8th workshop on Graph Classes, Optimization and Width Parameters

GROW

Toronto, October 10-13, 2017

Invited Speakers:

- Bruno Courcelle - University of Bordeaux 1, LaBRI
- Zdenek Dvorak - Charles University
- Anna Lubiw - University of Waterloo

Organizing Committee:

- Derek Corneil - University of Toronto (Chair)
- Jan Kratochvil - Charles University
- Lalla Mouatadid - University of Toronto
- Andrzej Proskurowski - University of Oregon

Tuesday

9:00 – 9:15	Welcome Speech
	Chair: Christophe Paul
9:15 – 10:15	Tree-width, clique-width and fly-automata, **Bruno Courcelle**
10:15 – 10:45	Coffee Break
10:45 – 11:10	Graph Width and Practical Existential Second Order Model Checking, **David Mitchell**
11:10 – 11:35	Efficient FO-Model Checking on Preferential Attachment Graphs, **Peter Rossmanith**
11:35 – 12:00	Combinatorial n-fold Integer Programming and Applications, **Dušan Knop**
12:00 – 1:30	Lunch
	Chair: Irena Penev
1:30 – 1:55	On Structural Parameterizations of the Edge Disjoint Paths Problem, **Robert Ganian**
1:55 – 2:20	Kernelization algorithms for some link stream editing problems, **Pierre Meyer**
2:20 – 2:45	Digraph Classes and Homomorphism Problems, **Arash Rafiey**
2:45 – 3:15	Coffee Break
	Chair: Lalla Mouatadid
3:15 – 3:40	Minimum Connected Transversals in Graphs: New Hardness Results and Tractable Cases Using the Price of Connectivity, **Martin Milanič**
3:40 – 4:05	Graph classes defined via vertex orderings avoiding patterns, **Laurent Feuilloley**
4:05 – 4:30	On H-topological intersection graphs, **Peter Zeman**
4:30 – 6:00	Problem Session, **chaired by Lalla Mouatadid**
7-00	Banquet

Wednesday

9:00 – 9:15	Announcements
	Chair: Chinh Hoang
9:15 – 9:40	A new graph parameter to measure linearity, **Michel Habib**
9:40 - 10:05	AT-free BFS Orders, **Jesse Beisegel**
10:05 - 10:30	Maximum Induced Matching Algorithms via Vertex Ordering Characterizations, **Lalla Mouatadid**
10:30 - 11:00	Coffee Break
	Chair: Lorna Stewart
11:00 - 11:25	Solving Colouring and Max Weight Stable Set on (Cap, Even Hole)-Free Graphs, **Kathie Cameron**
11:25 - 11:50	On Efficient Domination for Some Classes of H-Free Chordal Graphs, **Andreas Brandstaedt**
11:50 - 12:15	Three graph classes: mock threshold, cute, and nice graphs, **Vaidy Sivaraman**
12:15	Lunch Hike (Humber River Valley) or other Toronto attractions

Thursday

9:00 – 9:15	Announcements
	Chair: Jan Kratochvil
9:15 - 10:15	Structure of Critical Graphs and Complexity of Coloring, **Zdenek Dvorak**
10:15 – 10:45	Coffee Break
	Chair: Andreas Brandstaedt
10:45 – 11:10	On the structure of graphs without odd or even holes, **Chinh Hoang**
11:10 – 11:35	Unit Interval Vertex Deletion: Fewer Vertices are Relevant, **Yixin Cao**
11:35 – 12:00	Parameterized complexity of meta theorems of fair deletion problems, **Tomáš Masařík**
12:00 – 1:30	Lunch
	Chair: Andrzej Proskurowski
1:30 – 1:55	Chi-boundedness of graph classes excluding wheel vertex-minors, **Sang-il Oum**
1:55 – 2:20	Half-integral Erdos-Posa property for topological minors, **Chun-Hung Liu**
2:20 – 2:45	Clique-cutsets beyond chordal graphs, **Irena Penev**
2:45 – 3:15	Coffee break.
	Chair: Jan Kratochvil
3:15 – 3:40	Bids for GROW2019
3:40 – 4:05	Connected search against a lazy robber and connected treewidth, **Christophe Paul**
4:05 – 4:30	Algorithms and Complexity on Temporal Graphs, **George Mertzios**
4:30 – 6:00	Problem Session, **chaired by Kathie Cameron**

Friday

9:00 – 9:15	Announcements
	Chair: Derek Corneil
9:15 - 10:15	Morphing and Compatible Triangulations of Planar Graph Drawings, **Anna Lubiw**
10:15 – 10:45	Coffee Break
	Chair: Ekkehard Köhler
10:45 – 11:10	How to navigate a robot through obstacles? **Iyad Kanj**
11:10 – 11:35	Beyond Outer Planarity, **Steven Chaplick**
11:35 – 12:00	Fine-grained complexity of coloring unit disks, **Till Miltzow**
12:00 – 1:30	Lunch and end of workshop

Abstracts

Tuesday

Bruno Courcelle
Bordeaux University
Title: **Tree-width, clique-width and fly-automata**
Abstract:
Tree-width and clique-width are two important graph parameters for obtaining Fixed-parameter tractable (FPT) graph algorithms. In particular for problems expressible in monadic second-order (MSO) logic. FPT algorithms can be based on finite automata.
The huge size problem is solved by means of fly-automata (FA) that compute their transitions (they cannot be tabulated). FA have been implemented and tested. Fly-Automata run on algebraic terms denoting the input graphs, and reflecting appropriate decompositions (in particular, tree-decompositions).
The algebraic operations upon which clique-width is based make easy the construction of FA from logical formulas and can also represent tree-decompositions, but there is in bad cases an exponential jump in widths. However, we have linear bounds on clique-width in terms of tree-width for sparse graphs: planar graphs, graph of bounded degree, incidence graphs and 1-planar graphs. These results hold for directed graphs. Incidence graphs allow to check MSO formulas with edge set quantifications for graphs of bounded tree-width.

David Mitchell
Simon Fraser University
Title: **Graph Width and Practical Existential Second Order Model Checking.**
Abstract:
For two decades we have known how to automatically generate linear-time algorithms for MSO model checking on any bounded-tree-width class of structures. However, obtaining practical algorithms remains a major challenge. Over the same time period, software systems for ∃SO model checking have become very effective in practical applications. However, they do not generally provide FPT performance even for ∃MSO formulas, leading to the question of when they can (or could be adapted to) do so. I will survey properties relevant to this question, in part by viewing the systems as implementing MSO transformations.

Peter Rossmanith
RWTH Aachen University
Title: **Efficient FO-Model Checking on Preferential Attachment Graphs**
Abstract:
There exist several random graph models that are used to model real life network because they tend to look very similar to graphs you can find in many areas. On example are preferential attachment graphs, in particular the Barabasi-Albert model. It turns out that, with high probability, such graphs do not belong to any graph class for which nice meta-theorems are known that guarantee efficient algorithms for a wide variety of problems. Such problems are for example all problems expressible in first-order logic and such

graph classes are for example classes with locally bounded treewidth or nowhere-dense graphs. We nevertheless can show that FO-model checking is in FPT for Barabasi-Albert graphs.

Dušan Knop
Charles University
Title: **Combinatorial n-fold Integer Programming and Applications**
Abstract:
Integer Linear Programming is a famous NP-complete problem. Lenstra showed that in the case of small dimension, it can be solved in polynomial time. This algorithm became a ubiquitous tool, especially in the design of parameterized algorithms for NP-complete problems, where we wish to isolate the hardness of an instance to some parameter. However, it was discovered that in many cases using Lenstra's algorithm has two drawbacks. First, the dependence of the resulting algorithms is often doubly-exponential in the parameter, and second, an ILP formulation in small dimension can not easily express problems which involve many different costs.
Inspired by the work of Hemmecke, Onn and Romanchuk~[Math. Prog. 2013], we develop a single-exponential algorithm for so called combinatorial n-fold integer programs, which are remarkably similar to prior ILP formulations for various problems, but unlike them, also allow variable dimension. We then apply our algorithm to a few representative problems like Closest String, Swap Bribery, Weighted Set Multicover etc., and obtain exponential speedups in the dependence on the respective parameters, the input size, or both.
Unlike Lenstra's algorithm, which is essentially a bounded search tree algorithm, our result uses the technique of augmenting steps. At its heart is a deep result stating that in combinatorial n-fold IPs an existence of an augmenting step implies an existence of a "local" augmenting step, which can be found using dynamic programming. Our results provide an important insight into many problems by showing that they exhibit this phenomenon, and highlights the importance of augmentation techniques.
This is joint work with Martin Koutecký and Matthias Mnich. This work was supported by NSERC grant 12345. This research was supported by the CE-ITI grant project P202/12/G061 of GA ČR, the GA UK grant project 1784214, and ERC Starting Grant 306465 (BeyondWorstCase). An extended abstract of these results appeared in the Proceedings of the 25th European Symposium of Algorithms. Available at https://arxiv.org/abs/1705.08657.

Robert Ganian
Faculty of Informatics, TU Wien
Title: **On Structural Parameterizations of the Edge Disjoint Paths Problem**
Abstract:
We revisit the classical Edge Disjoint Paths (EDP) problem, where one is given an undirected graph G and a set of terminal pairs P and asks whether G contains a set of pairwise edge-disjoint paths connecting every terminal pair in P. Our focus lies on structural parameterizations for the problem that allow for efficient (polynomial-time or fpt) algorithms. As our first result, we answer an open question stated in Fleszar, Mnich, and Spoerhase (2016), by showing that the problem can be solved in polynomial time if the input graph has a feedback vertex set of size one. We also show that EDP parameterized by the treewidth and the maximum degree of the input graph is fixed-parameter tractable.

Having developed two novel algorithms for EDP using structural restrictions on the input graph, we then turn our attention towards the augmented graph, i.e., the graph obtained from the input graph after adding one edge between every terminal pair. In constrast to the input graph, where EDP is known to remain NP-hard even for treewidth two, a result by Zhou et al. (2000) shows that EDP can be solved in non-uniform polynomial time if the augmented graph has constant treewidth; we note that the possible improvement of this result to an fpt-algorithm has remained open since then. We show that this is highly unlikely by establishing the W[1]-hardness of the problem parameterized by the treewidth (and even feedback vertex set) of the augmented graph. Finally, we develop an fpt-algorithm for EDP by exploiting a novel structural parameter of the augmented graph.
This is joint work with S. Ordyniak and M. S. Ramanujan.

Pierre Meyer
Ecole Normale Supérieure de Lyon
Title: **Kernelization algorithms for some link stream editing problems**
Abstract:
Given a link stream L and a positive integer k, the Sparse Split Link Stream Editing problem asks to transform L into a link stream which consists of a clique plus isolated vertices during an interval and is linkless outside that interval, by performing at most k edge insertions and deletions.
We present a kernelization algorithm for the sparse split link stream editing problem by adapting an algorithm for graphs (by Falk Hüffner, Christian Komusiewicz, and André Nichterlein). Further, we give ideas on how to similary adapt kernelization algorithms from graph problems to their link stream counterparts.
This is a joint work with Binh-Minh Bui-Xuan and Clémence Magnien.

Arash Rafiey
Indiana State University
Title: **Digraph Classes and Homomorphism Problems**
Abstract:
We discuss several of digraph classes and their forbidden obstruction characterizations. Each of theses digraph classes plays an important role in a special type of digraph homomorphism problem. In the digraph homomorphism problem, we are given an input digraph G and a fixed target digraph H and the goal is to find a homomorphism from G to H with certain conditions. List homomorphism problem, minimum cost homomorphism problem, and approximation of minimum cost homomorphism problem are the typical types of the digraph homomorphism problem.

Martin Milanič
University of Primorska
Title: **Minimum Connected Transversals in Graphs: New Hardness Results and Tractable Cases Using the Price of Connectivity**
Abstract:
We perform a systematic study in the computational complexity of the connected variant of three related transversal problems: Vertex Cover, Feedback Vertex Set, and Odd Cycle

Transversal. Just like their original counterparts, these variants are NP-complete for general graphs. It is known that Connected Vertex Cover is NP-complete even for H-free graphs whenever H contains a claw or a cycle. We show that the two other connected variants also remain NP-complete in such cases. In the remaining case H is a disjoint union of paths. We show that Connected Vertex Cover, Connected Feedback Vertex Set, and Connected Odd Cycle Transversal are polynomial-time solvable for sP2-free graphs for every constant s≥1. For proving these results we use polynomial-time algorithms for enumerating all minimal vertex covers, minimal feedback vertex sets, and minimal odd cycle transversals of a given sP2-free graph. We also use known results on the price of connectivity for vertex covers, feedback vertex sets, and odd cycle transversals. These are the first applications of the price of connectivity that result in polynomial-time algorithms.
This is joint work with N. Chiarelli, T. R. Hartinger, M. Johnson, and D. Paulusma. This work was supported by a London Mathematical Society Scheme 4 Grant, Leverhulme Trust Grant RPG-2016-258 and by the Slovenian Research Agency (I0-0035, research programs P1-0285, research projects N1-0032, J1-5433, J1-6720, J1-6743, J1-7051, and a Young Researchers Grant).

Laurent Feuilloley
Université Paris Diderot
Title: **Graph classes defined via vertex orderings avoiding patterns**
Abstract:
Using the seminal work of Damaschke (1990) we propose a systematic study of structured graph classes that can be defined by the existence of an ordering of the vertices avoiding some forbidden patterns. Among these classes we have : bipartite, trees, split, chordal, interval, comparability, outerplanar...
Hell, Mohar and Rafiey (2014) proved that for patterns on 3 vertices, the given class is always polynomially recognizable. We propose a simpler proof of this fact and give the complete list of graph classes defined with 2 patterns on 3 vertices. There exists classes defined by a 4 vertices pattern which are NP-complete to recognize.
Furthermore Duffus, Ginn and Rödl (1995) showed that for almost all 2-connected patterns the associated class is NP-Complete to recognize. But following Nesestril (2017), it seems that on this problem there is no dichotomy.
Furthermore we show that most of the good recognition algorithms use this notion of patterns.
We end with an application of this framework to distributed local recognition and some open problems.
Joint work with Y. BoufKad, P. Charbit and M. Habib.

Peter Zeman
Charles University
Title: **On H-topological intersection graphs**
Abstract:
Biró, Hujter, and Tuza (1992) introduced the concept of H-graphs, intersection graphs of connected subregions of a graph H thought of as a one-dimensional simplicial complex. They relate to and generalize many important classes of geometric intersection graphs, e.g., interval graphs, circular-arc graphs, split graphs, and chordal graphs.

Surprisingly, we negatively answer the 25-year-old question of Biró, Hujter, and Tuza which asks whether H-graphs can be recognized in polynomial time, for a fixed graph H. Moreover, our paper opens a new research area in the field of geometric intersection graphs by studying H-graphs from the point of view of fundamental computational problems of theoretical computer science: recognition, graph isomorphism, dominating set, clique, and colourability.
For the recognition problem, we prove that it is NP-complete if H contains the *diamond* as a minor. For each fixed tree T, we provide a polynomial-time algorithm recognizing T-graphs. When T is a star S_d of degree d, the running time improves to O(n^4).
For the minimum dominating set problem, we give FPT- and XP-time algorithms solving the problem on S_d-graphs (parameterized by d) and H-graphs (parameterized by the size of H), respectively. As a byproduct, the dominating set algorithm for H-graphs also provides XP-time algorithm for the independent set and the independent dominating set problems on H-graphs.
If H contains the *double triangle* as a minor, we prove that the graph isomorphism problem is GI-complete and that the clique problem is APX-hard. On the positive side, we show that the clique problem can be solved in polynomial time if H is a cactus. Also, when a graph G has a Helly H-representation, the clique problem can be solved in polynomial time.
Finally, we use treewidth techniques to show that both the k-clique and the list k-coloring problems are solvable in FPT-time (parameterized by k and the treewidth of H) on H-graphs.

Wednesday

Michel Habib
University Paris Diderot
Title: **A new graph parameter to measure linearity**
Abstract:
Joint work with P. Charbit (IRIF, Paris Diderot), L. Mouatadid (Dept. Computer Science, Univ. Toronto) and R. Naserasr (IRIF, Paris Diderot)
Since its introduction to recognize chordal graphs by Rose, Tarjan, and Lueker, Lexicographic Breadth First Search (LexBFS) has been used to come up with simple, often linear time, algorithms on various classes of graphs. These algorithms, called multi-sweep algorithms, compute a number of LexBFS orderings σ1,…,σk, where σi is used to break ties for σi+1, we write LexBFS+(σi) = σi+1. For instance, Corneil et al. gave a linear time multi-sweep algorithm to recognize interval graphs [SODA'98], Kratsch et al. gave a certifying recognition algorithm for interval and permutation graphs [SODA'03]. Since the number of LexBFS orderings for a graph is finite, after some fixed number of + sweeps, we will eventually loop in a sequence of σ1,…,σk vertex orderings such that σi+1=LexBFS+(σi) mod k.
We study this new graph invariant that we name *LexCycle*(G), and define as the maximum length of a cycle of vertex orderings obtained via a sequence of LexBFS+. In this work, we focus on graph classes with small LexCycle. We give evidence that a small LexCycle often leads to linear structure that has been exploited algorithmically on a number of graph classes. In particular, we show that for proper interval, interval, co-bipartite, domino-free cocomparability graphs, as well as trees, there exists two orderings σ and τ such that σ=LexBFS+(τ) and τ=LexBFS+(σ). One of the consequences of these results is the simplest algorithm to compute a transitive orientation for these graph classes.
It was conjectured by Stacho [2015] that LexCycle is at most the asteroidal number of the graph class, we disprove this conjecture by giving a construction for which LexCycle(G)>an(G), the asteroidal number of G.

Jesse Beisegel
BTU Cottbus - Senftenberg
Title: **AT-free BFS Orders**
Abstract:
An asteroidal triple free graph is a graph such that for every independent triple of vertices no path between any two avoids the third. In a recent result by Corneil and Stacho, these graphs were characterised through a linear vertex ordering called an AT-free order.
Here, we use techniques from abstract convex geometry to improve on this result by giving a vertex order characterisation with stronger structural properties and thus resolve an open question by Corneil and Stacho.
These orderings are generated by a modification of BFS which runs in polynomial time. Furthermore, we give a linear time algorithm which employs multiple applications of (L)BFS to compute AT-free orders in claw-free AT-free graphs and a generalisation of these.

Lalla Mouatadid
University of Toronto
Title: **Maximum Induced Matching Algorithms via Vertex Ordering Characterizations**
Abstract:
We study the maximum induced matching problem on a graph G. Induced matchings correspond to independent sets in L2(G), the square of the line graph of G. The problem is NP-complete on bipartite graphs. In this work, we show that for a number of graph families with forbidden vertex orderings, almost all forbidden patterns on three vertices are preserved when taking the square of the line graph. These orderings can be computed in linear time in the size of the input graph. In particular, given a graph class G characterized by a vertex ordering, and a graph G=(V,E)∈G with a corresponding vertex ordering σ of V, one can produce (in linear time in the size of G) an ordering on the vertices of L2(G), that shows that L2(G)∈G - for a number of graph classes G - without computing the line graph or the square of the line graph of G. These results generalize and unify previous ones on showing closure under L2(·) for various graph families. Furthermore, these orderings on L2(G) can be exploited algorithmically to compute a maximum induced matching on G faster. We illustrate this latter fact in the second half of the talk where we focus on cocomparability graphs, a large graph class that includes interval, permutation, trapezoid graphs, and co-graphs, and we present the first O(mn) time algorithm to compute a maximum *weighted* induced matching on cocomparability graphs; an improvement from the best known O(n4) time algorithm for the *unweighted* case.
Joint work with Michel Habib. This work was supported by NSERC.

Kathie Cameron
Wilfrid Laurier University
Title: **Solving Colouring and Max Weight Stable Set on (Cap, Even Hole)-Free Graphs**
Abstract:
A hole is a chordless cycle with at least 4 vertices, and is even if it has an even number of vertices. A cap consists of a cycle with at least 5 vertices with exactly one chord and that chord creates a triangle with the cycle. A graph is (cap, even hole)-free if it has no induced cap or even hole.
We give an explicit construction of (cap, even-hole)-free graphs. We prove that (triangle, even hole)-free graphs have treewidth at most 5 and that (cap, even hole)-free graphs without clique cutsets have treewidth at most 6ω(G)−1, and that both of these classes have clique-width at most 48. We use these results to give an O(nm) algorithm for q-colouring (cap, even-hole)-free graphs for fixed q and an O(nm) algorithm for maximum weight stable set, where, as usual, n is the number of vertices and m the number of edges of the input graph. We also give a polynomial-time algorithm for minimum colouring.
This is joint work with Murilo V. G. da Silva, Shenwei Huang and Kristina Vušković.

Andreas Brandstaedt
University of Rostock
Title: **On Efficient Domination for Some Classes of H-Free Chordal Graphs**
Abstract:
A vertex set D in a finite undirected graph G is an *efficient dominating set* (*e.d.s.*\ for short) of G if every vertex of G is dominated by exactly one vertex of D. The *Efficient Domination* (ED) problem, which asks for the existence of an e.d.s. in G, is known to be NP-complete even for very restricted graph classes such as for 2P3-free chordal graphs while it is solvable in polynomial time for P6-free chordal graphs (and even for P6-free graphs). A standard reduction from the NP-complete Exact Cover problem shows that ED is NP-complete for a very special subclass of chordal graphs generalizing split graphs.
The reduction implies that ED is NP-complete e.g. for double-gem-free chordal graphs while it is solvable in linear time for gem-free chordal graphs (by various reasons such as bounded clique-width, distance-hereditary graphs, chordal square etc.), and ED is NP-complete for butterfly-free chordal graphs while it is solvable in linear time for 2P2-free graphs.
We show that (weighted) ED can be solved in polynomial time for H-free chordal graphs when H is net, extended gem, or S1,2,3.
This is joint work with Raffaele Mosca.

Vaidy Sivaraman
University of Amsterdam
Title: **Three graph classes: mock threshold, cute, and nice graphs**
Abstract:
A graph class, defined in one way, can be characterized in several other ways. Forbidden induced subgraphs, intersection of subobjects, relationship among invariants, and vertex ordering are some of the most common ways. A graph is mock threshold if every induced subgraph of it has a vertex with degree or codegree at most 1. I will present the forbidden induced subgraph characterization for this class due to Richard Behr, Thomas Zaslavsky, and myself. A graph is cute if every induced cycle in it is a triangle or a quadrilateral. We discuss chi-boundedness, recognition and optimization for this class. A graph is nice if the difference between the chromatic number and clique number is either 0 or 1 for every induced subgraph of it. Perfect graphs, planar graphs, tripartite graphs, and line graphs are nice. We will address the following question: Is there anything nice about nice graphs?

Thursday

Zdenek Dvorak
Charles University in Prague
Title: **Structure of critical graphs and complexity of coloring**
Abstract:
One of the most successful approaches towards design of efficient algorithms for graph coloring (in restricted graph classes) is through study of structural properties of critical graphs, i.e., minimal obstructions for given chromatic number. The talk will give overview of known structural properties and corresponding algorithms, focusing especially on recent results following from the hyperbolicity theory, applications of the potential method, and computer-assisted enumeration.

Chinh Hoang
Wilfrid Laurier University
Title: **On the structure of graphs without odd or even holes**
Abstract:
A hole is an induced cycle with at least four vertices. A hole is odd (even) if its length is odd (even). Holes play a central role in the structure of graphs. For example, hole-free graphs (i.e. chordal graphs) can be decomposed by clique cutsets into cliques. Two natural generalizations of chordal graphs are odd-hole-free and even-hole-free graphs. It is known that graphs in these two classes have their chromatic numbers bounded by a function of their clique numbers. We will discuss a number of open problems on the structure of odd-hole-free and even-hole-free graphs. In particular, we will discuss a conjecture by Cameron, Chaplick and the author that the tree width of an even-hole-free graph is bounded by a function of its clique number.

Yixin Cao
The Hong Kong Polytechnic University
Title: **Unit Interval Vertex Deletion: Fewer Vertices are Relevant**
Abstract:
The unit interval vertex deletion problem asks for a set of at most k vertices whose deletion from a graph makes it a unit interval graph. We develop an O(k4)-vertex kernel for the problem, significantly improving the O(k53)-vertex kernel of Fomin, Saurabh, and Villanger [ESA'12; SIAM J.\ Discrete Math 27(2013)]. We start from a constant-approximation solution and study its interaction with other vertices, which induce a unit interval graph. We partition vertices of this unit interval graph into cliques in a naive way, and pick a small number of representatives from each of them. Our constructive proof for the correctness of our algorithm, using interval models, greatly simplifies the ``destructive'' proofs, based on destroying forbidden structures, for similar problems in literature. Our algorithm can be implemented in O(mn+n2) time, where n and m denote respectively the numbers of vertices and edges of the input graph.

Tomáš Masařík
Charles University
Title: **Parameterized complexity of meta theorems of fair deletion problems**
Abstract:
Deletion problems are those where given a graph G and a graph property π, the goal is to find a subset of vertices (or edges) such that after its removal the graph G will satisfy the property π. Typically, we want to minimize the number of elements removed. In fair deletion problems we change the objective: we minimize the maximum number of deletions in a neighborhood of a single vertex.
We study the parameterized complexity of fair deletion meta theorems, where a graph property is expressed in a certain graph logic, with respect to several structural parameters of the graph.
The list of our results for the Vertex Deletion problem: The problem is W[1]-hard on tree-depth for any logic that can express the edgeless graph. The problem has an FPT algorithm for MSO1 logic on graphs with bounded neighborhood diversity, or bounded twin cover.
The list of our results for the Edge Deletion problem: The problem is W[1]-hard on tree-depth for First order logic. The problem has an FPT algorithm for MSO2 logic on graphs with bounded vertex cover.
This is joint work with Dušan Knop and Tomáš Toufar. Research partly supported by the CE-ITI grant project P202/12/G061 of GA ČR and by GAUK project 1784214.

Sang-il Oum
KAIST
Title: **Chi-boundedness of graph classes excluding wheel vertex-minors**
Abstract:
A class of graphs is *χ-bounded* if there exists a function f:N→N such that for every graph G in the class and an induced subgraph H of G, if H has no clique of size q+1, then the chromatic number of H is less than or equal to f(q). We denote by Wn the wheel graph on n+1 vertices. We show that the class of graphs having no vertex-minor isomorphic to Wn is χ-bounded. This generalizes several previous results; χ-boundedness for circle graphs, for graphs having no W5 vertex-minors, and for graphs having no fan vertex-minors. This is a joint work with Hoijn Choi, O-joung Kwon, and Paul Wollan.

Chun-Hung Liu
Princeton University
Title: **Half-integral Erdos-Posa property for topological minors**
Abstract:
Fix a family F of graphs, what is the maximum number of disjoint subgraphs of the input graph G where each of them is isomorphic to a member of F? And what is the minimum number of vertices of G required to intersect all such subgraphs? The former is called a packing problem and the latter is called a covering problem. These two optimization problems form a pair of dual integer programming problems. We say F has the Erdos-Posa property if the solutions of these two problems with respect to F can be bounded by functions of each other. It is well-known that if H is a graph such that the set of H minors has the Erdos-Posa property, then H must be planar. Thomas conjectured that the planarity is not

required if half-integral solutions of the packing problem are allowed. The main theorem of this talk is a stronger statement that easily implies Thomas' conjecture. Namely, we prove that for every graph H, there exists a function f such that for every graph G, either G contains k subdivisions of H such that every vertex of G is contained in at most two of them, or there exists a set of at most f(k) vertices intersecting all subdivisions of H in G.

Irena Penev
University of Leeds
Title: **Clique-cutsets beyond chordal graphs**
Abstract:
Truemper configurations (thetas, pyramids, prisms, and wheels) have played an important role in the study of complex hereditary graph classes (e.g. the class of perfect graphs and the class of even-hole-free graphs), appearing both as excluded configurations, and as configurations around which graphs can be decomposed. We study the structure of graphs that contain (as induced subgraphs) no Truemper configurations other than (possibly) universal wheels and twin wheels. We also study several subclasses of this class. We use our structural results to analyze the complexity of the recognition, maximum weight clique, maximum weight stable set, and optimal vertex coloring problems for these classes. Furthermore, we obtain polynomial χ-bounding functions for these classes.
This is joint work with Valerio Boncompagni and Kristina Vušković.

Christophe Paul
CNRS
Title: **Connected search against a lazy robber and connected treewidth**
Abstract:
The node search game against a lazy/agile (invisible) robber has been introduced as a search-game analogue of the graph parameters of treewidth/pathwidth. In the “connected” variants of the above two games, we additionally demand that, at each moment of the search, the “clean” territories are connected. The connected search game against an agile and invisible robber has been extensively examined. The monotone variant (where we also demand that the clean territories are progressively increasing) of this game, corresponds to the graph parameter of connected pathwidth. It has been shown that the value of the connected pathwidth cannot be more than the double (asymptotically) of its non-connected counterpart. This implied that the “price of connectivity” is bounded by 2 for the case of an agile robber.
In this talk, we consider the connected variant of the node search game where the robber is lazy: he/she moves only when the searchers strategy threatens the location that he/she currently occupies. We introduce two alternative graph-theoretical formulations of its monotone variant, one in terms of (connected) layouts and one on terms of (connected) tree decompositions, leading to the graph parameter of connected treewidth. For this “lazy-robber” variant we prove that there is no bound in the price of connectivity, which comes in contrast to the case of an agile robber. We also observe that the corresponding parameter, i.e. connected treewidth, is closed under contractions and we study the contraction-obstruction set class of the class of graphs with connected treewidth at most k. It follows that this set is infinite for every $k \geq 2$. We also provide a complete characterisation for the case where $k=2$.

This is joint work with Isolde Adler (University of Leeds) and Dimitrios M. Thilikos (CNRS, LIRMM).

George Mertzios
Durham University
Title: **Algorithms and Complexity on Temporal Graphs**
Abstract:
A temporal graph is a graph that changes over time. Assuming discrete time and a fixed set V of vertices, a temporal graph can be viewed as a discrete sequence G1,G2,… of static graphs, each with vertex set V. Research in this area is motivated by the fact that many modern systems are highly dynamic and relations (edges) between objects (vertices) vary with time. Although static graphs have been extensively studied for decades from an algorithmic point of view, we are still far from having a concrete set of structural and algorithmic principles for temporal graphs. Many notions and algorithms from the static case can be naturally transferred in a meaningful way to their temporal counterpart, while in other cases new approaches are needed to define the appropriate temporal notions. In particular, some problems become radically different and substantially more difficult when the time dimension is additionally taken into account. In this talk we will introduce temporal graphs and we will survey recent algorithmic results.

Friday

Anna Lubiw
University of Waterloo
Title: **Morphing and Compatible Triangulations of Planar Graph Drawings**
Abstract:
To morph a planar graph drawing is to move it continuously, preserving planarity. This is useful for animations and also for constructing 3-dimensional objects from 2-dimensional slices, where time becomes the third dimension.
I will survey results on planar graph morphing when the initial and final graph drawings are given.
I will also discuss some new work on morphing an initial planar graph drawing to become convex, which involves a new application of Tutte's graph drawing algorithm.
For many algorithms on planar graphs, a first step is to triangulate the graph. For morphing between two given planar graph drawings, a first step is to find "compatible triangulations" of the two drawings, which necessitates adding new Steiner points, possibly a quadratic number. I will survey work on compatible triangulations, including a new result about hardness of minimizing the number of Steiner points. For the case of morphing, I will describe a way to avoid the quadratic blow-up.

Iyad Kanj
DePaul University
Title: **How to navigate a robot through obstacles?**
Abstract:
We consider the following motion-planning problem: Given a set of obstacles in the plane, can we navigate a robot between two designated points without crossing more than k different obstacles? Equivalently, can we remove k obstacles so that there is an obstacle-free path between the two designated points?
This problem is known to be NP-hard, even when each obstacle is either a square or a straight-line segment. It can be formulated and generalized into the following graph problem: Given a planar graph G whose vertices are colored by color sets, two designated vertices s,t∈V(G), and k∈N, is there an s-t path in G that uses at most k colors? If each obstacle is connected, the resulting graph from this formulation satisfies the property that each color induces a connected subgraph.
In this work, we study the complexity and design algorithms for this motion-planning problem. We first show that the problem is W[SAT]-hard parameterized by k, and is W[1]-complete on graphs of pathwidth 4 parameterized by both k and the length of the path. We then focus on the case where each color is connected. We first show that this problem is \NP-hard, even when restricted to 2-outerplanar graphs of pathwidth 3. We then exploit the planarity of the graph and the connectivity of the colors to prove the following graph-theoretic structural result. For any vertex v in the graph, there exists a set of paths whose cardinality is upper bounded by some function of k, that ``represents'' the valid s-t paths containing subsets of colors from v. We then employ this structural result to design an FPT algorithm for the problem parameterized by both k and the treewidth of the graph.

Steven Chaplick
Universität Würzburg
Title: **Beyond Outerplanarity**
Abstract:
We study straight-line drawings of graphs where the vertices are placed in convex position in the plane, i.e., *convex drawings*. We consider two families of graph classes with nice convex drawings: *outer k-planar* graphs, where each edge is crossed by at most k other edges; and, *outer k-quasi-planar* graphs where no k edges can mutually cross.
We show that the outer k-planar graphs are $(\lfloor \sqrt{4k+1} \rfloor+1)$-degenerate, and consequently that every outer k-planar graph can be $(\lfloor \sqrt{4k+1} \rfloor+2)$-colored, and this bound is tight. We further show that every outer k-planar graph has a balanced separator of size at most 2k+3. For each fixed k, these small balanced separators allow us to test outer k-planarity in quasi-polynomial time, i.e., none of these recognition problems are NP-complete unless ETH fails.
For the outer k-quasi-planar graphs we discuss the edge-maximal graphs which have been considered previously under different names. We also construct planar 3-trees that are not outer 3-quasi-planar.
Finally, we restrict outer k-planar and outer k-quasi-planar drawings to *closed* drawings, where the vertex sequence on the boundary is a cycle in the graph. For each k, we express *closed outer k-planarity* and *closed outer k-quasi-planarity* in *extended monadic second-order logic*. Thus, since outer k-planar graphs have bounded treewidth, closed outer k-planarity is linear-time testable by Courcelle's Theorem.
This is joint work with M. Kryven, G. Liotta, A. Löffler, and A. Wolff.

Till Miltzow
Université Libre de Bruxelles
Title: **Fine-grained complexity of coloring unit disks**
Abstract:
On planar graphs, many classic algorithmic problems enjoy a certain square root phenomenon and can be solved significantly faster than what is known to be possible on general graphs: for example, Independent Set, 3-Coloring, Hamiltonian Cycle, Dominating Set can be solved in time $2^{O(\sqrt{n})}$ on an n-vertex planar graph, while no $2^{o(n)}$ algorithms exist for general graphs, assuming the Exponential Time Hypothesis (ETH). The square root in the exponent seems to be best possible for planar graphs: assuming the ETH, the running time for these problems cannot be improved to $2^{o(\sqrt{n})}$. In some cases, a similar speedup can be obtained for 2-dimensional geometric problems, for example, there are $2O(\sqrt{n}\log n)$ time algorithms for Independent Set on unit disk graphs or for TSP on 2-dimensional point sets.
In this paper, we explore whether such a speedup is possible for geometric coloring problems. On the one hand, geometric objects can behave similarly to planar graphs: 3COLORING can be solved in time $2^{O(\sqrt{n})}$ on the intersection graph of n unit disks in the plane and, assuming the ETH, there is no such algorithm with running time $2^{o(\sqrt{n})}$. On the other hand, if the number ℓ of colors is part of the input, then no such speedup is possible: Coloring the intersection graph of n unit disks with ℓ colors cannot be solved in time $2^{o(n)}$, assuming the ETH. More precisely, we exhibit a smooth increase of complexity as the number ℓ of colors increases: If we restrict the number of colors to $\ell=\Theta(n^\alpha)$ for some $0\leq\alpha\leq1$, then the problem of coloring the intersection graph of n unit disks with ℓ colors
- can be solved in time $\exp(O(n^{(1+\alpha)/2}\log n))=\exp(O(\sqrt{n\ell}\log n))$, and

- cannot be solved in time exp(o(n^((1+α)/2)))=exp(o(sqrt(nℓ))), unless the ETH fails.
joint work with Csaba Biró, Édouard Bonnet, Dániel Marx, and Paweł Rzazewski