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55th Czech-Slovak Conference on Graph Theory 2020

AUGUST 17–20, 2020

FACULTY OF INFORMATICS,
MASARYK UNIVERSITY, BOTANICKÁ 68A, BRNO

Speakers

Jan Ekstein (UWB Pilsen)
Irena Penev (Charles University)
Dieter Rautenbach (Ulm University)
Jozef Skokan (LSE)
Jan Volec (Czech TU)

Dear Participants of the 55th Czech-Slovak Conference on Graph Theory,

On behalf of the whole organizing committee, I would like to welcome all of you in Brno and thank you for coming to the annual Czech-Slovak graph theory conference. Undoubtedly, this year will remain in our memories associated with the COVID pandemic, which also affected organizing the conference. In March, we had to make a decision to shift the conference from its traditional time in late May to the summer and to change the format of the conference in a way that we can better cope with many uncertainties related to organizing the conference. In particular, we moved the location of the conference to Brno, where I am delighted to welcome you now, and we had to restructure the budget of the conference. On the positive side, this resulted in a significant reduction of the registration fee, which still includes the conference dinner and coffee breaks. I very much hope that you will excuse that some of the traditional aspects of the conference had to be altered so that we could organize the conference without a major risk of significant financial loss.

All of us are now looking forward to four days full of very interesting talks on many different topics in graph theory, which include the invited talks of Jan Ekstein, Irena Penev, Dieter Rautenbach, Jozef Skokan and Jan Volec, whom I would particularly like to thank for coming. Indeed, when we moved the conference, we were very happy that most of our invited speakers were still able and willing to come despite the travel difficulties caused by the COVID pandemic. Unfortunately, three originally planned invited talks had to be cancelled, but we will hopefully be able to hear both of them in Bratislava next year.

I would also like to thank the members of the organizing committee, Darina Boukalová, Michał Dębski, Robert Hancock, Petr Hliněný, Adam Kabela and Théo Pierron for their enormous effort they put in organizing this event. My job as the chair of the organizing committee has indeed been much easier than I expected. I am particularly grateful to Darina Boukalová, who was co-chairing the organizing committee; without her, we would not have been able to deal with all of the consequences of the COVID pandemic on organizing the conference, and we would not be able to meet in Brno today.

I believe that all of you will enjoy your time in Brno and I am looking forward to meeting most of you again next year in Bratislava and also at the international symposium in Prague in two years.

Kind regards,

Dan Král'
Chair of the Organizing Committee

Monday 17th, room D2

8:30 **Opening**

9:00-9:50 J. Skokan – Clique factors in randomly perturbed graphs

Coffee Break

10:20-10:40 P. Borg – Isolation of graphs

10:45-11:05 R. Lang – An improved bound for the Linear Arboricity Conjecture

Short Break

11:20-11:40 R. Nedela – The Weisfeiler-Leman dimension of distance-hereditary graphs

11:45-12:05 P. Zeman – Testing isomorphism of bounded leafage chordal graphs

12:10-12:30 D. Ağaoğlu – Isomorphism Problem for S_d-graphs

Lunch Break

14:00-14:20 P. Hliněný – Improved constructions of 13-crossing-critical graphs

14:25-14:45 R. Soták – Structural properties of 1- and 2-planar graphs

14:50-15:10 T. Kaiser – Quadrangulations of manifolds

15:15-15:35 J. Širáň – Regular maps with no non-trivial exponents

Coffee Break

16:05-16:25 M. Skyvová – Edge transitive graphs of prescribed genus

16:30-16:50 K. Pekárková – An FPT algorithm for computing matroid branch-depth

16:55-17:15 F. Pokrývka – Clique-Width of Point Configurations

17:20-17:40 J. Kratochvíl – Computational complexity of covering graphs with semi-edges

Tuesday 18th, room D2

9:00-9:50 I. Penev – Coloring certain even-hole-free graphs

Coffee Break

10:20-10:40 T. Pierron – Hadwiger meets Cayley

10:45-11:05 S. Mohr – Rooted Structures in Graphs

11:10-11:30 C. Feghali – Planar graph recoloring: two proofs

Short Break

11:45-12:05 E. Hurley – An improved procedure for colouring graphs of bounded local density

12:10-12:30 M. Dębski – Conflict-free coloring of graphs

Free afternoon / Trip to Špilberk

Wednesday 19th, room D2

9:00-9:50 J. Volec – On degree thresholds of cycles in oriented graphs

Coffee Break

10:20-10:40 N. Sanhueza-Matamala – Minimum degree conditions for tight Hamilton cycles

10:45-11:05 J. Rajník – Strictly critical snarks with cyclic connectivity 5 and 6

Short Break

11:20-11:40 R. Lukoťka – Determining the circular flow number of a cubic graph

11:45-12:05 E. Máčajová – Cubic graphs with perfect matching index 5 and circular flow number smaller than 5

12:10-12:30 A. Kompišová – Cyclically 7-connected signed cubic graphs with no nowhere-zero 4-flow

Lunch Break

14:00-14:50 J. Ekstein – General structures of graphs with hamiltonian or hamiltonian connected square

15:00-15:20 R. Jajcay – Extremal edge-girth-regular graphs

15:25-15:45 Š. Gyürki – Small directed strongly regular graphs

15:50-16:10 P. Jánoš – On small regular graphs of a given degree and girth 6 and 8 arising from lifts of dipoles

Coffee Break

16:40-17:00 Y. Pehova – Characterising quasirandom permutations by a pattern sum

17:05-17:25 M. Kurečka – Lower bound on the size of a quasirandom forcing set of permutations

17:30-17:50 A. Kabela – Disproving a conjecture on layered permutation density maximisers

Short Break

18:05-18:25 O. Çağırıcı – On some special cases of axes-parallel unit disk graph recognition problem

18:30-18:50 S. Pavlíková – Balanced inverses of graphs

19:30 **Conference dinner**

Thursday 20th, room D2

9:00-9:50 D. Rautenbach – Approximating induced and acyclic matchings

Coffee Break

10:20-10:40 R. Hancock – An asymmetric random Rado theorem for single equations: the 0-statement

10:45-11:05 C. Purcell – Exclusive sum labellings of hypergraphs

Short Break

11:20-11:40 P. Kovář – Vertex in-out-antimagic total labeling of digraphs

11:45-12:05 A. Onderko – On M_f-edge colorings of graphs

Abstracts

Invited talks

General structures of graphs with hamiltonian or hamiltonian connected square

Jan Ekstein, *University of West Bohemia, Pilsen.*
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Joint work with Herbert Fleischner.

The square of a graph G, denoted G^2, is a graph obtained from G joining by an edge any two vertices which have a common neighbour. Famous Fleischner's theorem from 1974 says that G^2 of a 2-connected graph G is hamiltonian. In the same year, it was even shown that this result implied that G^2 is hamiltonian connected for a 2-connected graph G by Chartand, Hobbs, Jung, Kapoor, and Nash-Williams. The aim of this talk is to present the most general block-cutvertex structure of a connected graph such that the square of this graph is hamiltonian or hamiltonian connected. We generalized some results for 2-connected graphs by introducing concepts of the $\mathcal{F}_{\|}$ property for hamiltonian paths and the $\mathcal{H}_k$ property for hamiltonian cycles.

Coloring certain even-hole-free graphs

Irena Penev, *Computer Science Institute, Charles University, Prague.*
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A *ring* is a graph R whose vertex set can be partitioned into $k \geq 4$ nonempty sets $X_1, \dots, X_k$ such that for all $i \in \{1, \dots, k\}$ the set X_i can be ordered as $X_i = \{u_i^1, \dots, u_i^{|X_i|}\}$ so that

$$X_i \subseteq N_R[u_i^{|X_i|}] \subseteq \cdots \subseteq N_R[u_i^1] = X_{i-1} \cup X_i \cup X_{i+1},$$

with subscripts taken modulo k. Under such circumstances, we say that the ring R is of *length* k. A *hole* is an induced cycle of length at least four, and a *hyperhole* is any graph obtained from a hole by blowing up each vertex to a nonempty clique. Clearly, hyperholes are rings. Furthermore, it is easy to see that every (hyper)hole in a ring is of the same length as the ring itself.

Together with Maffray and Vušković, we showed that every ring R satisfies

$$\chi(R) = \max\{\chi(H) \mid H \text{ is a hyperhole in } R\},$$

and we used this to construct a polynomial-time coloring algorithm for rings. The main part of the talk will be devoted to this result, and in the remainder of the talk, we will discuss various applications of this coloring algorithm.

Truemper configurations are prisms, pyramids, thetas, and wheels. In an earlier paper (joint with Boncompagni and Vušković), we obtained decomposition theorems for several classes defined by excluding certain Truemper configurations as induced subgraphs, and rings appeared as a "basic class" in a couple of those theorems. Using the coloring algorithm for rings, one can easily color graphs in one of those classes in polynomial time.

Finally, it is not known whether even-hole-free graphs can be colored in polynomial time, and it is also not known whether this is possible for $(4K_1, C_4)$-free graphs. Foley, Fraser, Hoàng, Holmes, and LaMantia considered the intersection of these two problems, that is, they asked whether Graph Coloring is polynomially solvable for $(4K_1, \text{even hole})$-free graphs, i.e. for $(4K_1, C_4, C_6)$-free graphs. They showed that this is indeed possible for $(4K_1, C_4, C_6)$-free graphs that contain an induced C_7. We recently obtained a decomposition theorem for $(4K_1, C_4, C_6, C_7)$-free graphs, and using our coloring algorithm for rings (among other results), we showed that these graphs can be colored in polynomial time. Together with the result of Foley et al, this implies that Graph Coloring is polynomially solvable for $(4K_1, \text{even hole})$-free graphs.

Approximating induced and acyclic matchings

Dieter Rautenbach, *Ulm University, Germany.*
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Joint work with Julien Baste and Maximilian Fürst.

A matching M in a graph G is *induced* if the subgraph $G(M)$ of G induced by the vertices of G incident to an edge in M is 1-regular. Similarly, the matching M is *acyclic* if $G(M)$ is a forest. The maximum sizes of induced matchings and acyclic matchings in G are the *induced matching number* $\nu_s(G)$ and the *acyclic matching number* $\nu_{ac}(G)$ of G, respectively. If $\nu(G)$ is the ordinary matching number of G, then

$$\nu(G) \geq \nu_{ac}(G) \geq \nu_s(G) \geq \nu_{ac}(G)/2.$$

The induced matching number and the acyclic matching number are hard graph parameters even when restricted to the class $\mathcal{G}_\Delta$ of graphs of maximum degree at most Δ. More precisely, it is unlikely that there are efficient approximation algorithms with an approximation factor that is considerably better than Δ.

We present new efficient approximation algorithms for graphs in $\mathcal{G}_\Delta$. Based on an integer linear programming formulation and a primal-dual scheme, we obtain the approximation factor $0.97995\Delta+0.5$ for the maximum induced matching problem. For the maximum acyclic matching problem our approximation algorithms have the following guarantees:

- Approximation factor Δ (based on a coloring approach)

- Asymptotic approximation factor $\Delta - 1$ (based on a greedy strategy)
- Approximation factor $\frac{2(\Delta+1)}{3}$ (based on local search)

Furthermore, combining greedy and local search strategies, we obtain an efficient algorithm that returns, for a given graph of order n, maximum degree at most Δ, and no isolated vertex, an acyclic matching of size at least $(1 - o(1))\frac{6n}{\Delta^2}$.

Clique factors in randomly perturbed graphs

Jozef Skokan, *London School of Economics, UK.*
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Joint work with Julia Böttcher, Olaf Parczyk and Amedeo Sgueglia.

We study the model of randomly perturbed dense graphs, which is the union of any n-vertex graph G_α with minimum degree αn and the binomial random graph $G(n,p)$. In this talk, we shall examine in detail one of the central questions in this area: to determine when $G_\alpha \cup G(n,p)$ contains clique factors, i.e. spanning subgraphs consisting of vertex disjoint copies of the complete graph K_k. We offer several new sharp and stability results.

On degree thresholds of cycles in oriented graphs

Jan Volec, *Czech Technical University, Prague.*
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Joint work with Roman Glebov and Andrzej Grzesik.

Motivated by Caccetta-Häggkvist and Behzad-Chartrand-Wall conjectures, Kelly, Kühn and Osthus initiated the study of minimum degree conditions which force an oriented graph to contain a cycle of a given length. They proved, for every $l \geqslant 4$, that a sufficiently large n-vertex oriented graph with minimum semi-degree $(n+1)/3$ contains a cycle of length l, which is sharp whenever l is not divisible by 3. However, when $l \geqslant 6$ is a multiple of 3, they conjectured that this bound can be significantly improved. In this talk, we determine the best possible semi-degree condition which forces a large oriented graph to contain a cycle of a fixed length $l \geqslant 6$.

Contributed talks

Isomorphism Problem for S_d-graphs

Deniz Ağaoğlu, *Masaryk University, Brno.*
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Joint work with Petr Hliněný.

An H-graph is the intersection graph of connected subgraphs of a suitable subdivision of a fixed graph H, introduced by Biró, Hujter and Tuza (1992). We focus on S_d-graphs as a special case generalizing interval graphs. A graph G is an S_d-graph iff it is the intersection graph of connected subgraphs of a subdivision of a star S_d with d rays. We give an FPT algorithm to solve the isomorphism problem for S_d-graphs with the parameter d. This solves an open problem of Chaplick, Töpfer, Voborník and Zeman (2016). In the course of our proof, we also show that the isomorphism problem of S_d-graphs is computationally at least as hard as the isomorphism problem of posets of bounded width.

Isolation of graphs

Peter Borg, *Department of Mathematics, Faculty of Science, University of Malta, Malta.*
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Joint work with Kurt Fenech and Pawaton Kaemawichanurat.

In 2017, Caro and Hansberg introduced the isolation problem, which generalizes the domination problem. Given a graph G and a set $\mathcal{F}$ of graphs, the *$\mathcal{F}$-isolation number of G* is the size of a smallest subset D of the vertex set of G such that the graph obtained from G by removing the closed neighbourhood of D does not contain a copy of a graph in $\mathcal{F}$. When $\mathcal{F}$ consists of a 1-clique, the $\mathcal{F}$-isolation number is the domination number. Caro and Hansberg obtained many results on the $\mathcal{F}$-isolation number, and they asked for the best possible upper bound on the $\mathcal{F}$-isolation number for the case where $\mathcal{F}$ consists of a k-clique and for the case where $\mathcal{F}$ is the set of cycles. The solutions to these problems will be presented together with other results, including an extension of Chvátal's Art Gallery Theorem.

On special cases of axes-parallel unit disk graph recognition problem

Onur Çağırıcı, *Masaryk University, Brno.*
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Given a simple graph G, a set $\mathcal{H}$ of k straight lines that are parallel to x-axis, and a set $\mathcal{V}$ of m straight lines that are parallel to y-axis, *axes parallel unit disk recognition* problem (APUD(k, m)) recognition is deciding whether the vertices of G can be realized as unit disks onto $\mathcal{H}$ and $\mathcal{V}$. Last year in CSGT, we showed that APUD recognition is NP-hard. This year, we discuss some special subcases, including the case where all lines are pairwise parallel, and the case where there are only two perpendicular lines. We show that the former is NP-complete, and the latter is a non-trivial case, needs to be investigated.

Conflict-free coloring of graphs

Michał Dębski, *Masaryk University, Brno.*
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We say that a vertex coloring of a graph G is *conflict-free* if for every vertex $v \in V(G)$ there is a color that appears exactly once in the closed neighborhood of v. The minimum number of co lors in such a coloring is called the *conflict-free chromatic number* of G and denoted by $\chi_{CF}(G)$.

In this talk we will focus on the question: what is the maximum possible conflict-free chromatic number of a graph with given maximum degree Δ? We will restrict our attention to regular graphs and line graphs – as it turns out, in those classes the answer is at most logarithmic in Δ.

Planar graph recoloring: two proofs

Carl Feghali, *Computer Science Institute of Charles University, Prague, Czech Republic.*
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Joint work with Zdeněk Dvořák.

The reconfiguration graph $R_k(G)$ for the k-colorings of a graph G has as vertices all possible k-colorings of G and two colorings are adjacent if they differ in the color of exactly one vertex. A result of Bousquet and Perarnau (2016) concerning graphs with bounded degeneracy implies that if G is a planar graph, then $R_{12}(G)$ has diameter $O(|V(G)|)$. We improve on the number of colors, showing, by two different proofs, that $R_{10}(G)$ has diameter at most $8|V(G)|$ for every planar graph G. Our first proof uses the discharging method and reducible configurations and is rather long and involved. Our second proof is shorter and uses a list coloring technique inspired by results of Thomassen.

Small directed strongly regular graphs

Štefan Gyürki , *Slovak University of Technology, Bratislava.*
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A *directed strongly regular graph* (DSRG) with parameters (n, k, t, λ, μ) is a regular directed graph on n vertices with valency k such that every vertex is incident with t undirected edges; the number of directed paths of length 2 directed from a vertex x to another vertex y is λ, if there is an arc from x to y and μ otherwise.

In the talk we will focus on properties of small DSRGs.

This research was supported by the APVV Research Grant 17-0428.

An asymmetric random Rado theorem for single equations: the 0-statement

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Joint work with Andrew Treglown.

A famous result of Rado characterises those integer matrices A which are partition regular, i.e. for which any finite colouring of the positive integers gives rise to a monochromatic solution to the equation $Ax = 0$. Aigner-Horev and Person recently stated a conjecture on the probability threshold for the binomial random set $[n]_p$ having the asymmetric random Rado property: given partition regular matrices $A_1, \ldots, A_r$ (for a fixed $r \geq 2$), however one r-colours $[n]_p$, there is always a colour $i \in [r]$ such that there is an i-coloured solution to $A_i x = 0$. This generalises the symmetric case, which was resolved by Rödl and Ruciński, and Friedgut, Rödl and Schacht. Aigner-Horev and Person proved the 1-statement of their asymmetric conjecture. We resolve the 0-statement in the case where the $A_i x = 0$ correspond to single linear equations.

Improved constructions of 13-crossing-critical graphs

Petr Hliněný , *Masaryk University, Brno.*
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Joint work with D. Bokal, Z. Dvořák, J. Leanos, B. Mohar and T. Wiedera.

We have recently proved that $c = 13$ is the least integer c such that there exists a family of c-crossing-critical graphs with unbounded maximum degree. In the talk we outline this result and present improved constructions of 3-connected 13-crossing-critical graphs with additional nice properties. In particular, our graphs contain arbitrary numbers of vertices of any prescribed even degrees. We conclude with two interesting related open questions; whether an analogous construction is possible achieving any odd degrees, and whether such a construction can produce 3-connected 13-crossing-critical graphs which are simple.

An improved procedure for colouring graphs of bounded local density

Eoin Hurley, *Heidelberg University, Germany.*
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Joint work with Rémi de Joannis de Verclos and Ross Kang.

We develop an improved bound for the chromatic number of graphs of maximum degree Δ under the assumption that the number of edges spanning any neighbourhood is at most $(1-\delta)\Delta^2$ for some fixed $0 < \delta < 1$. As two consequences, we advance the state of the art in two long standing and well-studied graph colouring conjectures, the Erdős–Nešetřil conjecture and Reed's conjecture.

Extremal edge-girth-regular graphs

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Joint work with A. Zavrtanik Drglin, S. Filipovski and T. Raiman.

An *edge-girth-regular* $egr(v,k,g,\lambda)$*-graph* G is a k-regular graph of order v and girth g in which every edge is contained in λ distinct g-cycles. Edge-girth-regularity is shared by several interesting classes of graphs which include edge- and arc-transitive graphs, Moore graphs, as well as many of the extremal k-regular graphs of prescribed girth or diameter. Infinitely many $egr(v,k,g,\lambda)$-graphs are known to exist for sufficiently large parameters (k,g,λ), and in line with the well-known *Cage Problem* we attempt to determine the smallest graphs among all edge-girth-regular graphs for given parameters (k,g,λ).
To facilitate the search for $egr(v,k,g,\lambda)$-graphs of the smallest possible orders, we derive lower bounds in terms of the parameters k, g and λ. We also determine the orders of the smallest $egr(v,k,g,\lambda)$-graphs for some specific parameters (k,g,λ), and address the problem of the smallest possible orders of bipartite edge-girth-regular graphs.

On small regular graphs of a given degree and girth 6 and 8 arising from lifts of dipoles

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The degree-girth problem, introduced by Tutte [Proceeding of the Cambridge Philosophical Society, 1947], is to find the smallest number $n(k, g)$ of vertices in a k-regular graph of girth g. The lower bounds on $n(k, g)$, history of a problem and known results have been surveyed by Exoo and Jajcay [Electronic Journal of Combinatorics, 2008]. One of the approaches of finding small k-regular graphs of given girth are the lifting constructions; prominent example in the case of $g = 6$ are the constructions by Loz et al. [Journal of Graph Theory, 2011] achieving orders of the form $2q^2$, $2(q^2 - 1)$, $2q(q - 1)$, and $2(q - 1)^2$, where q is a prime power, obtained as lifts of Cayley graphs.

The purpose of this paper is to examine possibilities of constructions of small vertex-transitive k-regular graphs of girth 6 and 8, and to show that Cayley constructions by Loz et al. are also obtained as lifts of dipoles with q parallel edges carrying suitable voltage assignments in finite fields.

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Disproving a conjecture on layered permutation density maximisers

Adam Kabela, *Masaryk University, Brno.*
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Joint work with Dan Král, Jon Noel and Théo Pierron.

We recall that a permutation is *layered* if it can be obtained from the identity permutation $(1, 2, \ldots, k)$ by splitting it and reverting the ordering within each layer. For instance, the permutation $(13, 12, \ldots, 1, 14, 16, 15)$ is layered; it has three layers of sizes $13, 1, 2$.

It is known that for every layered permutation π and every positive integer n, the set of all permutations of length n maximising the density of π contains a layered permutation. In addition, consider π such that the first and last layer are of sizes greater than 1 and no two layers of size 1 are consecutive. Albert et al. [The Electronic Journal of Combinatorics 9, 2002] conjectured that for every such π, its layered density maximisers have a bounded number of layers.

We disprove this conjecture by showing that for some choices of π, the number of layers of the layered maximisers goes to infinity as n goes to infinity. For instance, π can be chosen as the permutation with layers of sizes $13, 1, 2$.

Quadrangulations of manifolds

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Joint work with Atsuhiro Nakamoto and Kenta Ozeki.

Following the definition given by M. Stehlík and the speaker in [J. Combin. Theory Ser. B 113 (2015), 1–17], a *quadrangulation* in a simplicial complex K is a subgraph Q of its 1-skeleton such that the induced subgraph of Q on the vertex set of any maximal face of K is a complete bipartite graph with at least one edge. It is easy to see that not every simplicial complex admits a quadrangulation. We investigate the existence of quadrangulations in triangulated manifolds and give some questions and initial results regarding the chromatic number of such quadrangulations in projective spaces and higher-dimensional tori.

Cyclically 7-connected signed cubic graphs with no nowhere-zero 4-flow

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In 1980, Jaeger and Swart conjectured that every cyclically 7-connected cubic graph admits a nowhere-zero 4-flow. Although cyclically 6-edge connected cubic graphs without nowhere-zero 4-flow do exist, all known such graphs are either Isaacs snarks or their superposition. In the talk we treat the similar problem for signed graphs. We develop a new technique for proving that a signed cubic graph does not admit a nowhere-zero 4-flow. Using this tool we show that there exist cyclically 7-connected flow admissible signed cubic graphs with no nowhere-zero 4-flow and construct a new infinite family of such graphs with cyclic connectivity 6. As a result, the conjecture of Jaeger and Swart cannot be extended to the family of signed cubic graphs.

Vertex in-out-antimagic total labeling of digraphs

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Joint work with Martin Bača, Tereza Kovářová and Andrea Semaničová-Feňovčíková.

A vertex in-out-antimagic total labeling of a directed graph (digraph) $D = (V, A)$ with n vertices and m arcs is a bijection from the set of veretices and edges to the set of the first $m+n$ integers such that all n vertex in-weights are pairwise distinct and simultaneously all n vertex out-weights are pairwise distinct, where the vertex in-weight is the sum of the vertex label and the labels of all incoming arcs and the vertex out-weight is the sum of the vertex label and the labels of all outgoing arcs. We conjecture that all digraphs allow such labeling and provide a general way how to label dense digraphs. Labeling sparse digraphs is more chalenging, some partial results are presented as well.

Computational complexity of covering graphs with semi-edges

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Joint work with Jan Bok, Jiri Fiala, Petr Hliněný and Nikola Jedlickova.

The notion of graph covers stems from topology, namely covering spaces, and finds applications in graph theory (for construction of highly synmmetric graphs) and computer science (models of local computation). The question of determining the computational complexity of deciding if an input graph covers a fixed (small) multigraph was raised in 1990's by Abello et al. Despite the connection to CSP, the full catalogue of easy/hard variants is not known, neither P/NP-co dichotomy has been proved. The most general results concern simple regular target graphs, and a full characterization for 2- and 3-vertex target multigraphs. Though it has been widely accepted that multigraphs with semi-edges play an important role in topologicaql graph theory, semi-edges have not been considered in the research of complexity of graph covers so far. We initiate such a study with first complexity results, showing that in several aspects multigraphs with semi-edges behave quite different than without them.

Lower bound on the size of a quasirandom forcing set of permutations

Martin Kurečka, *Masaryk University, Brno.*
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A set S of permutations is forcing if the following holds: a sequence Π_i of permutations is quasirandom if and only if the density $d(\sigma, \Pi_i)$ converges to $\frac{1}{|\sigma|!}$ for every permutation σ from the set S. Graham asked whether there exists an integert k such that the set of all k-point permutations is forcing; this has been shown to be true for any $k \geq 4$. In particular, the set of all twenty-four 4-point permutations is forcing. We provide the first non-trivial lower bound on the size of a forcing set of permutations: there is no set of three permutations (with arbitrary orders) that is forcing. We also present an example of a set of four permutations, which we suspect to be forcing.

An improved bound for the Linear Arboricity Conjecture

Richard Lang, *Heidelberg University, Germany.*
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Joint work with L. Postle.

A forest is linear if all its components are paths. The linear arboricity conjecture states that any graph G of maximum degree Δ can be decomposed into at most $\lceil \Delta/2 \rceil$ linear forests. Here, we show that G admits a decomposition into at most $\Delta/2 + 3\sqrt{\Delta}\log^4 \Delta$ linear forests provided Δ is large enough. This improves a recent result of Ferber, Fox and Jain. Moreover, our result also holds in a more general list setting, where edges have (possibly different) sets of permissible linear forests.

Determining the circular flow number of a cubic graph

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A *circular nowhere-zero r-flow* on a bridgeless graph G is an orientation of the edges and an assignment of real values from $[1, r-1]$ to the edges in such a way that the sum of incoming values equals the sum of outgoing values for every vertex. The *circular flow number*, $\phi_c(G)$, of G is the infimum over all values r such that G admits a nowhere-zero r-flow. A flow has its *underlying orientation*. If we subtract the number of incoming and the number of outgoing edges for each vertex, we get a mapping $V(G) \to \mathbb{Z}$, which is its *underlying balanced valuation*. In this paper we describe efficient and practical polynomial algorithms to turn balanced valuations and orientations into circular nowhere zero r-flows they underlie with minimal r. Using this algorithm one can determine the circular flow number of a graph by enumerating balanced valuations. For cubic graphs we present an algorithm that determines $\phi_c(G)$ in case that $\phi_c(G) \leq 5$ in time $O(2^{0.6 \cdot |V(G)|})$. If $\phi_c(G) > 5$, then the algorithm determines that $\phi_c(G) > 5$

and thus the graph is a counterexample to Tutte's 5-flow conjecture. The key part is a procedure that generates all (not necessarily proper) 2-vertex-colourings without a monochromatic path on three vertices in $O(2^{0.6\cdot|V(G)|})$ time. We also prove that there is at most $2^{0.6\cdot|V(G)|}$ of them.

Cubic graphs with perfect matching index 5 and circular flow number smaller than 5

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The perfect matching index of a bridgeless cubic graph G ($pmi(G)$) is the smallest number of perfect matchings that cover all the edges of G. The Berge-Fulkerson conjecture implies that $pmi(G) \leq 5$ for every bridgeless cubic graph. Cubic graphs having $pmi = 5$ are of particular interest, as many conjectures and open problems can be reduced to them. Such snarks are difficult to find, but several infinite families of such snarks have been constructed. Somewhat surprisingly, all these snarks have circular flow number (cfn) equal to 5. In this talk we present the first family of cubic graphs known to have $pmi = 5$ and $cfn < 5$.

Rooted Structures in Graphs

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A transversal of a partition is a set which contains exactly one element from each member of the partition and nothing else. Given a graph G and a subset T of its vertex set, a rooted minor of G is a minor such that T is a transversal of its branch set. In this talk, we present several concepts of attaching rooted relatedness to ideas in structural graph theory. As an example, we discuss sufficient conditions for a rooted accentuation of Hadwiger's conjecture: Given a transversal of a colouring of a graph G, does G contain a rooted minor traversed by the transversal?

The Weisfeiler-Leman dimension of distance-hereditary graphs

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Joint work with I. Ponomarenko and A. Gavrilyuk.

A graph is said to be distance-hereditary if the distance function in every connected induced subgraph is the same as in the graph itself. We prove that the ordinary Weisfeiler-Leman algorithm correctly tests the isomorphism of any two graphs if one of them is distance-hereditary; more precisely, the Weisfeiler-Leman dimension of the class of finite distance-hereditary graphs is equal to 2. The previously best known upper bound for the dimension was 7. Note that for a class of graphs with a bounded WL-dimesion the Graph Isomophism problem can be solved in a polynomial time.

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On M_f-edge colorings of graphs

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Joint work with Jaroslav Ivančo.

An edge coloring φ of a graph G is called an M_f-edge coloring if $|\varphi(v)| \leq f(v)$ for every vertex v of G, where $\varphi(v)$ is the set of colors used on edges incident with v, and f is a positive integer-valued function on $V(G)$. The problem is to find the maximum number of colors $\mathcal{K}_f(G)$ used in an M_f-edge coloring of G. We establish several bounds of $\mathcal{K}_f(G)$ depending on the number of connected components of the subgraph induced on vertices of a dominating set D, and the number of edges of a subgraph H of $G - D$ with the property $\deg_H(v) < f(v)$ for each $v \in V(H)$. We present sufficient conditions for graphs achieving this bounds. As a corollary we determine exact values of $\mathcal{K}_f(G)$ for forests and certain cacti. We also determine exacts values of $\mathcal{K}_f(G)$ for dense graphs (according to f) with a dominating vertex and a constant function f.

Balanced inverses of graphs

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The inverse of a weighted graph (with weights in some ordered ring) having a non-singular adjacency matrix is another weighted graph with spectrum consisting of reciprocals of the eigenvalues of the original graph. We will present new results on balanced inverses (those with a positive product of labels along every cycle) of weighted trees and constructions of new graphs with balanced inverses from old ones. We will also consider the so-called positively and negatively invertible graphs; the latter ones contain models of important organic molecules and invertibility implies bounds on their binding energy. (Research supported by the APVV Research Grant 17-0428.)

Characterising quasirandom permutations by a pattern sum

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Joint work with Timothy Chan, Daniel Král', Jon Noel, Maryam Sharifzadeh and Jan Volec.

We say that a sequence $\{\pi_i\}$ of permutations is quasirandom if, for each $k > 1$ and each $\sigma \in S_k$, the probability that a uniformly chosen k-set of entries of π_i induces σ tends to $1/k!$ as i tends to infinity. It is known that a much weaker condition already forces π_i to be quasirandom; namely, if the above property holds for all $\sigma \in S_4$. We further weaken this condition by exhibiting sets $S \subseteq S_4$, such that if randomly chosen four entries of π_i induce an element of S with probability tending to $|S|/24$, then $\{\pi_i\}$ is quasirandom. Moreover, we are able to completely characterise the sets S with this property. In particular, there are exactly ten such sets, the smallest of which has cardinality eight.

An FPT algorithm for computing matroid branch-depth

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Joint work with Timothy Chan, Jacob Cooper, Martin Koutecký and Daniel Král'.

Branch-depth is a matroid parameter that may be viewed as the matroid analogue of graph tree-depth. We design an FPT algorithm for computing branch-depth of a matroid representable over a finite field. Our algorithm is explicit, unlike the existing FPT algorithm by Hliněný and Oum for computing branch-width of such matroids. We then use the designed algorithm to construct an FPT algorithm for reducing a constraint matrix from integer programming to a row-equivalent matrix of minimum dual tree-depth.

Hadwiger meets Cayley

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Joint work with Jacob W. Cooper, Adam Kabela and Daniel Král'.

A graph is said to be k-chromatic if it admits a proper vertex coloring with k colors but not with $k-1$ colors. The well-known Hadwiger's conjecture states that every such graph contains K_k as a minor. If true, this would imply that every connected k-chromatic graph contains at least k^{k-2} spanning trees (by Cayley's formula on the number of spanning trees of complete graphs). We give a direct and short proof of this statement, which answers a problem recently posted by Sivaraman in his talk at the "New Perspectives in Colouring and Structure" Workshop in Banff.

Clique-Width of Point Configurations

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Joint work with Onur Çağırıcı, Petr Hliněný and Abhisekh Sankaran.

While structural width parameters (of the input) belong to the standard toolbox of graph algorithms, it is not the usual case in computational geometry. As a case study we propose a natural extension of the structural graph parameter of clique-width to geometric point configurations represented by their order type. We study basic properties of this clique-width notion, and relate it to the monadic second-order logic of point configurations. As an application, we provide several linear FPT time algorithms for geometric point problems which are NP-hard in general, in the special case that the input point set is of bounded clique-width and the clique-width expression is also given.

Exclusive sum labellings of hypergraphs

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An assignment of distinct natural numbers to the vertices of a hypergraph H is called a k-exclusive sum labelling (k-ESL) if there exists a set S of k natural numbers (not appearing as labels) such that a subset of vertices is an edge in H if and only if the sum of their labels appears in S. We study the class of hypergraphs having a k-ESL, which is closed under deleting vertices. Graphs (i.e. 2-graphs) in this class are well understood, but a general characterisation is non-trivial even for $k = 1$. We will discuss several new results on exclusive sum labellings of hypergraphs, including a complete description of 3-graphs with vertex degree at most 2 having a 1-ESL.

Strictly critical snarks with cyclic connectivity 5 and 6

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Joint work with Ján Mazák and Martin Škoviera.

Critical snarks are non-3-edge-colourable cubic graphs such that the removal of any two adjacent vertices leaves a 3-edge-colourable graph. A vast majority of them is also bicritical – i.e. removing any two vertices leaves a colourable graph. Therefore, critical snarks that are not bicritical form a rather interesting class of snarks – they are called strictly critical snarks and were studied by Chladný and Škoviera along with their relation to bicriticality of cyclically 4-connected snarks. Inspired by the analysis of small cases, we construct an infinite family of strictly critical snarks with girth 6. Furthermore, by proving that a certain type of superposition preserves criticality, we construct an infinite class of cyclically 6-connected strictly critical snarks, which solves a problem proposed by Chladný and Škoviera.

Minimum degree conditions for tight Hamilton cycles

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We develop a new framework to study minimum d-degree conditions in k-uniform hypergraphs, which guarantee the existence of a tight Hamilton cycle. Our main theoretical result deals with the typical absorption, path cover and connecting arguments for all k and d at once, and thus sheds light on the underlying structural problems. Once this framework is established, we can easily derive two new bounds. We determine asymptotically best possible degree conditions for $k \geq 3$ and $d = k-2$. This generalizes a classic result of Rödl, Ruciński and Szemerédi for $k \geq 3$ and $d = k-1$. Moreover, we also provide a general upper bound of $1 - 1/(2(k-d))$ for the tight Hamilton cycle threshold, narrowing the gap to the lower bound of $1 - 1/\sqrt{k-d}$ due to Han and Zhao.

Regular maps with no non-trivial exponents

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Informally, a regular map is a graph embedding admitting the largest possible "level of symmetry". On top of this, such a map may be invariant under "external operators" such as

taking the dual, the Petrie dual, or a rotational power. We will briefly survey existing results and present new ones on regular maps (orientable or not) of a given valency and face length that are not invariant under any non-trivial rotational power operator. (Supported by the APVV Research Grant 17-0428.)

Edge transitive maps of prescribed genus

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Joint work with J. Karabáš and R. Nedela.

In this talk we consider exclusively maps on orientable surfaces. A map, in topological sense, is a cellular embeding of a graph into a compact connected surface. A map M is edge-transitive if its automorphism group, $Aut(M)$, acts transitively on the edges of the underlying graph of M. We consider the following problem: given orientable surface S_g of genus $g > 1$ determine all edge-transitive maps on S_g. Since $g > 1$ there are just finitely many edge-transitive maps of genus g. The automorphism group of an edge-transitive map of genus g is a discrete group G of genus g. It is well known that G is a quotient of a Fuchsian group F. There are just few families of admissible Fuchsian groups, namely the triangle groups, the quadrangular groups and groups with signature $\{1; m, k\}$. Solving the Riemann-Hurwitz equation we are able to determine possible orders of G. For small genera $g < 29$ one can determine the structure of G using computer packages MAGMA or GAP. Using the theory of voltage assignments taking values in G, we are able to reconstruct an edge-transitive map M from its quotient M/G. Applying the above algorithm, we produced a list of edge-transitive maps up to genus 28 (except $g = 25$), see https://www.savbb.sk/~karabas/edgetran.html This goes much further than the catalogue published by Orbanic et al. (2011).

Structural properties of 1- and 2-planar graphs

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A k-planar graph is a graph that can be drawn in the plane such that each edge is crossed at most k times. In the talk we consider 1- and 2-planar graphs and we will discuss some structural properties of these graphs compared to planar graphs (mainly the maximal number of edges and hamiltonicity of some subclasses of such graphs).

Testing isomorphism of bounded leafage chordal graphs

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Testing isomorphism of chordal graphs is as hard as the general isomorphism problem (1979, Lueker and Booth). It is well-known that every chordal graph can be represented as an intersection of subtrees of a suitable tree. A natural parameter is the leafage of a chordal graphs, which is the minimum d such that a given chordal graph can be represented on a tree with d leaves. We present an XP-time algorithm for testing isomorphism of chordal graphs of bounded leafage based on group theory.