide a method to construct doubly resolving sets from locating-dominating sets in general graphs.

Some relations between the partition dimension and the twin number of a graph

Carmen Hernando, carmen.hernando@upc.edu
Universitat Politècnica de Catalunya
Coauthors: Mercè Mora, Ignacio M. Pelayo

Let Π be a partition of the set of vertices of a graph G. We denote by $r(u|\Pi)$ the vector of distances from vertex u to the parts of Π. The partition Π is a *resolving partition* of G if $r(u,\Pi) \neq r(v,\Pi)$ for every pair of distinct vertices u, v. The *partition dimension* $\beta_p(G)$ of G is the minimum size of a resolving partition of G.

Two vertices u,v of G are called *twins* if they have exactly the same set of neighbors other than u and v. It is easy to prove that the twin relation defines an equivalence relation on the set of vertices of a graph. An equivalence class of the twin relation will be referred to as a *twin class*. The *twin number* $\tau(G)$ of G is the maximum size of a twin class of G.

In this talk, we study the relation between the twin number and the partition dimension of a graph. By the one hand, we focus our attention on the case of graphs having a twin number at least half its order. In this case, an upper bound for the partition dimension in terms of the twin number is given. From here, we revisit some results about graphs with partition dimension almost its order. By the other hand, we show that, in general, the ratio between the partition dimension and the twin number is not bounded by any constant.

The Simultaneous Metric Dimension of Graph Families

Ortrud Oellermann, o.oellermann@uwinnipeg.ca
University of Winnipeg
Coauthors: Yunior Ramirez-Cruz, Juan-Alberto Rodriguez-Velazquez

Let x, y and v be vertices of a graph G. Then v is said to resolve the pair x, y if $d_G(x,v) \neq d_G(y,v)$. A set S of vertices of G is a metric generator for G if every pair of vertices of G is resolved by some vertex of S. A smallest metric generator of G is called a metric basis and its cardinality the metric dimension of G. Let $F = \{G_1, G_2, \ldots, G_n\}$ be a family of graphs on a common (labeled) vertex set V. A subset S of V is a simultaneous metric generator of F if S is a metric generator for every member of F. A smallest simultaneous metric generator for F is called a simultaneous metric basis and its cardinality the simultaneous metric dimension of F. We show that the problem of finding the simultaneous metric dimension of families of graphs is NP-hard even for families of graphs (such as trees) for which the metric dimension of each member can be determined in polynomial time. We establish sharp upper and lower bounds for the simultaneous metric dimension of certain families of trees.

Distinguishing problems in interval graphs

Aline Parreau, aline.parreau@univ-lyon1.fr
CNRS - Université Lyon 1 (France)
Coauthors: Florent Foucaud, George Mertzios, Reza Naserasr, Petru Valicov

We consider the problems of finding optimal identifying codes, (open) locating-dominating sets and resolving sets of an interval or a permutation graph. In these problems, one asks to distinguish all vertices of a graph by a subset of the vertices, using either the neighbourhood within the solution set or the distances to the solution vertices. Using a general reduction for this class of problems, we prove that the decision problems associated to these four notions are NP-complete, even for graphs that are at the same time interval graphs and permutation graphs and have diameter 2. While finding an optimal identifying code and an (open) locating-dominating set are trivially fixed-parameter-tractable when parametrized by solution size, it is known that in the same setting finding the metric dimension of a graph (which is the size of an optimal resolving set) is W[2]-hard. We show that for interval graphs, this parametrization of metric dimension is fixed parameter tractable.

Strong Oriented Graphs with Largest Directed Metric Dimension

Rinovia Simanjuntak, rino@math.itb.ac.id
Institut Teknologi Bandung
Coauthor: Yozef G. Tjandra

Let D be a strongly connected oriented graph with vertex-set V and arc-set E. The distance from a vertex u to another vertex v, $d(u,v)$ is the minimum length of oriented paths from u to v. Suppose $B = \{b_1, b_2, b_3, ...b_k\}$ is a nonempty ordered subset of V. The representation of a vertex v with respect to B, $r(v|B)$, is defined as a vector $(d(v,b_1), d(v,b_2), \ldots, d(v,b_k))$. If any two distinct vertices u,v satisfy $r(u|B) \neq r(v|B)$, then B is a resolving set of D. If the cardinality of B is minimum then B is a basis of D and the cardinality of B is the directed metric dimension of D, $dim(D)$.

We proved that if D is a strongly connected oriented graph of order $n \geq 4$, then $dim(D) \leq n-3$. Furthermore, we characterized strong oriented graphs attaining the upper bound, i.e., strong oriented graphs of order n and metric dimension $n-3$.

Minisymposium

Polytopes And Graphs

Organized by Egon Schulte, *Northeastern University, Boston, USA*

Symmetric Geometric Embeddings of Cyclic 3-configurations: preliminary report, *Leah Berman*

The smallest regular hypertopes of various kinds, *Marston Conder*

Constructions for configurations of points and circles, *Gábor Gévay*

Hypertopes arising from Suzuki groups, *Dimitri Leemans*

Volumes of polyhedra with symmetries, *Alexander Mednykh*

Chiral polyhedra and almost simple groups with socle PSL(2,q), *Jeremie Moerenhout*

Fully Truncated Simplices, *Barry Monson*

Neighbour-transitive incidence structures in odd graphs., *Eugenia O'Reilly-Regueiro*

Tight non-orientable regular polyhedra, *Daniel Pellicer Covarrubias*

Compatibility fans for graphical nested complexes, *Vincent Pilaud*

Orientable maniplexes revisited, *Tomaž Pisanski*

Configurations in surfaces, *Klara Stokes*

C-groups of PSL$(2,q)$ and PGL$(2,q)$, *Connor Thomas*

Euclidean Symmetry of Closed Surfaces Immersed in 3-Space, Part II , *Thomas Tucker*

Understanding monodromy groups of abstract polytopes, *Gordon Williams*

Tiling of the Sphere by Congruent Equilateral Pentagons, *Min Yan*

Symmetric Geometric Embeddings of Cyclic 3-configurations: preliminary report

Leah Berman, lwberman@alaska.edu
University of Alaska Fairbanks
Coauthors: Jill Faudree, Phillip DeOrsey

A *cyclic configuration* is a combinatorial configuration in which all the lines (or blocks) of the configuration are formed via a cyclic permutation of an initial block. Moreover, the fact that the block [0,1,3] forms an initial block for a cyclic configuration $\mathcal{C}_3(n)$ for any $n \geq 7$ has been used to show that combinatorial 3-configurations exist for all possible n. There are well-known methods for geometrically embedding cyclic 3-configurations in the plane, but the embeddings these produce are typically without any geometric symmetry, which is undesirable for configurations with such high combinatorial symmetry (for example, all cyclic configurations are vertex transitive). This talk will present preliminary results on embeddings of cyclic 3-configurations that possess high degrees of rotational symmetry.

The smallest regular hypertopes of various kinds

Marston Conder, m.conder@auckland.ac.nz
University of Auckland, New Zealand

A *hypertope* is a generalisation of an abstract polytope, just as hypermaps generalise maps. Formally, a hypertope is a residually connected thin incidence geometry, with elements categorised according to their type.

The theory of hypertopes has been developed recently by Fernandes, Leemans and Weiss. The rank of a hypertope $\mathcal{H}$ is the number of distinct types. A *flag* is a set of pairwise incident elements, or equivalently, a clique in the incidence graph, and if this contains one element of each type, then it is called a *chamber* of $\mathcal{H}$.

For the purposes of this talk, the automorphism group Aut($\mathcal{H}$) of a hypertope $\mathcal{H}$ is the group of all incidence- and type-preserving bijections on $\mathcal{H}$, and then $\mathcal{H}$ is called *regular* if Aut($\mathcal{H}$) is transitive on the set of all chambers of $\mathcal{H}$. When this happens, Aut($\mathcal{H}$) is a smooth quotient of some Coxeter group. In the special case where $\mathcal{H}$ is a polytope, the underlying graph of the Coxeter/Dynkin diagram for the latter group is a path, but for general hypertopes, it can be any connected graph.

In this talk, I will describe some recent work with Dimitri Leemans and Daniel Pellicer in which we found the smallest regular hypertopes with a given graph underlying its Coxeter/Dynkin diagram. These are already known for all finite paths (namely the smallest regular polytopes of each rank), and so we concentrated on the following graphs: cycles C_n for $n \geq 3$, star graphs S_n for $n \geq 3$, and complete graphs K_n for $n \geq 3$, as well as the underlying graphs of the Coxeter/Dynkin diagrams of types D_n (for $n \geq 4$), $\tilde{D}_n$ (for $n \geq 5$), E_n (for $n \geq 6$), and $\tilde{E}_6$, $\tilde{E}_7$ and $\tilde{E}_8$. Some of what we discovered is a little surprising.

Constructions for configurations of points and circles

Gábor Gévay, gevay@math.u-szeged.hu
University of Szeged
Coauthor: Tomaž Pisanski

Configurations of points and circles in the plane go back to the classical incidence theorems of Miquel and Clifford, but relatively few results are known in the period since then. In this talk we present some constructions for new classes of such configurations, among them, of the point-circle versions of a generalization of the classical Desargues (10_3) point-line configuration. In these constructions, certain graphs with prescribed properties play a key role. We are interested, in particular, in obtaining configurations from the skeletons of regular maps such that they are isometric, i.e. all the circles in them are of the same size.

Hypertopes arising from Suzuki groups

Dimitri Leemans, d.leemans@auckland.ac.nz
University of Auckland
Coauthor: Thomas Connor

In this talk we will show that all hypertopes whose automorphism group is a Suzuki simple group are necessarily hyperpolyhedra. We will also discuss future research directions in the same vein.

Volumes of polyhedra with symmetries

Alexander Mednykh, smedn@mail.ru
Sobolev Institute of Mathematics, Novosibirsk State University and Laboratory of Quantum Topology, Chelyabinsk State University, Russia

In this lecture we describe a few methods to calculate the volumes of polyhedra with symmetries in the spaces of constant curvature. We apply the obtained results to find volume of some knots and links modelled in the hyperbolic, spherical or Euclidean geometries.

Chiral polyhedra and almost simple groups with socle PSL(2,q)

Jeremie Moerenhout, jermoer@gmail.com
University of Auckland

We discuss the existence of chiral polyhedra with automorphism group isomorphic to an almost simple groups with socle $PSL(2,q)$. We prove that there exists such a chiral polyhedron if and only if its group is not $M(1,9)$, $PSL(2,q)$ or $PGL(2,q)$ for any prime power q.

Fully Truncated Simplices

Barry Monson, bmonson@unb.ca
University of New Brunswick
Coauthors: Leah Berman, Deborah Oliveros, Gordon Williams

If you truncate an equilateral triangle $\{3\}$ to its edge midpoints you get another, smaller $\{3\}$. If you truncate a regular tetrahedron $\{3,3\}$ to its edge midpoints, you get (a little unexpectedly) a regular octahedron $\{3,4\}$. In higher ranks, the fully truncated n-simplex $\mathcal{T}_n$ is no longer regular, though it is uniform with facets of two types.

We want to understand the minimal regular cover $\mathcal{R}_n$ of $\mathcal{T}_n$, which in turn means we need to understand its monodromy group $M_n := \mathrm{Mon}(\mathcal{T}_n)$. For $n \geq 4$, we 'know' that this group has Schläfli type $\{3,12,3,\ldots,3\}$ and the impressive order

$$\frac{[(n+1)!]^{n-1} \cdot (n-1)!}{2^{n-2}}$$

I will discuss all this and report on the current state of my confusion amongst all this fun. (How can one call mathematics 'work'?)

Neighbour-transitive incidence structures in odd graphs.

Eugenia O'Reilly-Regueiro, eugenia@im.unam.mx
IMUNAM

Given $k > 0$ and a set X of size $2k+1$, the odd graph O_{k+1} is a $(k+1)$-regular graph whose vertices are the k-sets of X and any two are adjacent if and only if they are disjoint. For a subset Γ of $V(O_{k+1})$, there is an incidence structure D between the elements of X and those of Γ. If we define Γ_1 as the set of neighbours of Γ in D, (that is, Γ_1 is the set of vertices of O_{k+1} that are not in Γ and are adjacent in the graph to at least one element of Γ), then a group of automorphisms of D is neighbour-transitive if it is transitive on Γ_1. In this talk we will present some results and examples of these incidence structures, which are part of ongoing joint work with Brian Corr, Wei Jin, Cheryl Praeger, and Csaba Schneider.

Tight non-orientable regular polyhedra

Daniel Pellicer Covarrubias, pellicer@matmor.unam.mx
National University of Mexico
Coauthor: Gabe Cunningham

A polyhedron is said to be tight whenever every vertex belongs to every face. Conder and Cunningham determined the type of all tight orientably regular polyhedra. In this talk I present the recent classification of tight non-orientable polyhedra.

Compatibility fans for graphical nested complexes

Vincent Pilaud, vincent.pilaud@lix.polytechnique.fr
CNRS & LIX, École Polytechnique
Coauthor: Thibault Manneville

Generalizing the classical associahedron, M. Carr and S. Devadoss constructed graph associahedra which provide polytopal realizations of the nested complex of a graph G. This talk will present multiple alternative realizations of graphical nested complexes as complete simplicial fans, using ideas coming from compatibility degrees and cluster fans constructed by S. Fomin and A. Zelevinsky in their study of finite type cluster algebras. When the graph G is a path, this construction recovers F. Santos' Catalan many simplicial fan realizations of the associahedron. Preprint available at arXiv:1501.07152.

Orientable maniplexes revisited

Tomaž Pisanski, Tomaz.Pisanski@fmf.uni-lj.si
University of Primorska and University of Ljubljana

A maniplex is a discrete structure, introduced in 2012 by Steve Wilson, that generalizes the concept of a map on the one hand, and the concept of an abstract polytope on the other. In a preprint in 2013 Isabel Hubard et al. have defined the notions of orientable and oriented maniplex. In this talk we revisit these two concepts using symmetry type graphs as primary tools.

Configurations in surfaces

Klara Stokes, klara.stokes@his.se
University of Skövde

The existence of configurations in surfaces is a classical topic in algebraic geometry. In this talk I will describe some interesting configurations of points and circles coming from maps on surfaces. I will also discuss some details regarding the points of a configuration in a surface.

C-groups of PSL$(2,q)$ and PGL$(2,q)$

Connor Thomas, tconnor@ulb.ac.be
Université libre de Bruxelles
Coauthors: Jambor Sebastian, Leemans Dimitri

C-groups are smooth quotients of Coxeter groups. It is well known that there is a one-to-one correspondence between string C-groups and abstract regular polytopes.

Recently, some results were obtained in the more general case of C-groups without any condition on the diagram.

I will present the classification of C-group representations of the groups PSL$(2,q)$ and PGL$(2,q)$. We obtain that the C-rank of PSL$(2,q)$ and PGL$(2,q)$ is 3 except when $q \in \{7,9,11,19,31\}$ for PSL$(2,q)$ and when $q = 5$ for PGL$(2,q)$, in which case it is 4. We provide all representations of rank four.

Euclidean Symmetry of Closed Surfaces Immersed in 3-Space, Part II

Thomas Tucker, ttucker@colgate.edu
Colgate University
Coauthor: Undine Leopold

Given a finite group G of orientation-preserving isometries of euclidean 3-space E^3 and a closed surface S, an immersion $f : S \to E^3$ is in G-general position if $f(S)$ is invariant under G, points of S have disk neighborhoods whose images are in general position, and no singular points of $f(S)$ lie on an axis of rotation of G. For such an immersion, there is an induced action of G on S whose Riemann-Hurwitz equation satisfies certain natural restrictions. We classify which restricted Riemann-Hurwitz equations are realized by a G-general position immersion of S. In this part of the talk, we focus on the low-dimensional topology of immersions of the quotient surface S/G in the orbifold E^3/G

Understanding monodromy groups of abstract polytopes

Gordon Williams, giwilliams@alaska.edu
University of Alaska Fairbanks

In this talk I will provide a survey of some recent work on the structure of monodromy groups of abstract polytopes, as well as discussing open problems suggested by these investigations. This talk will emphasize families of well understood examples, and the methods used to study them. Particular areas of emphasis will include connections to representations of polytopes as quotients of regular abstract polytopes, and connections between the monodromy group and the automorphism group of non-regular symmetric polytopes.

Tiling of the Sphere by Congruent Equilateral Pentagons

Min Yan, mamyan@ust.hk
Hong Kong University of Science and Technology

The classification of the tiling of the sphere by congruent triangles was started in 1922 and completed 80 years later in 2002. We studied the similar problem for the pentagons and obtained the classification for the minimal case of the dodecahedron and some cases where there is enough variety of edge lengths. In contrast, the classification for the tilings of the sphere by congruent equilateral pentagons (i.e., no variety in edge length) calls for completely different technique, that includes the following:

1. The distribution of angles at vertices of degree 3 for general tilings of surfaces, and the distribution for spherical pentagonal tilings in particular.
2. The topological structure of the tiling in case there are only few vertices of degree > 3.
3. Massive amount of numerical calculation that yields rigorous conclusion on the possible pentagons suitable for tiling.

At the end, we conclude that there are total of 8 tilings of the sphere by congruent equilateral pentagons. We also got a glimpse on the tilings by congruent almost equilateral (four edges having equal length) pentagons, which is the only remaining challenging case for the complete classification.

Minisymposium

Spectral Graph Theory

Organized by Dragan Stevanović, *Serbian Academy of Science and Arts, Belgrade, Serbia and University of Primorska, Koper, Slovenia*

On the eigenspaces of signed line graphs and signed subdivision graphs, *Francesco Belardo*

Cospectral regular graphs with and without a perfect matching, *Zoltán L. Blázsik*

Non–Singular Bipartite Graphs with a Singular Deck, *Alexander Farrugia*

Graphs with three eigenvalues and second largest eigenvalue at most 1, *Gary Greaves*

Local geometry of graphs and random walks, *Paul Horn*

Non-negative spectrum of a digraph, *Irena Jovanović*

On some graph transformations that preserve $\mathrm{sgn}(\lambda_2 - 2)$, *Bojana Mihailović*

Hermitian adjacency spectrum of digraphs and four-way switching equivalence, *Bojan Mohar*

Large regular graphs of given valency and second eigenvalue, *Hiroshi Nozaki*

Minimizing Laplacian spectral radius of unicyclic graphs with fixed girth, *Kamal Lochan Patra*

Spectra and Distance Spectra of H-join Graphs, *Milan Pokorny*

Towards a conjecture on the distance spectral radius of trees, *Valisoa Razanajatovo Misanantenaina*

Maximal and Extremal Singular Graphs, *Irene Sciriha*

Hoffman graphs and edge-signed graphs, *Tetsuji Taniguchi*

Unitary Equivalent Graphs, *Mario Thüne*

Spectral Determination of Some Graphs Which are Derived From Complete Graphs, *Hatice Topcu*

On the eigenspaces of signed line graphs and signed subdivision graphs

Francesco Belardo, fbelardo@gmail.com
University of Primorska

In this talk we will consider the spectra of signed graphs, namely graphs with signs $\{+,-\}$ mapped on the edges. Recently, given a signed graph Γ, we have defined the signed line graph $\mathcal{L}(\Gamma)$ and the signed subdivision graph $\mathcal{S}(\Gamma)$ in a way that some well-known formulas on the characteristic polynomials of (unsigned) graphs are extended to signed graphs. Namely, if $\phi(\Gamma, x)$ and $\psi(\Gamma, x)$ denote the adjacency polynomial and the Laplacian polynomial of Γ, respectively, then $\phi(\mathcal{L}(\Gamma), x) = (x+2)^{m-n}\psi(\Gamma, x+2)$, and $\phi(\mathcal{S}(\Gamma), x) = x^{m-n}\psi(\Gamma, x^2)$. Here we will focus on the relations intercurring among the eigenspaces of the respective classes of signed graphs.

This is a joint research with S.K. Simić and I. Sciriha.

Cospectral regular graphs with and without a perfect matching

Zoltán L. Blázsik, blazsik@cs.elte.hu
Department of Computer Science, Eötvös University, Hungary
Coauthors: Willem H. Haemers, Jay Cummings

At the 22nd British Combinatorial Conference Prof. Willem H. Haemers posed a question if there exists a pair of cospectral d-regular graphs, where one has a perfect matching and the other one not. We solved this question by finding a family of such pair of graphs for $d \geq 5$ using the Godsil-McKay switching argument.

I would like to show you the construction and speak about the case of $d = 2, 3, 4$ with some related questions.

Non–Singular Bipartite Graphs with a Singular Deck

Alexander Farrugia, alex.farrugia@um.edu.mt
University of Malta

A NSSD is an undirected, non–singular graph on n vertices with weighted edges and no loops whose n vertex–deleted subgraphs are all singular. A graph with adjacency matrix $\mathbf{G}$ is a NSSD if and only if the graph with adjacency matrix $\mathbf{G}^{-1}$ is a NSSD. We show that this also holds for the subclass of bipartite NSSDs, that is, the inverse of the adjacency matrix of a bipartite NSSD is the adjacency matrix of another bipartite NSSD. Furthermore, we show that bipartite NSSDs must have an even number of vertices. We then focus on NSSD trees, which are a subclass of bipartite NSSDs, and provide a characterisation of this subclass by a constructive argument. Moreover, we show a Fiedler–type result that any NSSD tree remains an NSSD tree if its nonzero edge weights are changed to other arbitrary nonzero real numbers.

Graphs with three eigenvalues and second largest eigenvalue at most 1

Gary Greaves, grwgrvs@gmail.com
Tohoku University

The classification of regular graphs with second largest eigenvalue at most 1 is equivalent to the classification of regular graphs with smallest eigenvalue at least -2. Such graphs have received a great deal of attention. Another well-studied family of graphs are regular graphs having precisely three distinct eigenvalues. These graphs are well-known to be strongly regular. The study of non-regular graphs with second largest eigenvalue at most 1 and the study of non-regular graphs with precisely three distinct eigenvalues were initiated by Hoffman and Haemers respectively.

In this talk I will present some recent results about graphs having either of the properties above including a classification of graphs having both properties. This talk is based on joint work with Xi-Ming Cheng and Jack Koolen.

Local geometry of graphs and random walks

Paul Horn, paul.horn@du.edu
University of Denver

Coauthors: Frank Bauer, Yong Lin, Gabor Lippner, Dan Mangoubi, Shing-Tung Yau

Harnack inequalities relate the maximum and minimum values of eigenfunctions or positive solutions to the heat equation. These are classical in the manifold setting, and versions are also known for functions on graphs. It is known that a graph satisfying a so-called parabolic Harnack inequality is equivalent to the graph satisfying certain (hard to check) geometric conditions. In the non-negatively curved manifold case, the Li-Yau inequality is a stronger (local) gradient estimate which implies the (global) Harnack inequality. In this talk we describe a similar gradient estimate for graphs. This has immediate applications to the evolution of continuous time random walks on graphs, and yields a graph analogue of Buser's inequality (which states that for non-negatively curved graphs, the lower bound Cheeger's inequality gives on the first eigenvalue is of the correct order).

Along the way, we discuss the issue of defining curvature for graphs and some of the difficulties that arise when transferring a continuous result into a discrete setting along with some additional results on graphs.

Non-negative spectrum of a digraph

Irena Jovanović, irenaire@gmail.com
School of Computing, Union University

In this talk, digraphs will be considered by means of eigenvalues of the matrix AA^T (or A^TA) where A is the adjacency matrix of a digraph. The common spectrum of these matrices is called the *non-negative spectrum* or the *N-spectrum* of a digraph. Several properties of the N-spectrum together with a family of N-cospectral digraphs will be presented. The notion of cospectrality w.r.t. a graph matrix will be generalized to the cospectrality w.r.t. several graph matrices. In accordance with this, a family of cospectral multigraphs with respect to the adjacency matrix will be described. These multigraphs are isomorphic when they are associated to a circulant digraph. Some examples of the (N, Q)-cospectral mates of digraphs and multigraphs, where Q is the signless Laplacian matrix, will be exposed.

On some graph transformations that preserve sgn$(\lambda_2 - 2)$

Bojana Mihailović, mihailovicb@etf.rs
University of Belgrade - School of Electrical Engineering, Belgrade, Serbia
Coauthor: Marija Rasajski

For a simple graph G (a non-oriented graph without loops or multiple edges), with the $(0,1)$-adjacency matrix A, we define $P_G(\lambda) = \det(\lambda I - A)$ to be its *characteristic polynomial*. The roots of the characteristic polynomial are the *eigenvalues* of G, and, since they are all real numbers, we can assume the non-increasing order: $\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_n$. Graphs having $\lambda_2 \leq 2$ are called *reflexive graphs*. A *cactus* is a graph whose any two cycles have at most one common vertex.

So far we have determined all classes of reflexive cacti with 4 and 5 cycles and several classes of reflexive cacti with 2 and 3 cycles. Now we describe some graph transformations that preserve sgn$(\lambda_2 - 2)$, which establish connections between correspondent families of reflexive graphs within the same class, as well as between families that belong to different classes. Using these transformations, we improved our previous results and discovered some new classes of reflexive cacti.

Hermitian adjacency spectrum of digraphs and four-way switching equivalence

Bojan Mohar, mohar@sfu.ca
SFU & IMFM

It is shown that an undirected graph G is cospectral with the Hermitian adjacency matrix of a mixed graph D obtained from a subgraph H of G by orienting some of its edges if and only if $H = G$ and D is obtained from G by a four-way switching operation; if G is connected, this happens if and only if $\lambda_1(G) = \lambda_1(D)$.

All mixed graphs of rank 2 are determined and this is used to classify which mixed graphs of rank 2 are cospectral with respect to their Hermitian adjacency matrix. Several families of mixed graphs are found that are determined by their Hermitian spectrum in the sense that they are cospectral precisely to those mixed graphs that are switching equivalent to them.

Large regular graphs of given valency and second eigenvalue

Hiroshi Nozaki, hnozaki@auecc.aichi-edu.ac.jp
Aichi University of Education

It is known that for any given integer $k \geq 3$ and real number $\lambda < 2\sqrt{k-1}$, there are only finitely many k-regular graphs whose second largest eigenvalue is at most λ. In this talk, we give a new upper bound for the order of such a graph for given k and λ. The main tool is the linear programming method for regular graphs. A graph which satisfies $g \geq 2d$ attains this upper bound for some k and λ, where g is the girth and d is the number of distinct eigenvalues. This is a joint work with Cioaba, Koolen, and Vermette.

Minimizing Laplacian spectral radius of unicyclic graphs with fixed girth

Kamal Lochan Patra, klpatra@niser.ac.in
NISER, Bhubaneswar, India
Coauthor: Binod Kumar Sahoo

We consider the following problem: Over the class of all simple connected unicyclic graphs on n vertices with girth g (n, g being fixed), which graph minimizes the Laplacian spectral radius? Let $U_{n,g}$ be the lollipop graph obtained by appending a pendent vertex of a path on $n-g$ ($n > g$) vertices to a vertex of a cycle on $g \geq 3$ vertices. We prove that the graph $U_{n,g}$ uniquely minimizes the Laplacian spectral radius for $n \geq 2g-1$ when g is even and for $n \geq 3g-1$ when g is odd.

Spectra and Distance Spectra of H-join Graphs

Milan Pokorny, mpokorny@truni.sk
Trnava University, Faculty of Education
Coauthor: Pavel Hic

A spectrum of a graph is a set of eigenvalues of its adjacency matrix. Similarly, a distance spectrum of a graph is a set of eigenvalues of its distance matrix. A graph is called integral if all eigenvalues of its adjacency matrix are integers. Similarly, a graph is called distance integral if all eigenvalues of its distance matrix are integers. An energy of a graph is a sum of the absolute values of its eigenvalues. Similarly, a distance energy of a graph is a sum of the absolute values of its distance eigenvalues. A distance energy is a useful molecular descriptor in QSPR modelling.

In the talk we consider H-join on graphs, where H is an arbitrary graph. In terms of distance matrix, we determine the D-spectra of graphs obtained by this operation on distance regular graphs of diameter at most 2. Some additional consequences on D-spectral radius, D-integral graphs, D-cospectral graphs, D-equienergetic graphs, etc. are also obtained. Further, we construct an infinite family of pairs of non-cospectral integral and distance integral graphs having equal energy and distance.

Towards a conjecture on the distance spectral radius of trees

Valisoa Razanajatovo Misanantenaina, valisoa@aims.ac.za
Stellenbosch University
Coauthors: Stephan Wagner, Kenneth Dadedzi

The distance matrix of a graph is the matrix whose entry in the ith row, jth column is the distance $d(v_i, v_j)$ between the ith vertex v_i and the jth vertex v_j. A conjecture of Ilić and Stevanović states that among all trees with given order and maximum degree, the so-called Volkmann trees minimise the spectral radius of the distance matrix.

In this talk, we present our recent progress towards this conjecture and its analogue for a "reversed" version of the distance matrix. Our ideas are based on similar results for the Wiener index and the spectral radius of the adjacency matrix.

Maximal and Extremal Singular Graphs

Irene Sciriha, isci1@um.edu.mt
University of Malta

A graph G is singular of nullity η if the nullspace of its adjacency matrix $\mathbf{G}$ has dimension η. Such a graph contains η cores determined by a basis, with minimum support sum, for the nullspace of $\mathbf{G}$. These are induced subgraphs of singular configurations, the latter occurring as induced subgraphs of nullity one of G. Singular configurations may be considered as the 'atoms' of a singular graph. We show that there exists a set of η distinct vertices representing the singular configurations. We also explore how the nullity controls the size of the singular substructures and show that the graphs of maximal nullity contain a substructure reaching maximal size.

Hoffman graphs and edge-signed graphs

Tetsuji Taniguchi, t.taniguchi.t3@cc.it-hiroshima.ac.jp
Hiroshima Institute of Technology

Hoffman graphs were introduced by Woo and Neumaier [2] to extend the results of Hoffman [1]. Hoffman proved what we would call Hoffman's limit theorem which asserts that, in the language of Hoffman graphs, the smallest eigenvalue of a fat Hoffman graph is a limit of the smallest eigenvalues of a sequence of ordinary graphs with increasing minimum degree.

Woo and Neumaier [2] gave a complete list of fat indecomposable Hoffman graphs with smallest eigenvalue at least $-1-\sqrt{2}$. Moreover they [2, Open Problem 4] raised the problem of classifying fat Hoffman graphs with smallest eigenvalue at least -3. Therefore we study the problem. In the process, we noticed that it is necessary to know the details of special graphs of Hoffman graphs. There are deep relations between "Hoffman graph" and "Edge-signed graph".

In this talk, we introduce Hoffman graphs and edge-signed graphs. Moreover we talk about some results and problems.

References:

[1] A. J. Hoffman, On graphs whose least eigenvalue exceeds $-1-\sqrt{2}$, Linear Algebra Appl. 16 (1977), 153–165.

[2] R. Woo and A. Neumaier, On graphs whose smallest eigenvalue is at least $-1-\sqrt{2}$, Linear Algebra Appl. 226-228 (1995), 577–591 .

Unitary Equivalent Graphs

Mario Thüne, mario.thuene@uni-leipzig.de
Leipzig University

If the adjacency matrices of two graphs are related trough an unitary transformation we call those graphs unitary equivalent. For simple graphs this notion coincides with isospectrality. A construction for unitary equivalent graphs, which generalizes GM switching, will be given.

Spectral Determination of Some Graphs Which are Derived From Complete Graphs

Hatice Topcu, haticekamittopcu@gmail.com
Nevsehir Haci Bektas Veli University

Spectral determination of graphs is questioned by Haemers and Van Dam in the paper "Which graphs are determined by their spectrum?" as in a survey. Just after this paper is published, many results are seen in the literature such that they partially answer the question of Haemers and Van Dam.

In this talk, we make an arrangement of some kind of simple graphs which are derived from complete graphs. We investigate that they are determined by their spectrum (or not) and give proofs for some of them. Finally, we mention some open cases.

Minisymposium

Structure And Properties Of Vertex Transitive Graphs

Organized by Robert Jajcay, *Comenius University, Bratislava, Slovakia, and University of Primorska, Koper, Slovenia*

Which Haar graphs are Cayley graphs?, *István Estélyi*
Tetravalent vertex transitive graphs of order $4p^2$, *Mohsen Ghasemi*
Generalized Cayley graphs, *Ademir Hujdurović*
Which merged Johnson graphs are Cayley graphs?, *Gareth Jones*
Classification of vertex-transitive cubic partial cubes, *Tilen Marc*
Infinite cubic vertex-transitive graphs, *Rögnvaldur G. Möller*
Infinite graphs that are strongly orbit minimal, *Simon Smith*
Reachability relations in digraphs, *Primož Šparl*
XI of a Reflexible Map, *Steve Wilson*
Vertex-transitive graphs and their arc-types, *Arjana Žitnik*

Which Haar graphs are Cayley graphs?

István Estélyi, estelyii@gmail.com
University of Ljubljana, University of Primorska
Coauthor: Tomaž Pisanski

Haar graphs are regular covering graphs of dipoles. They can also be constructed in a Cayley graph-like manner, in terms of a group G and its subset S. Just like Cayley graphs, these graphs frequently appear in various constructions, due to their pleasant symmetry properties. For example, Haar graphs were used for constructing families of semi-symmetric graphs and approximate cages.

If G is an abelian group, then its Haar graphs are well-known to be Cayley graphs; however, there are examples of non-abelian groups G and subsets S when this is not the case. Thus it might be worth investigating the Cayley-ness and more generally the vertex-transitivity of Haar graphs.

In this talk I am going to address the problem of classifying finite non-abelian groups G with the property that every Haar graph of G is a Cayley graph. We will deduce an equivalent condition for a Haar graph of G be a Cayley graph of a group containing G in terms of G, S and Aut$G$. Moreover, the above problem will be solved for dihedral groups.

Tetravalent vertex transitive graphs of order $4p^2$

Mohsen Ghasemi, m.ghasemi@urmia.ac.ir
Department of Mathematics, Urmia university, Urmia, Iran

A graph is vertex-transitive if its automorphism group acts transitively on vertices of the graph. A vertex-transitive graph is a Cayley graph if its automorphism group contains a subgroup acting regularly on its vertices. In this present talk, tetravalent vertex-transitive non-Cayley graphs of order $4p^2$ are classified for each prime p.

Generalized Cayley graphs

Ademir Hujdurović, ademir.hujdurovic@upr.si
University of Primorska

For a given group G, an automorphism α of G of order two, and a subset S of G, we define a generalized Cayley graph to be the graph with the vertex set G, and the edge set $x, \alpha(x)|xinG$. In order to get an undirected graph without loops we add some additional constrains on the set S.

Every Cayley graph is a generalized Cayley graph, but the converse is false. Recently it was proved that there are infintely many generalized Cayley graphs which are vertex-transitive but not Cayley.

Since for defining a generalized Cayley graph one needs a group automorphism of order two, we will first discuss some properties of such automorphims, focusing on Abelian groups. We will also discuss the case when this automorphism maps every element of the group to its inverse, and we will characterize the groups for which we can never get a non-Cayley graph using this construction.

This is a joint work with Klavdija Kutnar, Pawel Petecki and Anastasiya Tanana.

Which merged Johnson graphs are Cayley graphs?

Gareth Jones, G.A.Jones@maths.soton.ac.uk
University of Southampton
Coauthor: Robert Jajcay

It has been conjectured that ‘most’ vertex-transitive connected graphs are Cayley graphs. Recently Dobson and Malnič, building on earlier work of Godsil on Kneser graphs and of Kantor on permutation groups, have determined which Johnson graphs $J(n,k)$ are Cayley graphs: most are not, although they are all vertex-transitive and connected. Using finite group theory we extend this result to the distance i Johnson graphs $J(n,k)_i$ and the merged Johnson graphs $J(n,k)_I$: despite some of these having much larger automorphism groups, no further Cayley graphs arise, apart from a few trivial examples. Indeed, in most cases the only vertex-transitive groups of automorphisms are the alternating and symmetric groups of degree n.

Classification of vertex-transitive cubic partial cubes

Tilen Marc, tilen.marc@imfm.si
IMFM

Partial cubes are graphs isometrically embeddable into hypercubes. In the talk I will present a complete classification of cubic, vertex-transitive partial cubes. Results can be seen as a generalization of results of Brešar et. al. from 2004 on cubic mirror graphs, and a contribution to the classification of all cubic partial cubes.

Infinite cubic vertex-transitive graphs

Rögnvaldur G. Möller, roggi@hi.is
University of Iceland

Tutte’s two papers from 1947 and 1959 on cubic graphs were the starting point of the in-depth study of the interplay between the structure of a group and the structure of a graph that the group acts on. In this talk I will describe applications of Tutte’s ideas where it is assumed that the graph is infinite and the stabilizers of vertices are infinite.

Infinite graphs that are strongly orbit minimal

Simon Smith, sismith@citytech.cuny.edu
City University of New York (City Tech)

We say that two permutation groups A, B on the same set X are *strongly orbit equivalent* if A and B have the same orbits on the power set 2^X. Groups strongly orbit equivalent to finite symmetric groups were first considered by J. von Neumann and O. Morgenstern in 1947.

We call a group B *strongly orbit minimal* if B is not strongly orbit equivalent to any of its proper subgroups. When looking for families of strongly orbit equivalent groups, it suffices to consider only those groups which are strongly orbit minimal.

We say a graph is *strongly orbit minimal* if its automorphism group is strongly orbit minimal. For example, the countable random graph is strongly orbit minimal, but the countable complete graph is not.

Strong orbit minimality appears to be related to other notions of minimality, like primitivity and 2-distinguishability. In this talk, I'll describe what is known about infinite graphs which are strongly orbit minimal; my talk will include a number of open problems and conjectures.

Reachability relations in digraphs

Primož Šparl, primoz.sparl@pef.uni-lj.si
University of Ljubljana and University of Primorska, Slovenia
Coauthors: Aleksander Malnič, Primož Potočnik, Norbert Seifter

In 2002 Marušič and Potočnik introduced an infinite family of relations (now called *reachability relations*) on (finite) digraphs and proved various interesting results regarding them. In 2008 these relations were studied in the context of infinite digraphs by Malnič, Marušič, Seifter, Šparl and Zgrablić, again producing some nice results. The interplay of various (di)graph theoretic properties and properties of these relations on infinite (vertex-transitive) digraphs was further investigated in a paper by Seifter and Trofimov from 2009.

In this talk we present a selection of the results on reachability relations from the above mentioned papers, together with a recent result by Malnič, Potočnik, Seifter and Šparl, linking the properties of reachability relations of a given vertex-transitive digraph admitting a nilpotent normal subgroup of automorphisms to the nilpotency class of this subgroup. We also present some preliminary results from a work in progress regarding the potential use of these relations in the polycirculant conjecture problem for infinite digraphs.

This is joint work with Aleksander Malnič, Primož Potočnik and Norbert Seifter.

XI of a Reflexible Map

Steve Wilson, Stephen.Wilson@nau.edu
Univerza na Primorskem

This talk describes a construction of a semisymmetric graph from a reflexible map. Mysteriously, the construction also yields a semisymmetric graph in a non-trivialnumber of cases when the input map is chiral. No one knows why.

Vertex-transitive graphs and their arc-types

Arjana Žitnik, Arjana.Zitnik@fmf.uni-lj.si
University of Ljubljana and IMFM
Coauthors: Marston Conder, Tomaž Pisanski

Let X be a finite vertex-transitive graph of valency d, and let A be the full automorphism group of X. Then the *arc-type* of X is defined in terms of the sizes of the orbits of the action of the stabiliser A_v of a given vertex v on the set of arcs incident with v. Specifically, the arc-type is the partition of d as the sum $n_1 + n_2 + \cdots + n_t + (m_1 + m_1) + (m_2 + m_2) + \cdots + (m_s + m_s)$, where $n_1, n_2, \ldots, n_t$ are the sizes of the self-paired orbits, and $m_1, m_1, m_2, m_2, \ldots, m_s, m_s$ are the sizes of the non-self-paired orbits, in descending order.

We find the arc-types of several interesting families of graphs. We also show that the arc-type of a Cartesian product of two 'relatively prime' graphs is the natural sum of their arc-types. Then using these observations, we show that with the exception of $1 + 1$ and $(1 + 1)$, every partition as defined above is *realisable*, in the sense that there exists at least one graph with the given partition as its arc-type.

Minisymposium

Vertex Colourings And Forbidden Subgraphs

Organized by Ingo Schiermeyer, *Technische Universität Bergakademie Freiberg, Germany*

Game Chromatic Number of a Cartesian Product Graph, *Emrah Akyar*

A version of the Turán problem for linear hypergraphs-density conditions, *Halina Bielak*

An algorithm for Independent Set and k-Path Vertex Cover in P_t-free graphs, *Christoph Brause*

Long rainbow path in proper edge colored complete graphs, *He Chen*

Turán numbers for wheels, *Tomasz Dzido*

Equitable total coloring of corona of cubic graphs, *Hanna Furmanczyk*

Anti-Ramsey numbers for cycles in complete split graphs, *Izolda Gorgol*

On relaxed strong edge-coloring of graphs, *Dan He*

On the palette index of complete bipartite graphs, *Mirko Horňák*

Facial colourings of plane graphs, *Stanislav Jendroľ*

Algorithms for the Weighted k-Path Vertex Cover Problem for Trees and Cacti, *Rastislav Krivoš Belluš*

Colorings avoiding monochromatic subgraphs- minimizing sum of colors, *Ewa Kubicka*

The Maximum Set Problems, *Ngoc Le*

Locally irregular graph colourings - distant generalizations, *Jakub Przybyło*

Game Chromatic Number of a Cartesian Product Graph

Emrah Akyar, eakyar@anadolu.edu.tr
Anadolu University
Coauthors: Ummahan Akcan, Handan Akyar

In this study we consider a graph coloring game invented by Bodlaender and Brams independently. Let $G = (V, E)$ be a finite simple graph and X be a set of colors. The game chromatic number of G is defined via a two-person finite game. Two players, generally called Alice and Bob, with Alice going first, alternatively color the uncolored vertices of G with a color from a color set X, such that no two adjacent vertices have the same color. Bob wins if at any stage of the game before the G is completely colored, one of the players has no legal move; otherwise, that is, if all the vertices of G are colored properly, Alice wins. The *game chromatic number* $\chi_g(G)$ of G is the least number of colors in the color set X for which Alice has a winning strategy.

In this talk we give an exact value for the game chromatic number of the Cartesian product graph $W_n \square P_2$ of two graphs, n-wheel W_n and the path graph P_2. This extends a previous work of Sia on the game chromatic number of certain families of Cartesian product graphs. We prove that the game chromatic number of graph $W_n \square P_2$ is 5, if $n \geq 3$.

A version of the Turán problem for linear hypergraphs-density conditions

Halina Bielak, hbiel@hektor.umcs.lublin.pl
Inst. of Math., UMCS, Lublin

Let $\mathcal{H} = (V, \mathcal{E})$ be a simple linear hypergraph. We consider a blow-up hypergraph $\mathcal{G}[\mathcal{H}]$ of $\mathcal{H}$. We are interested in the following problem. We have to decide whether there exists a blow-up hypergraph $\mathcal{B}[\mathcal{H}]$ of $\mathcal{H}$, with given hyperedge densities, such that $\mathcal{H}$ is not a transversal in $\mathcal{B}[\mathcal{H}]$. Recently the density Turán problem was studied by Csikvári and Nagy for simple graphs [*Combin. Prob. Comput.* 21 (2012) 531–553] and [*The Electronic J. Combin.* 18 (2011) # P46].

We generalize their results. We present an efficient algorithm to decide whether a given set of hyperedge densities ensures the existence of a linear hypertree $\mathcal{T}$ in all blow-up hypergraphs $\mathcal{B}[\mathcal{T}]$. Moreover, we show some conditions for critical hyperedge density of linear hypertrees and some other linear hypergraphs.

An algorithm for Independent Set and k-Path Vertex Cover in P_t-free graphs

Christoph Brause, brause@math.tu-freiberg.de
TU Bergakademie Freiberg

The Maximum Independent Set Problem (MISP for short) and the Minimum k-Path Vertex Cover Problem (MkPVCP for short) are known to be NP-hard [2,1]. For the first problem, there exists lots of graph classes in terms of forbidden subgraphs, where polynomial algorithms compute optimal solutions. A celebrated result of Lokshtanov et al. [3] states that we can solve the MISP for P_5-free graphs in polynomial time. Unfortunately, for larger forbidden paths, the complexity is unknown.

In this talk we will analyze an algorithm computing a maximum independent set in P_t-free graphs for $t \geq 6$. Furthermore, we will consider relations between the MISP and the MkPVCP, which gives nearly identical results for the solvability of both problems.

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Long rainbow path in proper edge colored complete graphs

He Chen, chenhe@seu.edu.cn
Department of Mathematics, Southeast University, China
Coauthor: Xueliang Li

Let G be an edge-colored graph. A rainbow (heterochromatic, or multicolored) path of G is such a path in which no two edges have the same color. Let the color degree of a vertex v to be the number of different colors that are used on edges incident to v, and denote it to be $d^c(v)$. It was showed that if $d^c(v) \geq k$ v of G, then G has a rainbow path of length at least $\min\{\lceil \frac{2k+1}{3} \rceil, k-1\}$. In the present paper, we consider proper edge-colored complete graph K_n only and improve the lower bound of the length of the longest rainbow path by showing that if $n \geq 20$, there must have a rainbow path of length no less than $\frac{3}{4}n - \frac{1}{4}\sqrt{\frac{n}{2} - \frac{39}{11}} - \frac{11}{16}$.

Turán numbers for wheels

Tomasz Dzido, tdz@inf.ug.edu.pl
University of Gdansk
Coauthor: Andrzej Jastrzębski

The Turán number $ex(n, G)$ is the maximum number of edges in any n-vertex graph that does not contain a subgraph isomorphic to G. A *wheel* W_k is a graph on k vertices obtained from a C_{k-1} by adding one vertex w and making w adjacent to all vertices of the C_{k-1}.

We obtain exact values for $ex(n, W_k)$ where $n \geq k$ and $k \leq 7$. It is interesting that exact values for $ex(n, C_4)$ and $ex(n, C_6)$, i.e. for rims of wheels W_5 and W_7 remain unknown in general. Even in the case of the C_4 cycle values are known only for $n \leq 32$ (the last result being $ex(32, C_4) = 92$, obtained in 2009 by Shao, Xu and Xu), whereas for larger n only the upper or lower bounds are known.

In addition, we present some bounds in general case.

Equitable total coloring of corona of cubic graphs

Hanna Furmanczyk, hanna@inf.ug.edu.pl
University of Gdansk

The minimum number of total independent sets of $V \cup E$ of graph $G(V, E)$ is called the *total chromatic number* of G, denoted by $\chi''(G)$. If difference of cardinalities of any two total independent sets is at most one, then the minimum number of total independent partition sets of $V \cup E$ is called the *equitable total chromatic number*, and denoted by $\chi''_=(G)$.

In the talk we consider equitable total coloring of corona of cubic graphs, $G \circ H$. It turns out that, independly on equitable total chromatic numbers of G and H, equitable total chromatic number of corona $G \circ H$ is equal to $\Delta(G \circ H) + 1$. Thereby, we confirm TCC and ETCC conjectures for coronas of cubic graphs. As a direct consequence we get that all coronas of cubic graphs are of Type 1.

Anti-Ramsey numbers for cycles in complete split graphs

Izolda Gorgol, i.gorgol@pollub.pl
Lublin University of Technology

A subgraph of an edge-coloured graph is *rainbow* if all of its edges have different colours. For graphs G and H the *anti-Ramsey number* $ar(G, H)$ is the maximum number of colours in an edge-colouring of G with no rainbow copy of H. The notion was introduced by Erdős, Simonovits and V. Sós and studied in case $G = K_n$. Afterwards results concernig bipartite graphs, cubes or product of cycles as G appeared. They were obtained by, among others, Axenovich, Li, Montellano-Ballesteros, Schiermeyer. In the talk the survey of these results will be given. Apart from that general results concerning complete split graphs as host graphs will be presented and in particular cycles will be considered.

On relaxed strong edge-coloring of graphs

Dan He, hedanmath@163.com
Department of mathematics, Southeast university
Coauthor: Wengsong Lin

Let G be a graph. For two nonnegative integers s and t, an (s,t)-relaxed strong k-edge-coloring is an assignment of k colors to the edges of G, such that for any edge e, there are at most s edges adjacent to e and t edges which are distance two apart from e assigned the same color as e. The (s,t)-relaxed strong chromatic index, denoted by $\chi'_{(s,t)}(G)$, is the minimum number k of an (s,t)-relaxed strong k-edge-coloring admitted by G. For a positive integer μ, a μ-relaxed strong k-edge-coloring is an assignment of k colors to the edges of G, such that for any edge e, there are at most μ edges which are at most distance two apart from e assigned the same color as e. The μ-relaxed strong chromatic index, denoted by $\chi'_{(\mu)}(G)$, is the minimum number k such that G has a μ-relaxed strong k-edge-coloring.

This paper studies the (s,t)-relaxed strong edge-coloring of graphs, especially trees. For a tree T, the tight upper bounds for $\chi'_{(s,0)}(T)$ and $\chi'_{(0,t)}(T)$ are given. And the $(1,1)$-relaxed strong chromatic index of an infinite regular tree is determined. Further results on $\chi'_{(1,0)}(T)$ are also presented. Finally, the μ-relaxed strong chromatic index is determined for almost μ.

On the palette index of complete bipartite graphs

Mirko Horňák, mirko.hornak@upjs.sk
P.J. Šafárik University Košice, Slovakia
Coauthor: Juraj Hudák

Let G be a graph, C a set of colours and $\varphi : E(G) \to C$ a proper edge colouring of G. The φ-palette of a vertex $v \in V(G)$ is the set $\{\varphi(vw) : vw \in E(G)\}$. The φ-diversity is the number of distinct φ-palettes of vertices of G and the palette index of G is the minimum of φ-diversities over all proper edge colourings φ of G. We present some results on the palette index of complete bipartite graphs $K_{m,n}$, $m \le n$, namely the exact values for $m \le 5$ as well as several upper bounds for general m. Moreover, we formulate three conjectures based on the proved statements.

Facial colourings of plane graphs

Stanislav Jendroľ, stanislav.jendrol@upjs.sk
P. J. Šafárik University in Košice
Coauthors: Igor Fabrici, Michaela Vrbjarová

Let $G = (V, E, F)$ be a connected loopless and bridgeless plane graph, with vertex set V, edge set E, and face set F. Let $X \in \{V, E, F, V \cup E, V \cup F, E \cup F, V \cup E \cup F\}$: Two elements x and y of X are *facially adjacent* in G if they are incident, or they are adjacent vertices, or adjacent faces, or facially adjacent edges (i.e. edges that are consecutive on the boundary walk of a face of G). A k-colouring is facial with respect to X if there is a k-colouring of elements of X such that facially adjacent elements of X receive different colours. It is known that:

1. G has a facial 4-colouring with respect to $X \in \{V, F\}$. The bound 4 is tight. (The Four Colour Theorem, Appel and Haken 1976)

2. G has a facial 6-colouring with respect to $X = V \cup F$. The bound 6 is tight. (The Six Colour Theorem, Borodin 1984)

   We prove that:

3. G has a facial 4-colouring with respect to $X = E$. The bound 4 is tight.

4. G has a facial 6-colouring with respect to $X \in \{V \cup E, E \cup F\}$. There are graphs required 5 colours in such a colouring.

5. G has a facial 8-colouring with respect to $X = V \cup E \cup F$. There is a graph requiring 7 colours in such a colouring.

Algorithms for the Weighted k-Path Vertex Cover Problem for Trees and Cacti

Rastislav Krivoš Belluš, rastislav.krivos-bellus@upjs.sk

P. J. Šafárik University in Košice, Slovakia

k-Path Vertex Cover Problem is NP-hard for several classes of graphs. We have focused on the weighted version of this problem. We will analyze complexity of exact algorithms for finding minimum k-Path Vertex Cover for trees and cacti graphs using dynamic programming and with parametrized complexity depending on its girth.

Colorings avoiding monochromatic subgraphs- minimizing sum of colors

Ewa Kubicka, ewa@louisville.edu

University of Louisville

Coauthors: Grzegorz Kubicki, Kathleen McKeon

Given graphs G and H, a vertex coloring $c : V(G) \to \mathbb{N}$ is an H-free coloring of G if no color class contains a subgraph isomorphic to H. The H-free chromatic number of G, $\chi(H, G)$, is the minimum number of colors in an H-free coloring of G. The H-free chromatic sum of G, $\Sigma(H, G)$, is the minimum value achieved by summing the vertex colors of each H-free coloring of G. We discuss the computational complexity of finding this parameter for different choices of H and prove exact formulas for some graphs G. For every integer k and for every graph H, we construct families of graphs, G_k with the property that k more colors than $\chi(H, G)$ are required to realize $\Sigma(H, G)$ for H-free colorings. More complexity results and constructions of graphs requiring extra colors are given for planar and outerplanar graphs.

The Maximum Set Problems

Ngoc Le, lechingoc@yahoo.com
Technische Universität Bergakademie Freiberg
Coauthors: Ingo Schiermeyer, Christoph Brause

The method of augmenting graphs is a general approach to solve the Maximum Independent Set problem. Our objective is to employ this approach to develop polynomial-time algorithms for some so-called Maximum Set problems, i.e. problems which can be stated as follows. Given a (simple, undirected) graph G, find a maximum vertex subset S of G such that the subgraph induced by S satisfies a given property Π. Such problems were shown to be NP-hard in general if the properties considered are non-trivial and hereditary. In this talk, using the augmenting graph technique, we describe a graph class, in which some problems can be solved in polynomial time. We also prove the NP-hardness of some Maximum Set problems where the considered properties are not hereditary.

Locally irregular graph colourings - distant generalizations

Jakub Przybyło, jakubprz@agh.edu.pl
AGH University of Science and Technology

It is well known that there are no *irregular graphs*, understood as simple graphs with pairwise distinct vertex degrees, except the trivial 1-vertex case. A graph invariant called the *irregularity strength* was thus introduced aiming at capturing a level of irregularity of a graph. Suppose that given a graph $G = (V, E)$ we wish to construct a multigraph with pairwise distinct vertex degrees of it by multiplying some of its edges. The least k so that we are able to achieve such goal using at most k copies of every edge is denoted by $s(G)$ and referred to as the irregularity strength of G. Alternately one may consider (not necessarily proper) edge colourings $c : E \to \{1, 2, \dots, k\}$ with $\sum_{e \ni u} c(e) \neq \sum_{e \ni v} c(e)$ for every pair of distinct vertices $u, v \in V$. Then the least k which permits defining a colouring c with this feature equals $s(G)$. Numerous papers have been devoted to study on this graph invariant since the middle 80's. It also gave rise to many naturally related concepts and the general field of vertex distinguishing graph colourings. The list making up these includes e.g. Zhang's Conjecture, 1–2–3–Conjecture and many others.

Within the talk we shall briefly overview main results concerning these as well as their generalizations aiming at distinguishing vertices at a limited distance in a graph. One of the motivations of introducing these is the well known concept of distant chromatic numbers.

General Session Talks

Tree-like Snarks

Marien Abreu, marien.abreu@unibas.it
Dipartimento di Matematica, Informatica ed Economia
Università degli Studi della Basilicata

Coauthors: Tomáš Kaiser, Domenico Labbate, Giuseppe Mazzuoccolo

In this talk, we present an infinite family of snarks which we call *tree-like snarks* and we prove that they have excessive index 5 ($\chi'_e(G) = 5$), circular flow number 5 ($\phi_C(G) = 5$), and admit a cycle double cover.

Conditions for k-connected graphs to have a k-contractible edge

Kiyoshi Ando, Kiyoshiando@nii.ac.jp
Natinal Institute of Informatics, JST ERATO Kawarabayashi Large Graph Project

An edge of a k-connected graph is said to be k-contractible if the contraction of it results a k-connected graph. When $k \leq 3$, each k-connected graph on more then $k+1$ vertices has a k-contractible edge. When $k \geq 4$, there are infinitely many k-connected graphs with no k-contractible edge. Hence, if $k \geq 4$, we can not expect the existence of a k-contractible edge in a k-connected graph with no condition. We say 'k-sufficient condition' for a condition for a k-connected graph to have a k-contractible edge. In this talk, we give some k-sufficient conditions involving forbidden subgraphs, one of which is an extension of a Kawarabayashi's result.

Distance Magic Labelings and Spectra of Graphs

Marcin Anholcer, m.anholcer@ue.poznan.pl
Poznan University of Economics

Let $G = (V, E)$ be a graph of order n. A distance magic labeling of G is a bijection $\ell\colon V(G) \to \{1, \ldots, n\}$ for which there exists a positive integer k such that $\sum_{x \in N(v)} \ell(x) = k$ for all $v \in V$, where $N(v)$ is the neighborhood of v. We show how the analysis of graph spectra may be used to identify the distance magic graphs. These results are applied to chosen families of graphs, in particular to some types of products.

Partitioning 2-edge-colored Ore-type graphs by monochromatic cycles

János Barát, barat@cs.elte.hu
MTA-ELTE GAC

Coauthor: Gábor Sárközy

We would like to report recent developments on Ramsey-type problems connected to the cycle partition number. We colour the edges of a graph G by red and blue. In this context, it is conventional to accept *empty graphs and one-vertex graphs* as a cycle (of any colour) and also *any edge* as a cycle (in its colour). With this convention, one can define the *cycle partition number* of any coloured graph G as the minimum number of vertex disjoint monochromatic cycles needed to cover the vertex set of G. Lehel conjectured that in every 2-colouring of the edges of K_n, there is a vertex disjoint red and blue cycle which span $V(K_n)$. First there were results for large n, and finally Bessy and Thomassé [3] gave a proof for all n.

One might suspect that the cycle partition number remains the same for dense graphs. Imposing large minimum degree is one natural condition. In [1] we posed the following

Conjecture 1. If G is an n-vertex graph with $\delta(G) > 3n/4$, then in any 2-edge-colouring of G, there are two vertex disjoint monochromatic cycles of different colours that span $V(G)$.

In [1] we proved that Conjecture 1. nearly holds in an asymptotic sense. That is, for all $\eta > 0$ there exists n_0 such that if G is a 2-edge-coloured graph on $n > n_0$ vertices, then there is a vertex disjoint red cycle and blue cycle spanning at least $(1-\eta)n$ vertices. This was improved by DeBiasio and Nelsen [4] who proved the statement for large n under the condition $\delta(G) > (3/4 + o(1))n$. Recently Letzter [5] proved Conjecture 1. for large n.

Generalising Conjecture 1. for graphs satisfying an Ore-type condition, we posed the following in [2]

Conjecture 2 If G is an n-vertex graph such that for any two non-adjacent vertices x and y of G, we have $deg(x)+deg(y) > 3n/2$, then in any 2-edge-colouring of G, there are two vertex disjoint monochromatic cycles of different colours, which together cover $V(G)$.

We were able to prove a statement slightly weaker than Conjecture 2.

Theorem 3. For every $\eta > 0$, there is an $n_0(\eta) = n_0$ such that the following holds. If G is an n-vertex graph with $n \geq n_0$ such that for any two non-adjacent vertices x and y of G, we have $deg(x) + deg(y) \geq (\frac{3}{2} + \eta)n$, then every 2-edge-coloring of G admits two vertex disjoint monochromatic cycles of different colors covering at least $(1 - \eta)n$ vertices of G.

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Hamiltonian cubic graphs

Simona Bonvicini, simona.bonvicini@unimore.it
University of Modena and Reggio Emilia
Coauthor: Tomaž Pisanski

A graph is Hamiltonian if it contains a spanning cycle (Hamiltonian cycle). A cubic Hamiltonian graph has a perfect matching (actually, three edge-disjoint perfect matchings). There are cubic graphs that have a perfect matching but are not Hamiltonian, see for instance the Petersen graph. Nevertheless, we may restrict our search for Hamiltonian graphs among the cubic graphs to the ones that possess a perfect matching. We give a necessary and sufficient condition for the existence of a Hamiltonian cycle in a cubic graph possessing a perfect matching. We use this condition to find a Hamiltonian cycle in some cubic graphs.

Clique Decompositions of the Distance Multigraph of the Cartesian Product of Graphs

Veerapas Boonthong, veerapas@gmail.com
Chulalongkorn University

The distance multigraph of a graph G is the multigraph having the same vertex set as G with $d_G(u,v)$ edges connecting each pair of vertices u and v, where $d_G(u,v)$ is the distance between vertices u and v in a graph G. This work gives a technique to find a clique decomposition of the distance multigraph of the Cartesian product of graphs.

The diameter of the generalized Petersen graph $GP[tk,k]$

Gulnaz Boruzanli, gulnaz.boruzanli@ege.edu.tr
Ege University
Coauthor: John Baptist Gauci

For integers $n \geq 3$ and $1 \leq k < n$, the generalized Petersen graph $GP[n,k]$ has $2n$ vertices $\{u_0, u_1, \ldots, u_{n-1}, v_0, v_1, \ldots, v_{n-1}\}$ and $3n$ edges $\{u_i u_{i+1}, v_i v_{i+k}, u_i v_i | i = 0, 1, \ldots, n-1; \text{addition mod } n\}$. We investigate the diameter, that is the maximum length of the shortest path between any two vertices, of this family of graphs, where $n = tk$ for any integer $t \geq 2$. The diameter is an important invariant in interconnection networks, and diameter problems are often encountered in network optimization. Most of the well–known networks have small girth, and, consequently, generalized Petersen graphs are good candidates for such networks since their girth is at most eight. The diameter of $GP[n,1]$ for $n \geq 3$ is trivially $\lfloor \frac{n}{2} \rfloor + 1$. We show that the diameter of $GP[tk,k]$ for $k \geq 2$ and $t \geq 2$ is $\lfloor \frac{t+k+3}{2} \rfloor$.

A conjecture about polygonal curves in the plane; let's play in "Burattiland"!

Marco Buratti, buratti@dmi.unipg.it
Università di Perugia
Coauthor: Simone Costa

Let V be the set of vertices of a regular polygon in the plane and let $L(V)$ be the set of all lengths of all open polygonal curves with vertex-set V. Which is the size of $L(V)$? I conjecture that if $|V| = 2n+1$ is a prime, then the answer is $\binom{3n-1}{n-1}$. I will show that this conjecture is equivalent to another conjecture - that bears my name even though I never worked on it - about Hamiltonian paths in the complete graph on a prime number of vertices. The conjecture can be also formulated by saying that a "perfect player" always wins in the game of "Burattiland".

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On the Hamilton-Waterloo problem with odd cycle lengths

Andrea Burgess, andrea.burgess@unb.ca
University of New Brunswick
Coauthors: Peter Danziger, Tommaso Traetta

The Hamilton-Waterloo problem HWP$(K_v; m, n; \alpha, \beta)$ asks whether there exists a decomposition of K_v into α m-cycle factors and β n-cycle factors, where $3 \leq m \leq n$. Necessarily, if such a decomposition exists, then m, n and v are all odd, m and n are divisors of v, and $\alpha + \beta = (v-1)/2$. We show that these necessary conditions are sufficient whenever $m \geq 5$, v is a multiple of mn and $v > mn$, except possibly if $\beta \in \{1, 3\}$. For $m \geq 5$ and $v = mn$, we solve the problem whenever $\beta > (n+5)/2$, except possibly if $(v, m, n, \alpha, \beta) = (35, 5, 7, 9, 8)$. Similar results are obtained when $m = 3$, with only a few extra possible exceptions in this case. Our results rely on the existence of factorizations of $C_m[n]$ (the lexicographic product of an m-cycle with the complement of K_n), which will be further discussed in Tommaso Traetta's talk.

New bounds on the average eccentricity of graphs

Peter Dankelmann, pdankelmann@uj.ac.za
University of Johannesburg

Let G be a connected graph of order n. The *eccentricity* $\mathrm{ecc}(v)$ of a vertex v of G is the distance from v to a vertex farthest from v, i.e., $\mathrm{ecc}(v) = \max_{w \in V(G)} d(v,w)$, where $V(G)$ is the vertex set of G and $d(v,w)$ denotes the distance between v and w in G. The *average eccentricity* $\mathrm{avec}(G)$ of G is the arithmetic mean of the eccentricities of all vertices of G, i.e.,

$$\mathrm{avec}(G) = \frac{1}{n} \sum_{v \in V(G)} \mathrm{ecc}(v).$$

The average eccentricity, originally conceived as a performance indicator for transportation networks, has also attracted much interest within graph theory. Several recent results on the average eccentricity have been inspired by conjectures of the computer programme AutoGraphiX. In this talk we give sharp bounds on the average eccentricity in terms of other graph parameters, in particular chromatic number, domination number, connected domination number and independence number. We also present bounds on the average eccentricity for graphs of given order and size, and for planar and maximal planar graphs. Our bounds are best possible, except for additive constants.

Local Properties that imply Global Cycle Properties

Marietjie Frick, marietjie.frick@gmail.com
University of South Africa
Coauthors: Susan van Aardt, Johan de Wet, Ortrud Oellermann

We say a graph G has a property $\mathcal{P}$ *locally* (or G is *locally* $\mathcal{P}$) if for every vertex v in G, the graph induced by the open neighbourhood $N(v)$ of G has property $\mathcal{P}$. For example, a graph G is *locally connected* if $G[N(v)]$ is connected for every vertex v in G. We discuss the global cycle structure of locally connected, locally traceable and locally hamiltonian graphs with bounded vertex degree.

From edge-dominating cycles to k-walks and Hamilton prisms of $2K_2$-free graphs

Mou Gao, gaom0002@e.ntu.edu.sg
Nanyang Technological University
Coauthor: Dmitrii Pasechnik

We show that every $\frac{1}{k-1}$-tough $2K_2$-free graph admits a k-walk, and it can be found in polynomial time. For this class of graphs, this proves a long-standing conjecture due to Jackson and Wormald (1990). Furthermore, we prove that every $(1+\epsilon)$-tough $2K_2$-free graph is prism-Hamiltonian. And, we also get some similar results of some other graphs.

The diameter of the generalized Petersen graph $GP[n,m]$ for coprime integers n and m

John Baptist Gauci, john-baptist.gauci@um.edu.mt
University of Malta
Coauthor: Gulnaz Boruzanli

The problem of calculating the distances among all pairs of vertices in a graph has been studied for a long time. The diameter of a graph is found by identifying the pair of vertices which are the furthest apart. In this work, we investigate the diameter of the family of generalized Petersen graphs $GP[n,m]$ where n and m are coprime positive integers. The graph $GP[n,m]$ is the graph on the $2n$ vertices $\{u_0, u_1, \ldots, u_{n-1}, v_0, v_1, \ldots, v_{n-1}\}$ having $3n$ edges $\{u_i u_{i+1}, v_i v_{i+m}, u_i v_i | i = 0, \ldots, n-1; \text{addition mod } n\}$. Zhang *et al.* [1] showed that the diameter of the generalized Petersen graphs is of the order $O(\frac{n}{2m})$. We show that, for coprime positive integers n and m, the diameter of $GP[n,m]$ depends on the parity of $\lfloor \frac{n}{m} \rfloor$ and on the value of n mod m, and establish exact values for the diameter of this family of graphs.

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Cyclic automorphism groups of graphs

Mariusz Grech, mgrec@math.uni.wroc.pl
Mathematical Institute Uniwersity of Wrocław

In 1978 and 1981, S. P. Mohanty, M. R. Sridharan, and S. K. Shukla [2,3] started to consider cyclic automorphism groups, of graphs, of prime and prime power order. Unfortunately the main results were false or had wrong proofs.

In [1], I gave a full description of cyclic automorphism groups, of graphs and edge-colored graphs, of prime power order. Now, I will present generalization of this description to all cyclic automorphism groups of graphs and edge-colored graphs.

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Finding Conjectures in Graph Theory with AutoGraphiX

Pierre Hansen, pierre.hansen@gerad.ca
GERAD and HEC Montréal
Coauthors: Mustapha Aouchiche, Gilles Caporossi

Computers have been used extensively to solve exactly or approximately a large variety of combinatorial otimization problems defined on graphs. It has also been noticed, in the last two decades, that computers can be used to advance graph theory *per se*. Several systems (e.g., Graph, Graffiti, AutoGraphiX, GrapHedron, GrInvIn, Nauty and Vega) have been proposed for that purpose. In this paper, we discuss the system AutoGraphiX developped at GERAD, Montreal, since 1997. Results of systematic experiments with conjectures of AGX Form 1: *i.e.*

$$(\mathcal{F}_{inf}) \quad L_n \leq i_1 \otimes i_2 \leq U_n \quad (\mathcal{F}_{sup})$$

where i_1 and i_2 are two graph invariants; $\otimes$ is one of $-, +, /$ or $\times$; L_n, U_n are lower and upper bounds as functions of n; and $\mathcal{F}_{inf}$ and $\mathcal{F}_{sup}$ are families of extremal graphs associated with these bounds, are discussed. Some conjectures with a more general form and their posterity are also considered.

Cores, joins and the Fano-flow conjectures

Ligang Jin, ligang@mail.upb.de
Paderborn University
Coauthors: Giuseppe Mazzuoccolo, Eckhard Steffen

The Fan-Raspaud Conjecture states that every bridgeless cubic graph has three 1-factors with empty intersection. A weaker one than this conjecture is that every bridgeless cubic graph has two 1-factors and one join with empty intersection. Both of these two conjectures can be related to conjectures on Fano-flows. In this talk, we show that these two conjectures are equivalent to some statements on cores and weak cores of a bridgeless cubic graph. In particular, we prove that the Fan-Raspaud Conjecture is equivalent to a conjecture proposed in [E. Steffen, 1-factor and cycle covers of cubic graphs, J. Graph Theory 78 (2015) 195-206]. Furthermore, we disprove a conjecture proposed in [G. Mazzuoccolo, New conjectures on perfect matchings in cubic graphs, Electron. Notes Discrete Math. 40 (2013) 235-238] and we propose a new version of it under a stronger connectivity assumption. The weak oddness of a cubic graph is the minimum number of odd components in the complement of a join of this graph. We obtain an upper bound of weak oddness in terms of weak cores, and thus an upper bound of oddness in terms of cores as a by-product.

Minimum difference representations of graphs

Ida Kantor, ida@iuuk.mff.cuni.cz
Charles University, Prague
Coauthor: Zoltan Furedi

In this talk, we want to represent the vertices of a graph with finite sets in such a way that two vertices are adjacent if and only if their sets are “very different" (this is similar, e.g., to the notion of Kneser graphs). More precisely, a *k-min-difference representation* of G is an assignment of a set A_i to each vertex $i \in V(G)$ so that

$$ij \in E(G) \Leftrightarrow \min\{|A_i \setminus A_j|, |A_j \setminus A_i|\} \geq k.$$

The smallest k such that there exists a k-min-difference representation of G is denoted by $\rho_{\min}(G)$.

After Boros, Gurvitch and Meshulam introduced this notion in 2004, it was not even known whether there are any graphs with $\rho_{\min}(G) \geq 3$. Balogh and Prince proved in 2009 that is indeed so: for every k there is a graph G with $\rho_{\min}(G) \geq k$ (in fact they proved more—for every k there is an n_0 such that whenever $n > n_0$, then for a graph G on n vertices we have $\rho_{\min}(G) \geq k$ with high probability). However, they used a Ramsey-type result in their proof, and as a consequence the resulting bounds are weak.

We improved this, using a different method. The main result of this talk is that there is a constant $c > 0$ such that if n is large enough, there is a bipartite graph G on n vertices such that $\rho_{\min}(G) \geq \frac{cn}{\log n}$.

Oriented edge-transitive maps

Ján Karabáš, karabas@savbb.sk
University of Primorska, Koper and Matej Bel University, Banská Bystrica
Coauthors: Roman Nedela, Tomaž Pisanski

An oriented map M is edge-transitive if its group of automorphisms, $\mathrm{Aut}\,M$, acts transitively on the edges of the underlying graph of M. The group of orientation-preserving automorphisms, $\mathrm{Aut}^+ M$, of index at most two of $\mathrm{Aut}\,M$. It follows that the quotient map of an edge-transitive map, $\bar{M} = M \setminus \mathrm{Aut}^+ M$, is a map on an (quotient) orbifold with at most two edges. We show that there are exactly 8 such quotient maps sitting on orbifolds with at most 4 singular points, seven are spherical and one is toroidal.

The (general) classification of edge-transitive maps is well-known, due to results of Graver and Watkins (1997), Širáň, Tucker and Watkins (1999) and recently by Orbanić, Pellicer, Pisanski and Tucker (2011). The general approach is computationally difficult. The complete classification ranges to the genus 4 (in oriented case, Orbanić et al.) Compared to that method we control the genus g of the underlying surface by choosing a proper g-admissible orbifold rather than number of edges. Thanks to the classification of ‘large groups of automorphisms’ (Conder, 2011) we are able to classify oriented edge-transitive maps up to genus 101.

We discuss the relationships among general classification of edge-transitive maps and the classification of oriented edge-transitive maps. We also consider the possibilities to extend the classification of *oriented* edge-transitive maps to general situation.

Zigzags on Interval Greedoids

Yulia Kempner, yuliak@hit.ac.il
Holon Institute of Technology
Coauthor: Vadim E. Levit

The pivot operation, i.e., exchanging exactly one element in a basis, is one of the fundamental algorithmic tools in linear algebra. Korte and Lovász introduced a combinatorial analog of this operation for bases of greedoids.

Let X, Y be two bases of a greedoid $(U, \mathcal{F})$ such that $|X - Y| = 1$ and $X \cap Y \in \mathcal{F}$. Then X can be obtained from Y by *a pivot operation* where the element $y \in Y - X$ is pivoted out and the element $x \in X - Y$ is pivoted in.

We extend this definition to all feasible sets of the same cardinality and introduce *lower and upper zigzags* comprising these sets.

A *zigzag* is a sequence of feasible sets $P_0, P_1, ..., P_{2m}$ such that:

(i) these sets have only two different cardinalities;

(ii) any two consecutive sets in this sequence differ by a single element.

Zigzag structures allow us to give new metric characterizations of some subclasses of interval greedoids including antimatroids and matroids.

Interval edge colorings of Hamming graphs

Hrant Khachatrian, hrant.khachatrian@ysu.am
Yerevan State University
Coauthor: Petros Petrosyan

An edge-coloring of a graph G with colors $1, \ldots, t$ is an interval t-coloring if all colors are used, and the colors of edges incident to each vertex of G are distinct and form an interval of integers. A graph G is interval colorable if it has an interval t-coloring for some positive integer t. For an interval colorable graph G, the least and the greatest values of t for which G has an interval t-coloring are denoted by $w(G)$ and $W(G)$, respectively.

Hamming graph $H(n_1, \ldots, n_k)$ is defined as a Cartesian product of complete graphs $K_{n_1} \square \ldots \square K_{n_k}$. Hamming graph $H(n_1, \ldots, n_k)$ is interval colorable if and only if $n_1 \cdot \ldots \cdot n_k$ is even. If $H(n_1, \ldots, n_k)$ is interval colorable, then $w(H(n_1, \ldots, n_k))$ is equal to its maximum degree and for every t between $w(H(n_1, \ldots, n_k))$ and $W(H(n_1, \ldots, n_k))$ it has an interval t-coloring. The exact value of $W(H(n_1, \ldots, n_k))$ is not known even in the case $k = 1$. In this talk we present improved upper and lower bounds on $W(H(n_1, \ldots, n_k))$.[1]

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Cyclical codes and operations on graphs

Jurij Kovič, jurij.kovic@siol.net
IMFM, UP FAMNIT

This talk will reveal a natural correspondence between rhombic tilings of planar polygonal regions and circle graphs. This correspondence leads to a simple coding of graphs with cyclical sequences that can be used for the classification of graphs. Using this code we can define also various new operations on graphs.

Optimal strategy for avoiding capture in a multiple stage random walk on a cycle

Grzegorz Kubicki, gkubicki@louisville.edu
University of Louisville, USA, and University of Opole, Poland
Coauthors: Ewa Kubicka, Małgorzata Kuchta, Michal Morayne

We want to maximize the number of moves for a random walk on an even cycle before visiting the vertex opposite to the starting position. Our payoff is the number of moves but it is reduced to 0 if we are not able to avoid the opposite vertex. Optimal stopping time and the expected value of the payoff are determined for this random process as well as for the corresponding multistage process with N stages. Asymptotic behavior of the expected payoff is determined as N increases without bound.

Even orientations of graphs.

Domenico Labbate, domenico.labbate@unibas.it
Dipartimento di Matematica, Informatica ed Economia - Università degli Studi della Basilicata - Potenza (Italy)
Coauthors: Marien Abreu, John Sheehan

A graph G is 1–extendable if every edge belongs to at least one 1–factor. Let G be a graph with a 1–factor F. Then an *even F–orientation* of G is an orientation in which each F–alternating cycle has exactly an even number of edges directed in the same fixed direction around the cycle.

We examine the structure of 1–extendible graphs G which have no even F–orientation where F is a fixed 1–factor of G and we give a characterization for k–regular graphs with $k \geq 3$ and graphs with connectivity at least four.

Moreover, we will point out a relationship between our results on even orientations and Pfaffian graphs.

Random colourings and automorphism breaking in locally finite graphs

Florian Lehner, mail@florian-lehner.net
Universität Hamburg

A colouring of a graph G is called distinguishing if it is not preserved by any nontrivial automorphism of G. Equivalently, a colouring is distinguishing if its stabiliser in the automorphism group is trivial, i.e., only consists of the identity. Tucker conjectured that, if each automorphism of a graph moves infinitely many vertices, then there is a distinguishing 2-colouring of G.

In this talk we investigate the stabiliser of a random 2-colouring of such a graph in order to make progress towards Tucker's conjecture. We show that these stabilisers are almost surely close to being trivial. More precisely, they are nowhere dense in the topology of pointwise convergence and have Haar measure 0 in the automorphism group.

A Linear Bound for the Traceability Conjecture

Nicolas Lichiardopol, nicolas.lichiardopol@neuf.fr
Lycée Craponne, Salon, France

Coauthors: Susan van Aardt, Jean. E Dunbar, Marietjie Frick

An oriented graph D is said to be traceable if it admits a hamiltonian path. For $k \geq 2$, an oriented graph D of order at least k, is said to be k-traceable if any subset of k vertices of D induces a traceable oriented graph. We denote by $t(k)$ the smallest integer bigger than or equal to k such that every k-traceable oriented graph of order at least $t(k)$ is traceable. The Traceability Conjecture states that $t(k) \leq 2k-1$ for every $k \geq 2$. (see [3]). It was proved in [2], [1] and [4] that $t(k) = k$ for $2 \leq k \leq 6$, $t(7) = 9$, $t(8) \leq 14$ and that $t(k) \leq 2k^2 - 20k + 59$ for $k \geq 9$ (which is a quadratic upper bound on $t(k)$). In this paper we prove that for $k \geq 4$, any k-traceable orgraph of order $n \geq 6k - 20$ is traceable. This is the first linear bound in the story of the Traceability Conjecture.

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Harmonious and achromatic colorings of fragmentable hypergraphs

Zbigniew Lonc, zblonc@mini.pw.edu.pl
Warsaw University of Technology, Warsaw, Poland
Coauthors: Michał Dębski, Paweł Rzążewski

A *harmonious* coloring of a k-uniform hypergraph H is a rainbow vertex coloring such that each k-set of colors appears on at most one edge. A rainbow coloring of H is *achromatic* if each k-set of colors appears on at least one edge. The *harmonious number* (resp. *achromatic number*) number of H, denoted by $h(H)$ (resp. $\psi(H)$) is the minimum (resp. maximum) possible number of colors in a harmonious (resp. achromatic) coloring of H. A class $\mathcal{H}$ of hypergraphs is *fragmentable* if for every $H \in \mathcal{H}$, H can be fragmented to components of a bounded size by removing a "small" fraction of vertices.

We show that for every fragmentable class $\mathcal{H}$ of bounded degree hypergraphs, for every $\epsilon > 0$ and for every hypergraph $H \in \mathcal{H}$ with $m \geq m_0(\mathcal{H}, \epsilon)$ edges we have $h(H) \leq (1+\epsilon)\sqrt[k]{k!m}$ and $\psi(H) \geq (1-\epsilon)\sqrt[k]{k!m}$.

As corollaries, we answer a question posed by Blackburn (concerning the maximum length of t-subset packing sequences of constant radius) and derive an asymptotically tight bound on the minimum number of colors in a vertex-distinguishing edge coloring of cubic planar graphs (which is a step towards confirming a conjecture of Burris and Schelp).

Langford sequences from products of labeled digraphs

Susana-C. López, susana@ma4.upc.edu
Universitat Politècnica de Catalunya
Coauthor: Francesc-A. Muntaner-Batle

For $m \leq n$, we denote the set $\{m, m+1, \dots, n\}$ by $[m, n]$. Let d be a positive integer. A *Langford sequence* of order m and defect d is a sequence $(l_1, l_2, \dots, l_{2m})$ of $2m$ numbers such that (i) for every $k \in [d, d+m-1]$ there exist exactly two subscripts $i, j \in [1, 2m]$ with $l_i = l_j = k$, (ii) the subscripts i and j satisfy the condition $|i-j| = k$. A Langford sequence of order m and defect $d = 1$ is a Skolem sequence of order m. Abraham showed that the number of Skolem sequences of order m is at least $2^{\lfloor m/3 \rfloor}$ for every $m \equiv 0$ or 1 (mod 4).

We say that a digraph D admits a labeling f if its underlying graph admits the labeling f. For any Skolem sequence of order m, we define a *Skolem labeling* g of the directed matching $m\overrightarrow{K_2}$, up to isomorphism. Let $f : E(m\overrightarrow{K_2}) \to [1, m]$ be any bijective function such that if $f(u,v) = k$, then the Skolem labeling g of $m\overrightarrow{K_2}$ assigns to u one of the two positions occupied by k and to v the other position occupied by k, in such a way that the label of u is strictly smaller than the label of v. In a similar way, we can define a *Langford labeling* of $m\overrightarrow{K_2}$, up to isomorphism, for any Langford sequence of order m and defect d.

In this talk, we present a study of Skolem and Langford sequences through Skolem and Langford labelings of $m\overrightarrow{K_2}$. By multiplying a Skolem labeled matching $m\overrightarrow{K_2}$ by a particular family of labeled 1-regular digraphs of order n, we obtain a Langford labeled matching $(mn)\overrightarrow{K_2}$. We will show that this procedure can also be applied to obtain Langford sequences from existing ones, and that in this way, we can obtain a lower bound for the number of Langford sequences, for particular values of the defect. We also extend this procedure to hooked and extended Skolem sequences.

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Key words: Skolem sequence, Langford sequence, $\otimes_h$-product, super edge-magic labeling.

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Gaussian paragraphs of pseudolinear arrangements

Jesus Leanos, jesus.leanos@gmail.com
Maribor University
Coauthor: Drago Bokal

Gauss has given necessary but not sufficient conditions for a sequence of letters to represent the sequence of self-crossings of some closed planar curve. Such sequences of letters were called Gaussian words and recently generalized to Gaussian paragraphs, sets of words that arise from sequences of crossings of several curves.

In this talk, we apply Gaussian paragraph representation to pseudo-linear arrangements and present an elementary characterization of pseudo-linear arrangements that can be used to recognize them in time linear in the number of crossings or quadratic in the number of lines. This is an improvement over the only other characterization known to us, which can be verified in time cubic in the number of lines.

The structure of graphs with Circular flow number 5 or more

Giuseppe Mazzuoccolo, mazzuoccolo@unimore.it
Università di Modena e Reggio Emilia
Coauthors: Louis Esperet, Michael Tarsi

For some time the Petersen graph was the only known Snark, with circular flow number 5 (or more, as long as Tutte's 5-flow Conjecture is in doubt). Although infinitely many such snarks were presented in "Macajova-Raspaud On the Strong Circular 5-Flow Conjecture JGT 52 (2006)", eight years ago, the variety of known methods to construct them and the structure of the obtained graphs were still rather limited. Here, we first perform an analysis of sets of flow values, which can be transferred through flow networks, with the flow capacity of each edge restricted to the open interval $(1,4)$ modulo 5. All these sets are symmetric unions, of open integer intervals in the ring $\mathbb{R}/5\mathbb{Z}$. We use the results to design an arsenal of methods for constructing snarks S, with circular flow number $\phi_c(S) \geq 5$. As one indication to the diversity and density of the obtained family of graphs, we show that it is rich enough for proving NP-completeness of the corresponding recognition problem.

Decomposing highly edge-connected graphs into trees of small diameter

Martin Merker, marmer@dtu.dk
Technical University of Denmark

The Tree Decomposition Conjecture by Bárat and Thomassen states that for every tree T there exists a natural number $k(T)$ such that the following holds: If G is a $k(T)$-edge-connected graph with size divisible by the size of T, then G can be edge-decomposed into subgraphs isomorphic to T. So far this conjecture has only been verified for paths, stars, and a family of bistars. We prove a weaker version of the Tree Decomposition Conjecture, where we require the subgraphs in the decomposition to be isomorphic to graphs that can be obtained from T by vertex-identifications. This implies the Tree Decomposition Conjecture under the additional constraint that the girth of G is greater than the diameter of T. We also show that the Tree Decomposition Conjecture holds for all trees of diameter at most 4, as well as for some trees of diameter 5.

Cyclic Hamiltonian cycle systems for the complete multipartite graph

Francesca Merola, merola@mat.uniroma3.it
Roma Tre University, Italy
Coauthors: Anita Pasotti, Marco A. Pellegrini, Michael W. Schroeder

A Hamiltonian cycle system (HCS) for a graph or multigraph Γ is a set $\mathcal{B}$ of Hamiltonian cycles of Γ whose edges partition the edge set of Γ. A cycle system is *regular* if there is an automorphism group G of the graph Γ acting sharply transitively on the vertices of Γ and permuting the cycles of $\mathcal{B}$, and it is called *cyclic* if G is the cyclic group.

The existence problem for cyclic HCS for the complete graph K_n, n odd, and for the graph $K_{2n} - I$, I a 1-factor, (the so-called *cocktail party graph*), has been solved by Buratti and Del Fra (2004), and Jordon and Morris (2008) respectively. In the talk I will consider existence results for cyclic Hamiltonian cycle systems for $K_{m\times n}$, the complete multipartite graph with m parts, each of size n. I will present necessary and sufficient conditions for the existence of a cyclic HCS for the graph $K_{m\times n}$ when the number of parts m is even, and more generally for mn even, and discuss some work in progress for the case in which both m and n are odd.

I will also touch on the symmetric HCS introduced by Brualdi and Schroeder in 2011 for the cocktail party graph, and recently generalized by Schroeder to complete multipartite graphs; indeed we may note that cyclic cycle systems often turn out to possess this additional symmetry requirement, so that it makes sense to discuss these results in this context.

On the construction of non-transitive graphs from groups

Vedrana Mikulić Crnković, vmikulic@math.uniri.hr
Department of Mathematics, University of Rijeka
Coauthor: Dean Crnković

Let G be a transitive group acting on a set Ω, P a subgroup of G and Δ be a union of some P orbits on Ω. Then Δ is the base block of the 1-design. In this talk we will apply this known method of construction of 1-designs, on which the group G acts as the transitive automorphism group, to construct regular graphs, on which the group G acts as non-transitive automorphism group.

An ABC-Problem for location and consensus on graphs

Martyn Mulder, hmmulder@ese.eur.nl
Econometrisch Instituut, Erasmus Universiteit
Coauthors: F.R. McMorris, Beth Novick, R.C. Powers

In social choice theory the process of achieving consensus can be modeled by a function L on the set of all finite sequences of vertices of a graph. It returns a nonempty subset of vertices. To guarantee rationality of the process *consensus axioms* are imposed on L. Three such axioms are Anonymity, Betweenness and Consistency. Functions satisfying these three axioms are called ABC-functions. The median function Med on a connected graph returns the set of vertices minimizing the distance sum to the elements of the input sequence. It is a prime example of an ABC-function. Recently Mulder & Novick proved that on median graphs Med is the unique function ABC-function. This inspired the *ABC-Problem* for location and consensus on graphs: (i) On what other classes of graphs is Med the unique ABC-function? (ii) If on class $\mathcal{G}$ there are other ABC-functions besides Med, which additional axioms still characterize Med? (iii) Find on $\mathcal{G}$ the other ABC-functions, and possibly characterize these. In this talk we present first non-trivial results for this ABC-Problem. Moreover we present some interesting voting procedures on n alternatives.

Searching for designs over finite fields with non-trivial autmorphism groups

Anamari Nakić, anamari.nakic@fer.hr
University of Zagreb

A design over the finite field $\mathbb{F}_q$ with parameters t-$(v,k,\lambda)_q$ is a pair $(\mathcal{V},\mathcal{B})$ where $\mathcal{V}$ is the v-dimensional vector space over $\mathbb{F}_q$ and $\mathcal{B}$ is a collection of k-dimensional subspaces of $\mathcal{V}$, such that each t-dimensional subspace of $\mathcal{V}$ is contained in precisely λ members of $\mathcal{B}$. We follow the trend of finding q-analogues of statements valid for classical combinatorial designs. In particular, we focus on necessary conditions on the existence of designs over finite fields with an assumed automorphism group. We give insight into the problems we encountered as well as results we obtained.

The Unimodular Intersection Problem

Shmuel Onn, onn@ie.technion.ac.il
Technion - Israel Institute of Technology

We show that finding minimally intersecting n paths from s to t in a directed graph or n perfect matchings in a bipartite graph can be done in polynomial time. This holds more generally for unimodular set systems.

Near 1-factors with prescribed edge-lengths in the complete graph

Anita Pasotti, anita.pasotti@unibs.it
Università degli Studi di Brescia
Coauthor: Marco A. Pellegrini

Let K_v be the complete graph with vertex-set $\{0,1,\ldots,v-1\}$. The length of any edge $[x,y]$ of K_v is defined by $d(x,y) = min(|x-y|, v-|x-y|)$. In 2007 Buratti conjectured that if v is a prime, then there exists a Hamiltonian path of K_v whose list of edge-lengths is ANY prescribed multiset L of $v-1$ integers in $\{1,2,\ldots,\lfloor \frac{v}{2} \rfloor\}$. Partial results about this conjecture can be found in [1-5].

Recently, Meszka proposed the following similar conjecture: "If v is an odd prime, then there exists a near 1-factor of K_v whose list of edge-lengths is ANY prescribed multiset L of $\frac{v-1}{2}$ integers in $\{1,2,\ldots,\lfloor \frac{v}{2} \rfloor\}$". Rosa [7] proved that the conjecture is true when the elements of the list are $\{1,2,3\}$ or $\{1,2,3,4\}$ or $\{1,2,3,4,5\}$. Also he proved that the conjecture is true when the list L contains a "sufficient" number of 1's.

In this talk we propose a generalization of this problem to the case in which v is an odd integer not necessarily prime [6]. In particular, we give a necessary condition for the existence of such a near 1-factor and we conjecture that such a condition is also sufficient. If v is a prime our conjecture reduces to Meszka's one. Then we show that our conjecture is true for any list L whose underlying set S has size 1, 2, or $\lfloor \frac{v}{2} \rfloor$, or when $S = \{1,2,t\}$ for any positive integer t not coprime with v. Also, we give partial results when t and v are coprime. Finally, we present a complete solution for $t \leq 11$.

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Geometric constructions for loops

Stefano Pasotti, stefano.pasotti@unibs.it
Università degli Studi di Brescia
Coauthors: Silvia Pianta, Elena Zizioli

Over the last ten years several authors established and studied the correspondence between geometric structures, loops and regular permutation sets. These relationships were first introduced in [2] in order to associate to the point-set of a general hyperbolic geometry over a Euclidean field the algebraic structure of a so-called *Bruck loop* (or *K-loop*) and use it for a "coordinatization" of the geometry.

This research is placed in the line of investigations aiming at employing geometric structures and the related insight in order to build up loops and to study their algebraic properties. In particular we present here two techniques (see [4], [3]). The first one is a generalization of the idea of describing loops by means of *complete graphs with a suitable edge-colouring* already considered in a special case in [1]. In a more general setting we employ complete directed graphs, we show how to relate a loop to suitable edge-colouring of these graphs and we find conditions characterizing graphs giving rise to the same loop, to isomorphic and to isotopic loops.

The second one exploits techniques related to *transversals and sections of groups*. Here we consider the group $\mathrm{PGL}_2(\mathbf{K})$ identified with the 3-dimensional projective space $\mathrm{PG}(3, \mathbf{K})$ deprived of the point-set of a ruled quadric $\mathcal{Q}$ and we consider a suitable subgroup $\mathcal{D}$. In this context we search for geometrically relevant subsets of $\mathrm{PG}(3, \mathbf{K}) \setminus \mathcal{Q}$ which are a complete set of representatives for the left cosets of $\mathcal{D}$ and equip them with the structure of (left) loops. In particular we consider both the case $\mathbf{K}$ is an Euclidean field (characterizing loops arising from planes of the projective space and from the tangent semicone to $\mathcal{Q}$ from the point 1) and the case $\mathbf{K} = \mathrm{GF}(q)$, q odd (considering different types of subgroups and transversals which are geometrically well characterized).

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A zero-free interval for chromatic polynomials of graphs with 3-leaf spanning trees

Thomas Perrett, tper@dtu.dk
Technical University of Denmark

The *chromatic polynomial* $P(G,t)$ of a graph G is a polynomial with integer coefficients which counts, for each non-negative integer t, the number of proper t-colourings of G. A real number t is called a *chromatic root* of G if $P(G,t) = 0$. An interval $I \subseteq \mathbb{R}$ is called *zero-free* for a class of graphs $\mathcal{G}$ if no $G \in \mathcal{G}$ has a chromatic root in I. It is known [1] that $(-\infty, 0)$, $(0,1)$, and $(1, 32/27]$ are maximal zero-free intervals for the class of all graphs, but one may find larger zero-free intervals for more restrictive classes. Indeed, Thomassen [2] showed that for graphs with a Hamiltonian path, the interval $(1, t_1]$ is maximally zero-free, where $t_1 \approx 1.295$ is the unique real root of the polynomial $(t-2)^3 + 4(t-1)$. We build on the techniques of Thomassen to prove that, for graphs containing a spanning tree with at most three leaves, the interval $(1, t_2]$ is maximally zero-free, where $t_2 \approx 1.2904$ is the smallest real root of the polynomial $(t-2)^6 + 4(t-1)^2(t-2)^3 - (t-1)^4$.

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Pyramidal k–cycle decompositions

Gloria Rinaldi, gloria.rinaldi@unimore.it
University of Modena and Reggio Emilia, Italy
Coauthors: Marco Buratti, Tommaso Traetta

A k–cycle system of order v is a decomposition of the complete graph on v vertices into cycles of length k. An automorphism group of the system is a permutation group on the vertex set preserving the decomposition into cycles. If we ask the group to satisfy some particular requests, then we have two problems, strongly connected. We ask which groups are admissible and we ask which is the spectrum of admissible values v and k for which a k-cycle system of order v with such an automorphism group exists.
We focus our attention on the particular situation of an automorphism group G whose action is t–pyramidal on the vertex set, i.e., G fixes t vertices and has a sharply transitive action on the remaining ones. The cases $t = 0$ and $t = 1$ are well known and largely studied in literature, especially when the group is cyclic or the length of the cycles is 3, even though many open questions still remain.
Here we examine the case $t > 1$ in some details. We point out some structural general properties of the group and we completely determine the spectrum of values v for which a 3–pyramidal 3–cycle decomposition of order v exists.

Some properties of k-geodetic graphs

Sanja Rukavina, sanjar@math.uniri.hr
Department of Mathematics, University of Rijeka
Coauthors: Dean Crnković, Marina Šimac

Graphs in which each pair of nonadjacent vertices has at most k paths of minimum length between them are called k-geodetic graphs. We will discuss some properties of k-geodetic graphs constructed from block designs. LDPC codes based on the adjacency matrix of k-geodetic graphs obtained from block designs will be introduced.

Cographs, orthologs, and the inference of species trees from paralogs

Peter F. Stadler, peter.stadler@bioinf.uni-leipzig.de
University Leipzig
Coauthors: Marc Hellmuth, Nick Wieseke, Adrian Fritz, Sarah Berkemer, Martin Middendorf, Markus Lechner, Hans-Peter Lehnhof, Maribel Hernandes-Rosales, Vincent Moulton, Katharina Huber, Marius Brunnert

Phylogenomics heavily relies on well-curated sequence data sets that consist, for each gene, exclusively of 1:1-orthologs, i.e., of genes that have arisen through speciation events. Paralogs, which arose from duplication events, are treated as a dangerous nuisance that has to be detected and removed. Building upon recent advances in mathematical phylogenetics we demonstrate that gene duplications convey meaningful phylogenetic information and allow the inference of plausible phylogenetic trees provided orthologs and paralogs can be distinguished with a high degree of certainty. Starting from tree-free estimates of orthology, co-graph editing can sufficiently reduce the noise to by translated into constraints on the species trees. While the resolution is very poor for individual gene families, we show that genome-wide data sets are sufficient to generate fully resolved phylogenetic trees. The mathematical content of this work comprises (1) the characterization of graphs of orthologous genes as co-graphs, (2) an analysis of cograph editing that allows the reliable correction of empirical data to mathematically correct co-graphs, (3) the identification of a triple set in the corresponding co-trees that constrains the species tree, and (4) results on the decomposition of co-graphs that suggest that paralgous gene pairs can in many be safely included in classical phylogenetic reconstruction pipelines.

The presentation will summarize results obtained by a larger group of authors in several publications as well recent unpublished results. Authors are listed in random order.

Nowhere-zero 5-flows

Eckhard Steffen, es@upb.de
Paderborn University
Coauthor: Giuseppe Mazzuoccolo

Tutte's 5-Flow Conjecture from 1954 states that every bridgeless graph has a nowhere-zero 5-flow. We prove that every cyclically 6-edge-connected cubic graph with oddness at most 4 has a nowhere-zero 5-flow. Therefore, every possible minimum counterexample to the 5-flow conjecture has oddness at least 6.

K_7-Minors in Optimal 1-Planar Graphs

Yusuke Suzuki, y-suzuki@math.sc.niigata-u.ac.jp
Niigata University

We discuss the existence of minors of given graphs in optimal 1-planar graphs. As our first main result, we prove that for any graph H, there exists an optimal 1-planar graph which contains H as a topological minor. Next, we consider minors of complete graphs, and prove that every optimal 1-planar graph has a K_6-minor. Furthermore, we characterize optimal 1-planar graphs having no K_7-minor.

Eulerian properties of 3-uniform hypergraphs

Mateja Šajna, msajna@uottawa.ca
University of Ottawa
Coauthors: Amin Bahmanian, Andrew Wagner

A *flag* of a hypergraph $H = (V, E)$ is an ordered pair (v, e) with $v \in V$, $e \in E$, and $v \in e$. A *closed trail* of H is a sequence $W = v_0 e_0 v_1 e_1 v_2 \ldots v_{k-1} e_{k-1} v_0$ with $v_i \in V$, $e_i \in E$, and $v_i, v_{i+1} \in e_i$ for each $i \in \mathbb{Z}_k$ such that no flag — that is, (v_i, e_i) or (v_{i+1}, e_i) — is repeated. A closed trail W is called an *Euler tour* of H if it traverses each flag (v, e) of H exactly once, and a *strict Euler tour* if it traverses each edge of H exactly once. A family of closed trails of H that jointly traverse each edge of H exactly once is called an *Euler family*.

For a connected graph, the concepts of Euler tour, strict Euler tour, and Euler family are identical, however, for a general hypergraph, they give rise to three rather distinct problems. For example, while the problems of existence of an Euler tour and Euler family are polynomial on the set of all hypergraphs, the problem of existence of a strict Euler tour is NP-complete even just on the set of all linear 2-regular 3-uniform hypegraphs. In this talk, we shall briefly compare the three problems, and then focus on two main results: (1) every 3-uniform hypergraph without cut edges has an Euler family, and (2) every triple system has a strict Euler tour.

Measuring closeness of graphs – the Hausdorff distance

Andrej Taranenko, andrej.taranenko@um.si
Faculty of Natural Sciences and Mathematics, University of Maribor
Coauthor: Iztok Banič

We introduce an apparatus to measure closeness or relationship of two given objects. This is a topology based apparatus that uses graph representations of the compared objects. In more detail, we obtain a metric on the class of all pairwise non-isomorphic connected simple graphs to measure closeness of two such graphs. To obtain such a measure, we use the theory of hyperspaces from topology to introduce the notion of the Hausdorff graph 2^G of any graph G. Then, using this new concept of Hausdorff graphs combined with the notion of graph amalgams, we present the Hausdorff distance, which proves to be useful when examining the closeness of any two connected simple graphs. We also present many possible applications of these concepts in various areas.

On the Hamilton-Waterloo problem for a class of Cayley graphs

Tommaso Traetta, tommaso.traetta@ryerson.ca
Ryerson University, Toronto (ON) Canada

The Hamilton–Waterloo problem HWP$(\Gamma; m, n; \alpha, \beta)$ asks for a factorization of the simple graph Γ into α C_m–factors and β C_n–factors. The classic version of the problem, that is, the case in which Γ is the complete graph is still open, although it has been the subject of an extensive research activity.

In this talk, I will consider the Cayley graph $C_m[n] = Cay(\mathbb{Z}_m \times \mathbb{Z}_n, S)$ with connection set $S = \{1, -1\} \times \mathbb{Z}_n$ and present an almost complete solution to HWP$(C_m[n]; m, n; \alpha, \beta)$ with m and n odd. Andrea Burgess will show how this result can be used to make progress on the classic problem.

This is joint work with Andrea Burgess and Peter Danziger.

Minimum Weighted Maximal Matching Problem in Trees

Mustafa Kemal Tural, tural@metu.edu.tr
Middle East Technical University

Given a weighted simple graph, the minimum weighted maximal matching (MWMM) problem is the problem of finding a maximal matching of minimum weight. The MWMM problem is NP-hard in general, but is polynomial-time solvable in some special classes of graphs. For instance, it has been shown that the MWMM problem can be solved in linear time in trees when all the edge weights are equal to one. We show that the convex hull of the incidence vectors of maximal matchings (i.e., the maximal matching polytope) in trees is given by the polyhedron described by the linear programming relaxation of a recently proposed integer programming formulation. This establishes the polynomial-time solvability of the MWMM problem in weighted trees. The question of whether or not the MWMM problem can be solved in linear time in weighted trees in open.

On the orders of Hypohamiltonian and Hypotraceable Graphs, Digraphs and Oriented Graphs

Susan Van Aardt, vaardsa@unisa.ac.za

University of South Africa

Coauthors: Marietjie Frick, Alewyn Burger, Arnfried Kemnitz, Ingo Schiermeyer

We give a short survey on old and new results on the orders of hypohamiltonian and hypotraceable graphs, digraphs and oriented graphs.

In particular we show that there exists a hypohamiltonian oriented graph of order n if and only if $n \geq 9$ and there exists a planar hypotraceable oriented graph of order n for every even $n \geq 10$, with the possible exception of $n = 14$.

Colouring of Multiplication Modules

Rezvan Varmazyar, varmazyar@iaukhoy.ac.ir

Department of Mathematics, Khoy Branch, Islamic Azad University, Khoy, Iran

Let R be a commutative ring. An R-module M is called a multiplication R-module provided that for every submodule N of M there exists an ideal I of R such that $N = IM$. Let $N = IM$ and $K = JM$ be submodules of a multiplication R-module M ,for some ideals I, J of R. The product of N and K, denoted by $N.K$, is defined to be $(IJ)M$. An element x of M is called a zero-divisor of M if there exists a nonzero element y of M such that $Rx.Ry = 0$. We associate a simple graph $\Gamma(M)$ to M with vertices $Z(M)^* = Z(M) - \{0\}$,the set of nonzero zero-divisors of M, and for distinct $x, y \in Z(M)^*$ the vertices x and y are adjacent if and only if $Rx.Ry = 0$. In this present talk we investigate the chromatic number of $\Gamma(M)$.

Finding a majority ball with majority answers

Mate Vizer, vizermate@gmail.com

MTA Alfred Renyi Institute of Mathematics

Coauthors: Daniel Gerbner, Balazs Keszegh, Balazs Patkos, Domotor Palvolgyi, Gabor Wiener

Suppose we are given a set of n balls $\{b_1, \ldots, b_n\}$ each colored either red or blue in some way unknown to us. To find out some information about the colors, we can query any triple of balls $\{b_{i_1}, b_{i_2}, b_{i_3}\}$. As an answer to such a query we obtain (the index of) a *majority ball*, that is, a ball whose color is the same as the color of another ball from the triple. Our goal is to find a *non-minority ball*, that is, a ball whose color occurs at least $\frac{n}{2}$ times among the n balls. We show that the minimum number of queries needed to solve this problem is $\Theta(n)$ in the adaptive case and $\Theta(n^3)$ inthe non-adaptive case. We also consider some related problems.

Hardness results for Buttons & Scissors

Aaron Williams, awilliams@simons-rock.edu
Bard College at Simon's Rock

Buttons & Scissors is a free single-player puzzle available on iOS and Android. The puzzle is played on an n-by-n grid, where each position is empty or has a coloured button sewn onto it. The player's goal is to remove all of the buttons using a sequence of horizontal, vertical, and diagonal scissor cuts. Each cut removes all buttons between two distinct buttons of the same colour, and is not valid if there is an intermediate button of a different colour. We prove that deciding whether a given level can be completed is NP-complete. In fact, NP-completeness still holds when only two different button colours are used, and only horizontal and vertical cuts are allowed. On the other hand, the problem is polytime solvable for a single button colour via matching in hypergraphs with edges containing two or three vertices. We also discuss inapproximability and integer programming solutions to the general problem.

This is joint work with three students from Bard College at Simon's Rock, and over a dozen researchers from the 30th Bellairs Winter Workshop on Computational Geometry

Forbidden subgraphs and hamiltonian propertices

Liming Xiong, lmxiong@bit.edu.cn
Beijing Insititute of Technology
Coauthors: Zdeněk Ryjáček, Petr Vrána

In this talk, we present some results relation between forbidden subgraphs and hamiltonian propertices (such as the existence of hamiltonian cycles, hamiltonian paths and spanning closed trails et.al). In particular, our results show how it affects the forbidden subgraphs to guarteeing the same hamiltonian propertices when adding the more condition of Hourglass-free on a 3-connected graph.

Distances in Sierpiński graphs

Sara Zemljič, saraz@hi.is
Science Institute, University of Iceland

Sierpiński graphs form a family of graphs which has been studied thoroughly especially due to its connections to the problem of the Tower of Hanoi puzzle. The puzzle is interesting because of several open problems, for example an optimal solution for 4 (or more) pegs. These can be linked to the state graphs of the puzzle, the Hanoi graphs. Sierpiński and Hanoi graphs have a very similar structure. We are particularly interested in the metric properties of Sierpiński graphs due to their close relation to optimal solutions to the Tower of Hanoi puzzle.

For arbitrary two vertices of a Sierpiński graph S_p^n, the general distance formula is given as the minimum of p values. Our aim is to find a closed or a simplified distance formula. This was first done for extreme vertices and recently also for so called almost-extreme vertices. In this talk we will generalize this idea for any vertex with only two different entries (i.e., a vertex on a geodesic between two extreme vertices).

Pancyclicity of 4-Connected Claw-free Net-free Graphs

Mingquan Zhan, Mingquan.Zhan@millersville.edu
Millersville University of Pennsylvania

A graph G is said to be pancyclic if G contains cycles of lengths from 3 to $|V(G)|$. The net $B(i,j)$ is obtained by associating one endpoint of each of the path P_{i+1} and P_{j+1} with distinct vertices of a triangle. Ferrara et al. (2013) [**?**] showed that every 4-connected $\{K_{1,3}, B(i,j)\}$-free graph with $i + j = 6$ is pancyclic. In this paper we show that every 4-connected $\{K_{1,3}, B(i,j)\}$-free graph with $i + j = 7$ is either pancyclic or it is the line graph of the Petersen graph.

Weighted domination of cactus graphs

Janez Žerovnik, janez.zerovnik@fs.uni-lj.si
University of Ljubljana
Coauthor: Tina Novak

Cactus is a graph in which every edge is on at most one cycle. Or, equivalently, each pair of cycles can meet in at most one vertex. A linear algorithm for weighted domination number of (vertex-weighted) cactus graphs is given. Although algorithms for the domination problem on trees and cacti are known for a long time [1,2], there seems to be no work that studies the weighted domination problem on cactus graphs. However, as cacti are graphs with tree-width $k = 2$, the general algorithm of [3] can be used that solves the weighted domination problem in $\mathcal{O}(3^{2k+1}n) = \mathcal{O}(3^5 n)$ steps. Our algorithm needs at most $16n$ additions and $10n$ min operations and thus substantially improves the constant factor.

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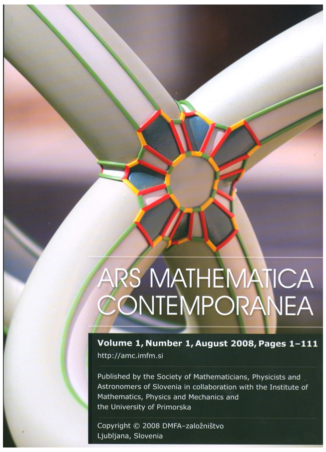
Author index

ARS MATHEMATICA CONTEMPORANEA

Ars Mathematica Contemporanea (AMC) is an international journal, published by the DMFA, the Slovenian Society of Mathematicians, Physicists and Astronomers. The Founding Editors and Editors-in-Chief of AMC are Dragan Marušič and Tomaž Pisanski and its Editorial Board includes a number of internationally recognized mathematicians and affiliations.

The aim of AMC is to publish peer-reviewed high-quality articles in contemporary mathematics that arise from the discrete and concrete mathematics paradigm. It favors themes that combine at least two different fields of mathematics. In particular, papers intersecting discrete mathematics with other branches of mathematics, such as algebra, geometry, topology, theoretical computer science, and combinatorics, are most welcome.



What do we publish in AMC?

Excerpt from the editorial to AMC issue Vol 8, No 2 (2015)

Our declared scope is clear: we are looking for high quality papers that cover at least two different subject fields, at least one of which is within discrete mathematics. Some easy statistical analysis tells us to what extent this has been realised in practice, and we hope this will be also of help to authors who are considering AMC as a potential venue for their papers.

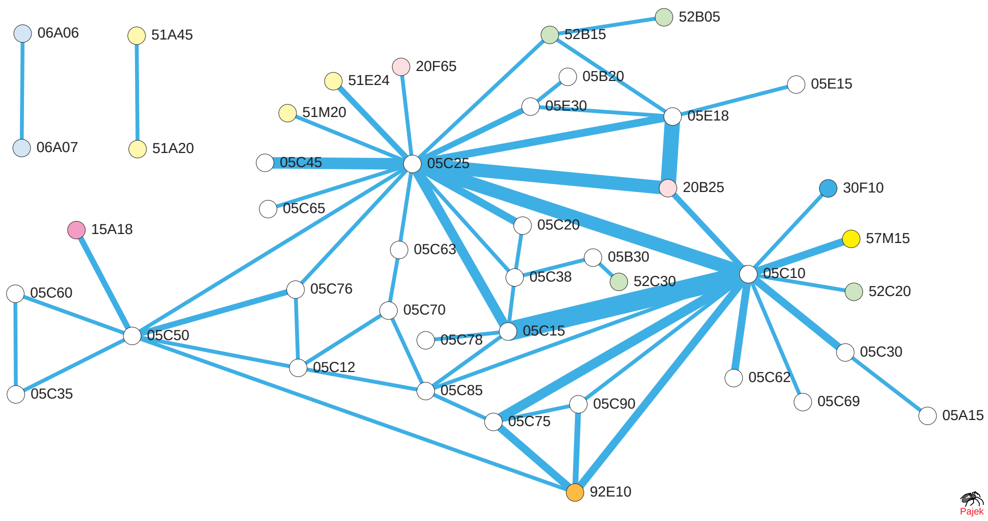
In the first seven years of AMC we have published 204 papers, totalling 2872 pages. This is a little more than 14 pages per paper. The minimum average page length so far was 12.05, in volume 1, while the maximum average page length was 16.20, in volume 5. Approx. 43% of these papers used at least two different 2-digit MSC codes, while 52% used at least two different 3-letter MSC codes. A little over 85% of the papers used both primary and secondary classifications.

A large majority of the primary 2-digit classification codes came under 05 (Combinatorics), followed by 52 (Convex and discrete geometry), 51 (Geometry) and 20

(Group theory and generalizations). In decreasing order, the other 2-digit primary codes were 57 (Manifolds and cell complexes), 68 (Computer science), 06 (Order, lattices, ordered algebraic structures), 91 (Game theory, economics, social and behavioral sciences), 01 (History and biography), 92 (Biology and other natural sciences) and 47 (Operator theory).

The ten most frequent 3-letter classification codes were: 05C (Graph theory), 05E (Algebraic combinatorics), 20B (Permutation groups), 52B (Polytopes and polyhedra), 05B (Designs and configurations), 51E (Finite geometry and special incidence structures), 52C (Discrete geometry), 57M (Low-dimensional topology), 92E (Chemistry), 20F (Structure and classification of infinite and finite groups), and 06A (Ordered sets).

The most frequent pairs of 5-letter MSC codes declared in a paper are shown as edges in the figure below, which comes from some analysis performed by Vladimir Batagelj using Pajek. The threshold value for inclusion of a pair as an edge was set to 2.



Among the 5-letter classifications by far the most frequent were 05C25 (Graphs and abstract algebra), 05C10 (Planar graphs; geometric and topological aspects of graph theory), followed by 05C15 (Colorings of graphs and hypergraphs), 05E18 (Group actions on combinatorial structures), 05C12 (Distance in graphs), 20B25 (Finite automorphism groups of algebraic, geometric and combinatorial structures), 05C50 (Graphs and linear algebra), 05C76 (Graph operations), 05C75 (Structural characterization of families of graphs), 05C45 (Eulerian and Hamiltonian graphs), 05E30 (Association schemes, strongly regular graphs), and 05C85 (Graph algorithms).

These figures show that we publish mostly papers in algebraic and topological graph theory, with discrete and convex geometry also having significant presence in AMC. We note, however, that papers with less frequent MSC codes still play an important role in world mathematics. According to MathSciNet at the time of writing of this editorial, the most highly cited paper in 05C76 (Graph operations) was published in our journal.

Abstracts of the 8th Slovenian Conference on Graph Theory KG'15.
Kranjska Gora, Slovenia, June, 21 – 27, 2015.

Edited by Gašper Košmrlj and Boštjan Kuzman.
Ljubljana, June 2015.