7th workshop on
Graph Classes, Optimization and Width Parameters

Aussois, 11–15 Oct. 2015

Invited Speakers

- Jørgen Bang-Jensen – University of Southern Denmark, Denmark
- Julia Chuzhoy – Toyota Technological Institute at Chicago, USA
- Gwenaël Joret – Université Libre de Bruxelles, Bruxelles, Belgium

---

Organizing committee

- Christophe Paul (CNRS, LIRMM, France) – Chair
- Ignasi Sau (CNRS, LIRMM, France)
- Julien Baste (Université de Montpellier, LIRMM)
- Valentin Garnero (Université de Montpellier, LIRMM)
- Jean-Florent Raymond (Université de Montpellier, LIRMM & Warsaw University)

Sunday 11th. The reception desk will open from 14:30 to 19:30. A buffet will be proposed from 19:30 to 22:00.

Monday

09:15 – 09:30	Welcome speech
	Chair : M. Habib
09:30 – 9:55	Partial Representation Extension of Interval Graphs, **Pavel Klavik**
9:55 – 10:20	Completion of the hierarchy of mixed unit interval graphs, **Jan Kratochvil**
10:20 – 10:50	Coffee Break
	Chair I. Sau
10:50 – 11:15	Automorphism Groups of Geometrically Represented Graphs, **Peter Zeman**
11:15 – 11:40	Intersection graphs of Non-Crossing Paths, **Steven Chaplick**
11:40 – 12:05	Path Graphs, Clique Trees, and Flowers, **Lalla Mouatadid**
12:30 – 13:30	Lunch
13:30 – 16:30	Afternoon break
	Chair : S.I. Oum
16:30 – 17:30	Mixed structures in digraphs and completing orientations of partially oriented graphs, **Jørgen Bang-Jensen**
17:30 – 18:00	Coffee Break
	Chair :
18:00 – 18:25	A Fixed Parameter Tractable Approximation Scheme for the Optimal Cut Graph of a Surface, **Vincent Cohen-Addad**
18:25 – 18:50	Parameterized Complexity Dichotomy for (r, ℓ)-Vertex Deletion, **Julien Baste**
18:50 – 19:30	Problem session 1
19:30 –	Dinner

Tuesday

9:15 – 10:15	Sparsity and dimension, **Gwenaël Joret**
10:15 – 10:45	Coffee Break
10:45 – 11:10	Erdös-Pósa Property of planar-H-minor models with prescribed vertex sets, **O-Joung Kwon**
11:10 – 11:35	The structure of graphs excluding Gem and $\hat{K}_4$ as induced minors, **Jean-Florent Raymond**
11:35 – 12:00	1-Sperner hypergraphs and new characterizations of threshold graphs, **Martin Milanic**
12:00 – 12:25	Fixed Parameter Algorithms for Completion Problems on Planar Graphs, **Archontia Giannopoulou**
12:30 – 13:30	Lunch
13:30 – 16:30	Afternoon break
16:30 – 16:55	Colouring graph classes with constraints on local connectivity, **Nick Brettell**
16:55 – 17:20	On the structure of (banner, odd hole)-free graphs, **Chinh T. Hoàng**
17:20 – 17:50	Coffee Break
17:50– 18:15	Constructive algorithm for path-width of matroids, **Sang-Il Oum**
18:15 – 18:40	Well-Structured Modulators: FPT Algorithms and Kernels, **Robert Ganian**
18:40 – 19:15	Bids for GROW 2017
19:30 – 21:30	Dinner
20:30 – 21:30	Problem session 2

Wednesday

9:15 – 10h15	Excluded Grid Theorem: Improved and Simplified, **Julia Chuzhoy**
10:15 – 10:45	Coffee Break
10:45 – 11:10	On the Parameterized Complexity of Finding Paths with Shared Edges, **Till Fluschnik**
11:10 – 11:35	Polynomial Fixed-Parameter Algorithms: A Case Study for Longest Path on Interval Graphs, **George Mertzios**
11:35 – 12:00	Phylogenetic incongruence through the lens of Monadic Second Order logic, **Céline Scornavacca**
12:00 – 12:25	Enumeration of Minimal Connected Dominating Sets and Minimal Connected Vertex Covers, **Dieter Kratsch**
12:30 – 13:30	Lunch Break
13:30 – 19:15 19:15 – 19:45	Free afternoon - Hiking trips Apéritif
19:45 –	Fondue Savoyarde

Thursday

9:15 – 9:40	Tree-depth and space efficiency of parameterized graph algorithms, **Marcin Wrochna**
9:40 – 10:05	Complexity and Approximability for Parameterized CSPs, **Valia Mitsou**
10:05 – 10:30	Cutwidth in Tournament and Applications, **Florian Barbero**
10:30 – 11:00	Coffee Break
11:00 – 11:25	FPT results through potential maximal cliques, **Pedro Montealegre**
11:25 – 11:50	Clique-width of Restricted Graph Classes, **Konrad Dabrowski**
11:50 – 12:15	On Maximum Matching Width, **Jisu Jeong**
12:30 – 13:30	Lunch – End of the workshop

Mixed structures in digraphs and completing orientations of partially oriented graphs

Based on joint works with C-J. Casselgren, J. Huang, M. Kriesell, A. Maddaloni, S. Simonsen and A. Yeo,
Jørgen Bang-Jensen – University of Southern Denmark

Abstract: This talk has two parts. We first discuss the complexity of problems concerning mixed structures in digraphs. Examples of such problems are

- [4,5,6] Given a digraph D; does its underlying undirected digraph $UG(D)$ contain two (edge)-disjoint cycles C, W so that C is a directed cycle in D, whereas the edges of W do not have to respect the orientation in D.
- [9, 7] Given a digraph D; does $UG(D)$ have two edge-disjoint spanning trees T_1, T_2 so that T_1 is an out-branching from some root s in D (that is, s can reach every other vertex using only the arcs of T_1), whereas the edges of T_2 do not have to respect the orientation in D.
- [3] Given a digraph D and vertices s, t, u, v of D; does $UG(D)$ contain two (edge)-disjoint paths P_1, P_2 so that P_1 is a directed (s, t)-path in D and P_2 is a path (not necessarily respecting the orientation of arcs of D) from u to v in $UG(D)$.
- [1] Given a digraph D; does $UG(D)$ contain a 2-factor (spanning collection of disjoint cycles) $C_1, \ldots, C_k$ so that C_1 is a directed cycle in D but the other cycles need not be directed cycles in D.
- [8] Mixed multicut: Given a digraph D vertices (terminals) $t_1, t_2, \ldots, t_r$ of D and a mixed pattern graph $M = (\{t_1, t_2, \ldots, t_r\}, \hat{E} \cup \hat{A})$ and a natural number k; Does there exist a set S of at most k arcs of D so that $D' = D - S$ satisfies the following: If $t_it_j \in \hat{E}$, then there is no path between t_i and t_j in $UG(D')$ and if $(t_i, t_j) \in \hat{A}$, then there is no directed (t_i, t_j)-path in D'.

In the second part of the talk we consider orientation completion problems. These can be defined as follows: Let $\mathcal{C}$ be a fixed class of digraphs (e.g. locally semicomplete, acyclic, having a directed cycle factor, strongly connected, locally transitive ...). The **orientation completion problem** for the class $\mathcal{C}$ is to decide, for a given partically oriented graph $P = (V, E \cup A)$, whether we can orient the edges in E so that the resulting digraph $D = (V, \overrightarrow{E} \cup A)$ belongs to the class $\mathcal{C}$. This is a common generalization of the recognition problems for the underlying graphs of digraphs and membership of a digraph class. The problem also has close relations to so-called **representation extension** problems where we are given a partial geometric representation of an induced subgraph of graph and the question is whether we can complete this to a full representation of the whole graph (see e.g. [11, 10]).

We will discuss recent results [2] on the problem when $\mathcal{C}$ is (a subclass of) the class of locally semicomplete digraphs. This includes the problem of orienting a semicomplete digraph as a locally transitive (every in- and out-neighbourhood is transitive) tournament.

References

[1] J. Bang-Jensen and C. J. Casselgren, Restricted cycle factors and arc-decompositions of digraphs, *Disc. Appl. Math.* **193** (2015) 80-93.

[2] J. Bang-Jensen, J. Huang and X. Zhu, Completing orientations of partially oriented graphs, arXiv 1509.01301v1

[3] J. Bang-Jensen and M. Kriesell, Disjoint directed and undirected paths and cycles in digraphs, *Theoretical Comp. Sci.* 410 (2009) 5138-5144.

[4] J. Bang-Jensen and M. Kriesell, On the problem of finding disjojnt cycles and dicycles in a digraph, *Combinatorica* **31** (2011) 639-668.

[5] J. Bang-Jensen, M. Kriesell, A. Maddaloni and S. Simonsen, Vertex-disjoint directed and undirected cycles in general digraphs, *J. Combin. Theory Ser B.* **106** (2014) 1-14.

[6] J. Bang-Jensen, M. Kriesell, A. Maddaloni and S. Simonsen, Arc-disjoint directed and undirected cycles in digraphs, *J. Graph Theory*, to appear.

[7] J. Bang-Jensen, S. Saurabh and S. Simonsen, Parameterized Algorithms for Non-separating Trees and Branchings in Digraphs, *Algorithmica*, to appear.

[8] J. Bang-Jensen and A. Yeo, The complexity of multicut and mixed multicut problems in (di)graphs, *Theoretical Comp. Sci.* **520** (2014) 87-96.

[9] J. Bang-Jensen and A. Yeo, Arc-disjoint spanning subdigraphs in digraphs, *Theoretical Comp. Sci* **438** (2012) 48-54.

[10] P. Klavik, J. Kratochvíl, T. Otachi, I. Rutter. T. Saitoth., M. Saumell and T. Vyskočil, Extending partial representations of proper and unit interval graphs, in Ravi and Gørtz (Eds.): SWAT 2014, LNCS 8503 (2014) 253-264.

[11] P. Klavik, J. Kratochvíl and T. Vyskočil, Extending partial representations of interval graphs, M. Ogihara and J. Tarui (Eds.): TAMC 2011, LNCS 6648 (2011) 276-285.

Cutwidth in Tournament and Applications

F. Barbero – LIRMM, Université de Montpellier, Montpellier, France
C. Paul – LIRMM, Université de Montpellier, Montpellier, France

Abstract: In the proof of the graph minor theorem [4], Robertson and Seymour introduced the concept of tree decompositions and their associated width measures. Alternative width measures have been proposed to deal with directed graphs. But so far, the development of a minor theory for directed graphs is still limited. Only recently [1], semi-complete digraphs have been proved to be well-quasi ordered under the *immersion* inclusion relation. The width measure associated to the immersion relation in semi-complete digraph is the *cutwidth* [2,1,3] which is defined as follows. Let $D = (V, E)$ be a digraph and π be an ordering of V. The *cutwidth* of π is

$$\mathsf{cw}(D, \pi) = \max_{0 \leqslant i \leqslant |V|} |E(V_i, V \setminus V_i)|$$

where V_i is the set containing the i first vertices of V in π and $E(V \setminus V_i, V_i)$ denotes the set of arcs from $V \setminus V_i$ to V_i. The *cutwidth* of D is given by

$$\mathsf{cw}(D) = \min_{\pi} \mathsf{cw}(D, \pi)$$

In this talk, we focus on *tournaments*, a subclass of semi-complete digraphs. It is easy to observe that the cutwidth of a transitive tournament is 0. It follows that the well-known Feedback Arc Set in Tournament (FAST) problem can be expressed as the problem of deciding the existence of a subset of at most k arcs whose reversal yields a cutwidth-0 tournament. A natural generalization is to consider the same question with respect to cutwidth-c for a fixed constant c. We call this problem c-Cutwidth Arc Reversal in Tournament (c-CART).

As a consequence of the facts that 1) tournaments are well-quasi ordered under the immersion inclusion relation [2,1] and 2) testing whether a digraph H is included as an immersion in a semi-complete D is FPT [1], the c-CART problem can be solved in non-uniform FPT time. We show that c-CART can be solved in single exponential FPT time. The algorithm follows from the fact that any tournament T such that $\mathsf{cw}(T) \geqslant c$, contains an induced subtournament T' with $O(c^2)$ vertices such that $\mathsf{cw}(T') \geqslant c$. Moreover such a quadratic size obstruction can be found in polynomial time. Finally we observe that these obstructions also lead to single exponential FPT algorithm for the vertex deletion version of the problem.

References

[1] M. Chudnovsky and A. Fradkin and P. Seymour. Tournament immersion and cutwidth. *Journal of Combinatorial Theory, Series B*, 102:93-101, 2012.

[2] M. Chudnovsky and P. Seymour. A well-quasi-order for tournaments. *Journal of Combinatorial Theory, Series B*, 101:47-53, 2011.

[3] M. Pilipczuk. Tournaments and optimality: new results in parameterized complexity. *University of Bergen*, 2013.

[4] N. Roberston and P. Seymour Graph minors XX: Wagner's conjecture. *Journal of Combinatorial Theory, Series B*, 92(2):325-357, 2004.

Parameterized Complexity Dichotomy for (r,ℓ)-Vertex Deletion

J. Baste – LIRMM, Université de Montpellier, Montpellier, France

L. Faria – FFP, Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil

S. Klein – Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil

I. Sau – LIRMM, CNRS, Montpellier, France

Abstract: For two integers $r,\ell \geq 0$, a graph $G = (V,E)$ is an (r,ℓ)-*graph* if V can be partitioned into r independent sets and ℓ cliques. In the parameterized (r,ℓ)-Vertex Deletion problem, given a graph G and an integer k, one has to decide whether at most k vertices can be removed from G to obtain an (r,ℓ)-graph. This problem is NP-hard if $r+\ell \geq 1$ and encompasses several relevant problems such as Vertex Cover and Odd Cycle Transversal. The parameterized complexity of (r,ℓ)-Vertex Deletion was known for all values of (r,ℓ) except for $(2,1)$, $(1,2)$, and $(2,2)$. We prove that each of these three cases is FPT and, furthermore, solvable in single-exponential time, which is asymptotically optimal in terms of k. We consider as well the version of (r,ℓ)-Vertex Deletion where the set of vertices to be removed has to induce an independent set, and provide also a parameterized complexity dichotomy for this problem.

Colouring graphs with constraints on local connectivity

P. Aboulker – Universidad Andres Bello, Santiago, Chile
N. Brettell – Institute for Computer Science and Control, Hungarian Academy of Sciences (MTA SZTAKI)
F. Havet – Project Coati, I3S (CNRS, UNS) and INRIA, Sophia Antipolis, France
D. Marx – Institute for Computer Science and Control, Hungarian Academy of Sciences (MTA SZTAKI)
N. Trotignon – LIP, ENS Lyon

Abstract: It is well known that deciding if a graph has a proper vertex k-colouring is NP-complete for any fixed k at least 3. On the other hand, if we restrict our attention to graphs with maximum degree at most k, Brooks' theorem implies that it is easy to find a k-colouring, or determine that none exists, in polynomial time. In this talk, we consider several generalisations of the class of graphs with maximum degree at most k — each defined by constraining the local connectivity of some, or all, pairs of vertices — and consider the complexity of k-colouring for graphs in these classes.

A graph has *maximal local connectivity* k (respectively, *maximal local edge-connectivity* k) if no pair of distinct vertices have more than k internally disjoint (respectively, edge-disjoint) paths between them. We characterise the 3-colourable graphs with maximal local edge-connectivity 3, the 3-colourable 3-connected graphs with maximal local connectivity 3, and the k-colourable k-connected graphs with maximal local edge-connectivity k. It follows that there is a polynomial-time algorithm that, for a graph in one of these classes, finds a 3- or k- colouring, or determines that none exists. On the other hand, deciding the k-colourability of minimally k-connected graphs, or deciding the 3-colourability of $(k-1)$-connected graphs with maximal local connectivity k, is shown to be NP-complete.

Intersection Graphs of Non-crossing Paths

Steven Chaplick – Universität Würzburg

Abstract: Intersection representations of graphs are ubiquitous in graph theory and covered in many graph theory textbooks (see, e.g., [4, 2]). For a given graph G, a collection $\mathcal{S}$ of sets, $\{S_v\}_{v \in V(G)}$, is an *intersection representation* of G when $S_u \cap S_v \neq \emptyset$ iff $uv \in E(G)$. Similarly, we say that G is the intersection graph of $\mathcal{S}$.

In this work we consider classes of intersection graphs where the sets are taken from a topological space, are *arc-connected*, and are pairwise *non-crossing*. A set S is *arc-connected* when any two of its points can be connected by a *curve* within the set (note: a *curve* is a homeomorphic image of a closed interval). Notice that when the topological space is a graph, arc-connectedness is precisely the usual connectedness of a graph and curves are precisely paths. Two connected sets S_1, S_2 are said to be *non-crossing* when both $S_1 \setminus S_2$ and $S_2 \setminus S_1$ are arc-connected. The most general case of intersection graphs of non-crossing sets which have been studied are those of non-crossing arc-connected (NC-AC) sets in the plane [3]. These were considered together with the intersection graphs of disks in the plane, or simply *disk* graphs – another non-crossing class. In particular, it has been shown that the recognition of both NC-AC graphs and disk graphs is NP-hard [3].

Our focus is on intersection graphs of non-crossing paths. Note that the class of non-crossing subpaths of a path is precisely the well-studied class of proper interval graphs. We study the graph classes listed below.

- NC paths in a tree.
- NC directed paths in a directed tree.
- NC directed paths in a rooted tree.

These graph classes naturally generalize the algorithmically convenient structure of proper interval graphs. For example, we will also show that the dominating set problem can be solved in polynomial time on the intersection graphs of non-crossing paths in a tree. This contrasts the fact that the dominating set problem is NP-complete on intersection graphs of paths in a tree (i.e., where paths are allowed to cross) [1]. We further characterize all of these classes by finite forbidden induced subgraph characterizations.

References

[1] Kellogg S. Booth and J. Howard Johnson, Dominating Sets in Chordal Graphs *SIAM Journal on Computing* 11(1):191-199, 1982.

[2] Martin C. Golumbic. Algorithmic graph theory and perfect graphs. *Annals of discrete mathematics.* Elsevier 2004.

[3] Jan Kratochvíl. Intersection graphs of noncrossing arc-connected sets in the plane, *In Graph Drawing, LNCS 1190:257-270,* 1997.

[4] T.A. McKee, T.A. and F.R. McMorris. Topics in Intersection Graph Theory. *Monographs on Discrete Mathematics and Applications.* SIAM 1999.

Excluded Grid Theorem: Improved and Simplified

Julia Chuzhoy – Toyota Technological Institute at Chicago

Abstract: One of the key results in Robertson and Seymour's seminal work on graph minors is the Excluded Grid Theorem. The theorem states that for every fixed-size grid H, every graph whose treewidth is large enough, contains H as a minor. This theorem has found many applications in graph theory and algorithms. Let $f(k)$ denote the largest value, such that every graph of treewidth k contains a grid minor of size $(f(k) \times f(k))$. Until recently, the best known bound on $f(k)$ was sub-logarithmic in k. In this talk we will survey new results and techniques that establish polynomial bounds on $f(k)$.

Partly based on joint work with Chandra Chekuri.

A Fixed Parameter Tractable Approximation Scheme for the Optimal Cut Graph of a Surface

Vincent Cohen-Addad – École Normale Supérieure, Paris

Arnaud de Mesmay – IST Austria, Klosterneuburg, Austria

Abstract: Given a graph G cellularly embedded on a surface Σ of genus g, a cut graph is a subgraph of G such that cutting Σ along G yields a topological disk. We provide a fixed parameter tractable approximation scheme for the problem of computing the shortest cut graph, that is, for any $\varepsilon > 0$, we show how to compute a $(1 + \varepsilon)$ approximation of the shortest cut graph in time $f(\varepsilon, g)n^3$.

Our techniques first rely on the computation of a spanner for the problem using the technique of brick decompositions, to reduce the problem to the case of bounded tree-width. Then, to solve

the bounded tree-width case, we introduce a variant of the surface-cut decomposition, which may be of independent interest.

Clique-width of Restricted Graph Classes

A. Brandstädt – Universität Rostock,
K.K. Dabrowski – Durham University,
F. Dross – Université de Montpellier,
S. Huang – Simon Fraser University,
D. Paulusma – Durham University

Abstract: The *clique-width* of a graph G, is the minimum number of labels needed to construct G using the following four operations:

- creating a new graph consisting of a single vertex v with label i;
- taking the disjoint union of two labelled graphs G_1 and G_2;
- joining each vertex with label i to each vertex with label j ($i \neq j$);
- renaming label i to j.

Clique-width is of great theoretical interest because many natural algorithmic problems that are NP-complete in general can be solved efficiently on graph classes of bounded clique-width. This includes all problems expressible in monadic second order logic with quantification over vertices, along with other problems such as vertex colouring and Hamiltonian cycle. Clique-width is a tricky parameter to deal with. Indeed, even for low values of c, such as $c = 4$, we do not know if graphs of clique-width c can be detected in polynomial time.

I will describe some of the tools available for dealing with clique-width and summarize our recent work on classifying which classes of graphs have bounded clique-width, in particular for: H-free graphs [6], H-free bipartite graphs [5], H-free split graphs [2], H-free chordal graphs [1], H-free weakly chordal graphs [1] and (H_1, H_2)-free graphs [1, 3, 4, 6].

References

[1] A. Brandstädt, K. K. Dabrowski, S. Huang, and D. Paulusma, Bounding the clique-width of H-free chordal graphs, *Proc. MFCS 2015, LNCS* 9235:139–150 (2015). Full version: *arXiv CoRR* abs/1502.06948 (2015).

[2] A. Brandstädt, K. K. Dabrowski, S. Huang, and D. Paulusma, Bounding the clique-width of H-free split graphs, *Proc. Eurocomb 2015, ENDM* (to appear). Full version: *arXiv CoRR* abs/1509.04273 (2015).

[3] K. K. Dabrowski F. Dross and D. Paulusma, New results on the clique-width of graph classes defined by two forbidden induced subgraphs, (working paper).

[4] K. K. Dabrowski, S. Huang, and D. Paulusma, Bounding clique-width via perfect graphs, *Proc. LATA 2015, LNCS* 8977:676–688 (2015). Full version: *arXiv CoRR* abs/1406.6298 (2014).

[5] K. K. Dabrowski and D. Paulusma, Classifying the clique-width of H-free bipartite graphs, *Proc. COCOON 2014, LNCS* 8591:489–500 (2014). Full version: *Discrete Applied Mathematics* (in press).

[6] K. K. Dabrowski and D. Paulusma, Clique-width of graph classes defined by two forbidden induced subgraphs, *Proc. CIAC 2015, LNCS* 9079:167–181 (2015). Full version: *arXiv CoRR* abs/1405.7092.

On the Parameterized Complexity of Finding Paths with Shared Edges

Till Fluschnik – TU Berlin

Abstract: We study the Minimum Shared Edges (MSE) problem on undirected graphs. Given an undirected graph, a source and a sink vertex, and two integers p and k, the question is whether there are p paths in the graph connecting the source with the sink that share at most k edges. Herein, an edge is shared if it appears in at least two paths. Complementing an NP-hardness result for the directed variant, we show that MSE is NP-complete even on planar graphs. Further, we show that MSE is W[2]-hard when parameterized by the number k of shared edges and W[1]-hard when parameterized by the treewidth. On the positive side, we show that MSE is fixed-parameter tractable with respect to the number p of paths. For the latter result, we employ the so-called treewidth reduction technique due to Marx, O'Sullivan and Razgon [1].

The talk is based on a joint work with Stefan Kratsch, Rolf Niedermeier and Manuel Sorge.

References

[1] D. Marx, B. O'Sullivan, and I. Razgon. Finding small separators in linear time via treewidth reduction. *ACM Transactions on Algorithms*, 9(4):30, 2013.

Well-Structured Modulators: FPT Algorithms and Kernels

Robert Ganian – TU Wien, Vienna, Austria
Eduard Eiben – TU Wien, Vienna, Austria
Stefan Szeider – TU Wien, Vienna, Austria

Abstract: A modulator of a graph G to a specified graph class $\mathcal{H}$ is a set of vertices whose deletion puts G into $\mathcal{H}$. The cardinality of a modulator to various tractable graph classes has long been used as a structural parameter which can be exploited to obtain both FPT algorithms and polynomial kernels for a range of hard problems. Here we investigate what happens when a graph contains a modulator which is large but "well-structured" (in the sense of having bounded rank-width). Can such modulators still be exploited to obtain efficient algorithms? And is it even possible to find such modulators efficiently?

We first show that the parameters derived from such well-structured modulators are more general (and hence applicable on broader graph classes) than modulators as well as other established parameters used for kernelization and fixed parameter tractability. Then, we develop algorithms for finding such well-structured modulators to a range of graph classes. Finally, we use the concept of well-structured modulators to develop algorithmic meta-theorems for deciding problems expressible in Monadic Second Order (MSO) logic, and prove that this result is tight in the sense that it cannot be generalized to LinEMSO problems. This talk is based on the results obtained in [1, 2].

References

[1] E. Eiben, R. Ganian, S. Szeider. Solving Problems on Graphs of High Rank-Width. In *Algorithms and Data Structures – 14th International Symposium (WADS)*, pp. 314-326, LNCS 9214, 2015.

[2] E. Eiben, R. Ganian, S. Szeider. Meta-Kernelization using Well-Structured Modulators. In *Parameterized and Exact Computation – 9th International Symposium (IPEC)*, 2015, *to appear.*

Fixed Parameter Algorithms for Completion Problems on Planar Graphs[1]

Dimitris Chatzidimitriou – Department of Mathematics, National and Kapodistrian University of Athens, Athens, Greece.
Archontia C. Giannopoulou – Institute of Informatics, University of Warsaw, Warsaw, Poland.
Spyridon Maniatis – Department of Mathematics, National and Kapodistrian University of Athens, Athens, Greece.
Clément Requilé – Freie Universität Berlin, Institut für Mathematik und Informatik, Berlin, Germany.
Dimitrios M. Thilikos – AlGCo project team, CNRS, LIRMM, Montpellier, France and Department of Mathematics, National and Kapodistrian University of Athens, Athens, Greece.
Dimitris Zoros – Department of Mathematics, National and Kapodistrian University of Athens, Athens, Greece.

Abstract: Given a partial relation $\leq$ on graphs we consider the PLANE $\leq$-COMPLETION ($\leq$ -PC) problem which, given a (possibly disconnected) plane graph G and a connected plane graph H, asks whether it is possible to add edges in G such that the resulting graph G^+ remains plane and $H \leq G^+$. We consider instantiations of this general problem when $\leq$ is the (embedded) subgraph relation, the (embedded) induced subgraph relation, the (embedded) topological minor relation, and the (embedded) minor relation and we prove that all of them admit fixed parameter algorithms when parameterized by the size of H.

On the structure of (banner, odd hole)-free graphs

Chính T. Hoàng – Department of Physics and Computer Science, Wilfrid Laurier University, Waterloo, Ontario, Canada, N2L 3C5

Abstract: A hole is a chordless cycle with at least four vertices. A hole is odd if it has an odd number of vertices. A banner is a graph which consists of a hole on four vertices and a single vertex with precisely one neighbor on the hole. We design a polynomial-time algorithm for recognizing (banner, odd hole)-free graphs. We also design polynomial-time algorithms to find, for such a graph, a minimum coloring and largest stable set.

On Maximum Matching Width

Sigve Hortemo Sæther and Jan Arne Telle – University of Bergen
Jisu Jeong – KAIST

Abstract: Tree-width and branch-width are connectivity parameters of importance in algorithm design. In 2012, Vatshelle introduced a graph parameter, maximum matching width, defined by a

[1]The first and the fifth authors were supported by the E.U. (European Social Fund - ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: "Thales. Investing in knowledge society through the European Social Fund". The second author was supported by the Warsaw Center of Mathematics and Computer Science. The fourth author was supported by the FP7-PEOPLE-2013-CIG project CountGraph (ref. 630749), and the Berlin Mathematical School.

branch-decomposition over the vertex set of a graph G, using the symmetric submodular function obtained by taking the size of a maximum matching of the bipartite graph crossing the cut.

Tree-width and branch-width have alternative definitions through intersections of subtrees of a tree, where tree-width focuses on vertices and branch-width focuses on edges. We show that maximum matching width combines both aspects, focusing on vertices and on edges. Based on this we prove that given a graph G and a branch-decomposition of maximum matching width k, we can solve Dominating Set Problem in time $O^*(8^k)$. This runtime beats $O^*(3^{tw(G)})$-time algorithm for tree-width whenever $tw(G) > 1.893k$.

Sparsity and dimension

Gwenaël Joret – Université Libre de Bruxelles, Bruxelles, Belgium

Abstract: In this talk we will look at posets and their dimension through the lens of the Nesetril-Ossona de Mendez theory of sparsity for graphs. The type of questions studied here are of the following form: Given some fixed sparse class of graphs, is it true that posets whose cover graphs are in the class have dimension bounded in terms of their height? This is the case for instance for planar graphs, as shown by Streib and Trotter. There has been a flurry of positive results in that direction recently, including classes with bounded treewidth, bounded genus, and more generally excluding a fixed minor. I will first give an introduction to this area, assuming no background knowledge on posets. Then I will sketch a proof that the above property holds more generally for every class with bounded expansion, a result obtained jointly with Piotr Micek and Veit Wiechert. This is in a sense best possible, as it cannot be extended to nowhere dense classes; in fact, it already fails for classes with locally bounded treewidth.

Partial Representation Extension Problem of Interval Graphs

Pavel Klavík – Charles University in Prague

Abstract: The recognition problems were studied for many graph classes, e.g., for interval graphs several linear-time algorithms are known. In this talk, I will describe a generalization of recognition called *partial representation extension*, introduced in [1]. For interval graphs, the input also gives several intervals which are *pre-drawn*, forming a partial representation. We ask whether we can add the remaining intervals to create an extending interval representation; see Figure

I will give an overview of known results and techniques. For interval graphs, there are two linear-time algorithms solving partial representation extension [3, 2]. Extendible representations were characterized by partial orderings of maximal cliques [1, 3]. Also minimal obstructions are known [5], generalizing minimal induced subgraphs of interval graphs of Lekkerkerker and Boland. We will also discuss other variations of the problem [4].

References

[1] P. Klavík, J. Kratochvíl, and T. Vyskočil. Extending partial representations of interval graphs. In *TAMC*, volume 6648 of *Lecture Notes in Computer Science*, pages 276–285. Springer, 2011.

[2] T. Bläsius and I. Rutter. Simultaneous PQ-ordering with applications to constrained embedding problems. In *SODA'13*, pages 1030–1043, 2013.

[3] P. Klavík, J. Kratochvíl, Y. Otachi, T. Saitoh, and T. Vyskočil. Extending partial representations of interval graphs. *CoRR*, abs/1306.2182, 2013.

[4] P. Klavík, J. Kratochvíl, Y. Otachi, I. Rutter, T. Saitoh, M. Saumell, and T. Vyskočil. Extending partial representations of proper and unit interval graphs. In *SWAT*, volume 8503 of *Lecture Notes in Computer Science*, pages 253–264. Springer, 2014.

[5] P. Klavík and M. Saumell. Minimal obstructions for partial representations of interval graphs. In *ISAAC*, volume 8889 of *Lecture Notes in Computer Science*, pages 401–413, 2014.

Completion of the mixed-unit interval graphs hierarchy

Alexandre Talon – ENS Lyon
Jan Kratochvil – Charles University, Prague

Abstract: We describe the missing class of the hierarchy of mixed unit interval graphs, generated by the intersection graphs of closed, open and one type of half-open intervals of the real line. This class lies strictly between unit interval graphs and mixed unit interval graphs. We give a complete characterization of this new class, as well as a polynomial time algorithm to recognize graphs from this class and to produce a corresponding interval representation if one exists.

A graph is an interval graph if one can associate to each of its vertices an interval of the real line such that two vertices are adjacent if and only if the corresponding intervals intersect. A well-studied subclass of the class of interval graphs is the one of proper interval graphs where it is required that no interval properly contains another one. This class coincides with the class of unit interval graphs where all intervals have length one [5].

However, in this description no particular attention is paid to the types of intervals we use: are they open, closed, or semi-closed? Dourado and al. proved in [3] that this is of no importance as far as interval graphs are concerned. This is no longer the case, though, for unit interval graphs: deciding which types of intervals are allowed to represent the vertices of a graph is crucial. This fact was notably studied in [5, 4, 2, 3, 1, 6]. In these papers one can find results about the classes of graphs we can get depending on the types of unit intervals we allow for their representations. In particular it is shown that if all intervals in a representation are required to be of the same type (all closed, all open, all left-closed-right-open, or all left-open-right-closed), one gets the same class of *unit interval graphs* which is a proper subclass of *mixed unit interval graphs*, i.e., graphs obtained if no restriction – apart from the unit length – on the intervals is imposed. Recently, Joos [1] gave a characterization of mixed unit interval graphs by an infinite class of forbidden induced subgraphs, and Shuchat et al. [6] complemented it by a polynomial-time recognition algorithm.

The aim of this paper is to complete this hierarchy of classes. We consider all subsets of the four types of unit intervals, show that several of them lead to the classic unit interval graphs (where all intervals are closed), recall the previously studied and characterized class determined by open and closed unit intervals, and then show that – with respect to this parametrization – there exists exactly one other proper subclass of the class of mixed unit interval graphs. We characterize this class by an infinite list of forbidden induced subgraphs, give a polynomial-time algorithm to check whether a graph belongs to this class, as well as an algorithm to produce an appropriate interval representation of any graph of this class. [2]

References

[1] F. Joos. A Characterization of Mixed Unit Interval Graphs. *J. Graph Theory* 79(4): 267-281 (2015).

[2] The result has been presented at TAMC 2015 in Singapore in May 2015.

[2] D. Rautenbach and J.L. Szwarcfiter. Unit Interval Graphs of Open and Closed Intervals. *J. Graph Theory* 72(4), 418-429 (2013).

[3] M.C. Dourado, V.B. Le, F. Protti, D. Rautenbach, and J.L. Szwarcfiter. Mixed unit interval graphs. *Discrete Math.* 312, 3357-3363 (2012).

[4] P. Frankl and H. Maehara. Open interval-graphs versus closed interval-graphs. *Disc. Math.* 63:97-100 (1987).

[5] F.S. Roberts. Indifference graphs. in *Proof Techniques in Graph Theory*, pp.139-146 (1969).

[6] A. Shuchat, R. Shull, A. N. Trenk, and L. C. West Unit Mixed Interval Graphs. arXiv:1405.4247 (2014).

Enumeration of Minimal Connected Dominating Sets and Minimal Connected Vertex Covers

P. Heggernes – University of Bergen
P. Golovach – University of Bergen
D. Kratsch – Université Lorraine

Abstract: Connected Dominating Set and Connected Vertex Cover are classical problems of computer science. Although the optimization and decision variants of the problems are well studied, surprisingly there is no work on the enumeration or maximum number of minimal connected dominating sets or vertex covers of a graph. We construct exact exponential enumeration algorithms for these problems for graphs classes and use the algorithms to obtain upper bounds for the number of minimal connected dominating sets and minimal connected vertex covers. For minimal connected dominating sets, we consider some graph classes of bounded chordality. In particular, we show that all minimal connected dominating sets of an n vertex chordal graph can be enumerated in time $O^*(1.7159^n)$. For split graphs, minimal connected dominating sets can be enumerated in time $O^*(1.3803^n)$, and for AT-free, strongly chordal and distance-hereditary graphs in time $O^*(3^{n/3})$. These algorithms immediately imply the corresponding upper bound for the number of minimal connected dominating sets. For minimal connected vertex covers, we show that the maximum number of minimal connected vertex covers of a graph is $O(1.8668^n)$, and these can be enumerated in time $O(1.8668^n)$. For graphs of chordality at most 5, we are able to give a better upper bound, and for chordal graphs and distance-hereditary graphs we are able to give tight bounds $O(3^{n/3})$ on the maximum number of minimal connected vertex covers.

Erdös-Pósa Property of planar-H-minor models with prescribed vertex sets

O-joung Kwon – MTA SZTAKI, Hungarian Academy of Sciences
Dániel Marx – MTA SZTAKI, Hungarian Academy of Sciences

Abstract: Robertson and Seymour [5] proved that for every planar graph H, the class of all H-expansions, which are the graphs can be contracted to H, has the Erdös-Pósa property, and this does not hold for non-planar graphs. We generalize this result for disjoint H-expansions containing vertices from two sets among several prescribed vertex sets. This generalization is motivated from Mader's $\mathcal{S}$-path theorem [2].

For a graph G and a set $\mathcal{Z} = \{Z_i \subseteq V(G) : 1 \le i \le m\}$ with $m \ge 2$, an H-expansion F in G is *$\mathcal{Z}$-connecting* if $V(F) \cap Z_i \neq \emptyset$ and $V(F) \cap Z_j \neq \emptyset$ for some $i \neq j$. We show that $\mathcal{Z}$-connecting H-expansions have the Erdös-Pósa property: for a positive integer k and a planar graph H, there

exists a function $f(k, H)$ such that if G is a graph and $\mathcal{Z} = \{Z_i \subseteq V(G) : 1 \leq i \leq m\}$ with $m \geq 2$, then either

1. G contains k pairwise vertex-disjoint $\mathcal{Z}$-connecting H-expansions, or

2. there is a vertex subset T of size at most $f(k, H)$ in G such that $G \backslash T$ contains no $\mathcal{Z}$-connecting H-expansions.

We point out that the function f does not depend on the number m of prescribed vertex sets. It implies the original theorem by Robertson and Seymour by taking $Z_1 = Z_2 = V(G)$, and further implies that for a vertex set $S \subseteq V(G)$, H-expansions intersecting S also have the Erdös-Pósa property by taking $Z_1 = S$ and $Z_2 = V(G)$, which is similar to the Erdös-Pósa property of cycles intersecting S [1, 4]. To prove it, we use the Rooted Grid Minor theorem developed by Marx, Seymour, and Wollan [3], and mainly develop a procedure to find a vertex in a graph of large tree-width, called an irrelavent vertex, whose deletion preserves the minimum size of a packing set for $\mathcal{Z}$-connecting H-expansions. We also give an example showing that if the number of required intersecting sets is more than two, then the Erdös-Pósa property does not hold. This is joint work with Dániel Marx.

References

[1] N. Kakimura, K. Kawarabayashi, and D. Marx. Packing cycles through prescribed vertices. *Journal of Combinatorial Theory, Series B*, 101(5):378 – 381, 2011.

[2] W. Mader. Über die Maximalzahl kreuzungsfreier H-Wege. *Arch. Math. (Basel)*, 31(4):387–402, 1978/79.

[3] D. Marx, P. Seymour, and P. Wollan. Rooted grid minors, 2013. arXiv:1307.8138.

[4] M. Pontecorvi and P. Wollan. Disjoint cycles intersecting a set of vertices. *Journal of Combinatorial Theory, Series B*, 102(5):1134 – 1141, 2012.

[5] N. Robertson and P. Seymour. Graph minors. V. Excluding a planar graph. *Journal of Combinatorial Theory, Series B*, 41(1):92 – 114, 1986.

Polynomial Fixed-Parameter Algorithms: A Case Study for Longest Path on Interval Graphs

Archontia C. Giannopoulou – University of Warsaw
George B. Mertzios – Durham University
Rolf Niedermeier – TU Berlin

Abstract: We study the design of fixed-parameter algorithms for problems already known to be solvable in polynomial time. The main motivation is to get more efficient algorithms for problems with unattractive polynomial running times. Here, we focus on a fundamental graph problem: Longest Path; it is NP-hard in general but known to be solvable in $O(n^4)$ time on n-vertex interval graphs. We show how to solve Longest Path on Interval Graphs, parameterized by vertex deletion number k to proper interval graphs, in $O(k^9 n)$ time. Notably, Longest Path is trivially solvable in linear time on proper interval graphs, and the parameter value k can be approximated up to a factor of 4 in linear time. From a more general perspective, we believe that the idea of using parameterized complexity analysis for polynomial-time solvable problems offers a very fertile ground for future studies for all sorts of algorithmic problems. It may enable a

refined understanding of efficiency aspects for polynomial-time solvable problems similarly to what classical parameterized complexity analysis does for NP-hard problems.

1-Sperner hypergraphs and new characterizations of threshold graphs

E. Boros – Rutgers University
V. Gurvich – Rutgers University
M. Milanič – University of Primorska

Abstract: We introduce a new class of hypergraphs, the class of 1-Sperner hypergraphs. A hypergraph $\mathcal{H}$ is said to be 1-*Sperner* if every two distinct hyperedges e, f of $\mathcal{H}$ satisfy $\min\{|e \setminus f|, |f \setminus e|\} = 1$. We prove a decomposition theorem for 1-Sperner hypergraphs and examine several of its consequences, including bounds on the size of 1-Sperner hypergraphs and a new, constructive proof of the fact that every 1-Sperner hypergraph is threshold. (A hypergraph $\mathcal{H} = (V, \mathcal{E})$ is said to be *threshold* if there exist a non-negative integer weight function $w : V \to \mathbb{Z}_+$ and a non-negative threshold $t \in \mathbb{Z}_+$ such that for every subset $X \subseteq V$, we have $\sum_{x \in X} w(x) \geq t$ if and only if X contains a hyperedge.)

A hypergraph is said to be *Sperner* (or: *a clutter*) if no hyperedge is contained in another one. Given a graph G, the *clique hypergraph of* G is the hypergraph $\mathcal{C}(G)$ with vertex set $V(G)$ in which the hyperedges are exactly the maximal cliques of G. The clique hypergraphs of graphs are known to be exactly those Sperner hypergraphs $\mathcal{H}$ that are also *normal* (or: *conformal*), that is, for every set $X \subseteq V(\mathcal{H})$ such that every pair of elements in X is contained in a hyperedge, there exists a hyperedge containing X. We show that within the class of normal Sperner hypergraphs, the (generally properly nested) classes of 1-Sperner hypergraphs, of threshold hypergraphs, and of 2-asummable hypergraphs coincide. This yields new characterizations of the class of threshold graphs.

The talk is based on [1].[3]

References

[1] E. Boros, V. Gurvich, and M. Milanič. 1-Sperner hypergraphs. Manuscript, 2015.

Complexity and Approximability for Parameterized CSPs

H. Dell – Saarland University and Cluster of Excellence, Saarbrücken, E. J. Kim – Université Paris Dauphine, M. Lampis – Université Paris Dauphine, V. Mitsou – SZTAKI, Hungarian Academy of Sciences, Budapest, T. Mömke – Saarland University, Saarbrücken.

Abstract: CONSTRAINT SATISFACTION PROBLEMS (CSPs) play a central role in almost all branches of theoretical computer science. Starting from CNFSAT, the prototypical NP-complete problem, the computational complexity of CSPs has been widely studied from various points of view. In this paper we focus on two aspects of CSP complexity which have mostly been considered separately so far in the literature: parameterized complexity and approximability. We study four standard predicates and contribute some of the first results in this joint area.

[3] Remark: The manuscript should be soon (hopefully before GROW) posted on arXiv, in which case the reference can be updated accordingly.

Parameterized CSPs. The vast majority of interesting CSPs are NP-hard [3]. This has motivated the study of such problems from a parameterized complexity point of view, and indeed this topic has attracted considerable attention in the literature [1]. In this paper we focus on *structurally* parameterized CSPs, that is, we consider CSPs where the parameter is some measure of the structure of the input instance. The central idea behind this approach is to represent the structure of the CSP using a (hyper-)graph and leverage the powerful tools commonly applied to parameterized graph problems (such as tree decompositions) to solve the CSP.

Approximation. CSPs also play a central role in the theory of (polynomial-time) approximation. In this context we typically consider a CSP as an optimization problem (MAXCSP) where the goal is to find an assignment to the variables that satisfies as many of the constraints as possible. Unfortunately, essentially all non-trivial CSPs are hard to approximate (APX-hard) [2]. This motivates the question of whether we can find cases where efficient approximations are possible.

Results. We consider four different types of CSPs with *or*, *and*, *parity* and *majority* constraints respectively. The new ingredient in our approach is that, in addition to trying to determine which parameters make a CSP FPT or W-hard, we also ask if the optimization versions of W-hard cases can be well-approximated. We show that these basic predicates display a diverse set of behaviors, ranging from being FPT to optimize exactly (parity), to being W-hard but well-approximable (or, majority), to being W-hard and inapproximable (and). Our results indicate that the point of view of approximability considerably enriches the parameterized complexity landscape of CSPs.

References

[1] M. Grohe. The structure of tractable constraint satisfaction problems. In R. Kralovic and P. Urzyczyn, editors, *MFCS 2006, Stará Lesná, Slovakia, August 28-September 1, 2006, Proceedings*, volume 4162 of *Lecture Notes in Computer Science*, pages 58–72. Springer, 2006.

[2] S. Khanna, M. Sudan, and D. P. Williamson. A complete classification of the approximability of maximization problems derived from boolean constraint satisfaction. In F. T. Leighton and P. W. Shor, editors, *Proceedings of the Twenty-Ninth Annual ACM Symposium on the Theory of Computing, El Paso, Texas, USA, May 4-6, 1997*, pages 11–20. ACM, 1997.

[3] T. J. Schaefer. The complexity of satisfiability problems. In R. J. Lipton, W. A. Burkhard, W. J. Savitch, E. P. Friedman, and A. V. Aho, editors, *Proceedings of the 10th Annual ACM Symposium on Theory of Computing, May 1-3, 1978, San Diego, California, USA*, pages 216–226. ACM, 1978.

FPT results through potential maximal cliques

Fedor V. Fomin – University of Bergen
Mathieu Liedloff – Université d'Orléans
Pedro Montealegre – Université d'Orléans
Ioan Todinca– Université d'Orléans

Abstract: In many graph problems, like LONGEST INDUCED PATH, MAXIMUM INDUCED FOREST, etc., we are given as input a graph G and the goal is to compute a largest induced subgraph $G[F]$, of treewidth at most a constant t, and satisfying some property $\mathcal{P}$. Fomin et al. [1] proved that this generic problem is polynomial on the class of graphs $\mathcal{G}_{\text{poly}}$, i.e., the graphs having at most poly(n) minimal separators for some polynomial poly, when property $\mathcal{P}$ is expressible in counting monadic

second order logic (CMSO). The algorithm is based on the enumeration of potential maximal cliques.

Here we extend this result in two directions:

- The generic problem can be solved in time $\mathcal{O}^*(4^{\mathrm{vc}})$ or $\mathcal{O}^*(1.7347^{\mathrm{mw}})$, where vc and mw correspond to the *vertex cover* and the *modular width* of the input graph.
- Consider the class $\mathcal{G}_{\mathrm{poly}} + kv$, formed by graphs of $\mathcal{G}_{\mathrm{poly}}$ to which we may add a set of at most k vertices with arbitrary adjacencies, called *modulator*. We prove that the generic optimization problem is fixed parameter tractable on $\mathcal{G}_{\mathrm{poly}} + kv$, with parameter k, if the modulator is also part of the input.

References

[1] Fedor V. Fomin, Ioan Todinca, and Yngve Villanger. Large induced subgraphs via triangulations and CMSO. In SIAM, editor, *Proceedings of SODA 2014*, 2014. See also http://arxiv.org/abs/1309.1559.

Path Graphs, Clique Trees, and Flowers[4]

Lalla Mouatadid – University of Toronto
Robert Robere – University of Toronto

Abstract: A classical result by Lekkerkerker and Boland showed that interval graphs are precisely the chordal graphs that do not have asteroidal triples [2]. Similar to Lekkerkerker and Boland, Cameron, Hoáng and Lévêque gave a characterization of directed path graphs by a "special type" of asteroidal triple, and asked whether or not there was such a characterization for path graphs [1]. We give strong evidence that asteroidal triples alone are insufficient to characterize the family of path graphs, and give a new characterization of path graphs via a forbidden induced subgraph family that we call sun systems. Key to our new characterization is the study of asteroidal sets in sun systems, which are a natural generalization of asteroidal triples.

References

[1] Cameron, K., Hoàng, C.T., Lévêque, B.: Characterizing directed path graphs by forbidden asteroids. Journal of Graph Theory 68(2), 103-112 (2011)

[2] Lekkerkerker, C.G, Boland, J.C.: Representation of a finite graph by a set of intervals on the real line. Fundamenta Mathematicae 51, 45-64 (1962)

Constructive algorithm for path-width of matroids

Jisu Jeong – KAIST
Eun Jung Kim – LAMSADE
Sang-il Oum – KAIST

Abstract: Given n subspaces of a finite-dimensional vector space over a fixed finite field $\mathbb{F}$, we wish to find a linear layout $V_1, V_2, \ldots, V_n$ of the subspaces such that $\dim((V_1 + V_2 + \cdots + V_i) \cap (V_{i+1} + \cdots + V_n)) \leq k$ for all i; such a linear layout is said to have width at most k. When

[4] With apologies to Jack Edmonds.

restricted to 1-dimensional subspaces, this problem is equivalent to computing the path-width of an $\mathbb{F}$-represented matroid in matroid theory and computing the trellis-width (or minimum trellis state-complexity) of a linear code in coding theory.

We present a fixed-parameter tractable algorithm to construct a linear layout of width at most k, if it exists, for input subspaces of a finite-dimensional vector space over $\mathbb{F}$. As corollaries, we obtain

- a fixed-parameter tractable algorithm to produce a path-decomposition of width at most k for an input $\mathbb{F}$-represented matroid of path-width at most k, and
- a fixed-parameter tractable algorithm to find a linear rank-decomposition of width at most k for an input graph of linear rank-width at most k.

In both corollaries, no such algorithms were known previously. Our approach is based on dynamic programming combined with the idea developed by Bodlaender and Kloks (1996) for their work on path-width and tree-width of graphs.

It was previously known that a fixed-parameter tractable algorithm exists for the decision version of the problem for matroid path-width; a theorem by Geelen, Gerards, and Whittle (2002) implies that for each fixed finite field $\mathbb{F}$, there are finitely many forbidden $\mathbb{F}$-representable minors for the class of matroids of path-width at most k. An algorithm by Hliněný (2006) can detect a minor in an input $\mathbb{F}$-represented matroid of bounded branch-width. However, this indirect approach would not produce an actual path-decomposition even if the complete list of forbidden minors were known. Our algorithm is the first one to construct such a path-decomposition and does not depend on the finiteness of forbidden minors.

Phylogenetic incongruence through the lens of Monadic Second Order logic

Steven Kelk – Maastricht University
Leo van Iersel – Delft University of Technology
Celine Scornavacca – I-SEM, CNRS, University of Montpellier
Mathias Weller – LIRMM, CNRS, University of Montpellier

Abstract: Within the field of phylogenetics there is growing interest in measures for summarising the dissimilarity, or *incongruence*, of two or more phylogenetic trees. Many of these measures are NP-hard to compute and this has stimulated a considerable volume of research into fixed parameter tractable algorithms. In this talk we use *Monadic Second Order* logic (MSOL) to give alternative, compact proofs of fixed parameter tractability for several well-known incongruence measures. In doing so we wish to demonstrate the considerable potential of MSOL - machinery still largely unknown outside the algorithmic graph theory community - within phylogenetics, introducing a number of "phylogenetics MSOL primitives" which will hopefully be of use to other researchers. A crucial component of this work is the observation that many incongruence measures, when bounded, imply the existence of an *agreement forest* of bounded size, which in turn implies that an auxiliary graph structure, the *display graph*, has bounded treewidth. It is this bound on treewidth that makes the machinery of MSOL available for proving fixed parameter tractability. Due to the fact that all our formulations are of constant length, and are articulated in the restricted variant of MSOL known as MSO_1, we actually obtain the stronger result that all these incongruence measures are fixed parameter tractable purely in the treewidth (in fact, if an appropriate decomposition is given:

the cliquewidth) of the display graph. To highlight the potential importance of this, we re-analyse a well-known dataset and show that the treewidth of the display graph grows more slowly than the main incongruence measures analysed in this talk.

The structure of graphs excluding Gem and $\hat{K}_4$ as induced minors

Jarosław Błasiok – School of Engineering and Applied Sciences, Harvard University, United States
Marcin Kamiński – Institute of Computer Science, University of Warsaw, Poland
Jean-Florent Raymond – Institute of Computer Science, University of Warsaw, Poland and LIRMM – Université de Montpellier
Théophile Trunck – LIP, ÉNS de Lyon

Abstract: A graph H is an *induced minor* of a graph G it it can be obtained by contracting an induced subgraph of G. When H is not an induced minor of G, then G is said to be H*-induced minor-free*. No decomposition theorem of H-induced minor-free graphs is known in the general case, unlike H-minor-free graphs.

We give two decomposition theorems corresponding to the cases $H = \text{Gem}$ and $H = \hat{K}_4$, where Gem can be constructed by adding a dominating vertex to P_4 and $\hat{K}_4$ by adding a vertex of degree 2 to K_4. Our motivation for the choice of these two graphs was a study of the well-quasi-ordered graph classes excluding one graph as induced minors.

Tree-depth and space efficiency of parameterized graph algorithms

Michal Pilipczuk
Marcin Wrochna – University of Warsaw

Abstract: One of the drawbacks of the standard technique of dynamic programming on path and tree decompositions is that the space usage is exponential in the decomposition's width. We investigate whether this is unavoidable by considering the computational complexity of graph problems limited to instances of small width or depth. We complete the landscape sketched for pathwidth and treewidth by Allender et al. [1], by considering the parameter tree-depth: We prove that computations on tree-depth decompositions correspond to a model of non-deterministic machines that work in polynomial time and logarithmic space, with access to an auxiliary stack of maximum height equal to the decomposition's depth. Together with the results of Allender et al., this describes a hierarchy of complexity classes for polynomial-time non-deterministic machines with different restrictions on the access to working space, which mirrors the classic relations between treewidth, pathwidth, and tree-depth. As corollaries we get equivalent characterizations of the complexity classes involved and a result on their determinization. We then comment on plausible deterministic time-space trade-offs.

References

[1] E. Allender, S. Chen, T. Lou, P. A. Papakonstantinou, and B. Tang. Width-Parametrized SAT: Time–Space Tradeoffs. *Theory of Computing 10, pp. 297–339, 2014*

Automorphism Groups of Geometrically Represented Graphs

Pavel Klavík – Charles University in Prague
Peter Zeman – Charles University in Prague

Abstract: We describe a technique to determine the automorphism group of a geometrically represented graph, by understanding the induced action of the automorphism group on the set of all geometric representations. Each automorphism of a graph can be decomposed into two parts: an automorphism of a representation and a morphism of a representation to another one. We apply this technique to interval graphs, unit interval graphs, permutation graphs, circle graphs and comparability graphs. We show that interval graphs have the same automorphism groups as trees and unit interval graphs the same as disjoint unions of caterpillars. For permutation (which are comparability graphs of the dimension two) and circle graphs, we show their classes of automorphism groups as slightly larger than for trees, and we give their inductive descriptions. On the other hand, we show that any finite group is the automorphism group of a comparability graph with the dimension at most four.

Our approach combines techniques from group theory (group products, homomorphisms, quotients, actions) with computer science data structures (PQ-trees, modular trees, split trees).

Speakers.

Jørgen Bang-Jensen, Florian Barbero, Julien Baste, Nick Brettell, Steven Chaplick, Julia Chuzhoy, Vincent Cohen-Addad, Konrad Dabrowski, Till Fluschnik, Robert Ganian, Archontia Giannopoulou, Chinh T. HoàngJisu JeongGwenaël Joret, Pavel Klavik, Dieter Kratsch, Jan Kratochvil, O-Joung Kwon, George Mertzios, Martin Milanic, Valia Mitsou, Pedro Montealegre, Lalla Mouatadid, Sang-Il Oum, Jean-Florent Raymond, Céline Scornavacca, Marcin Wrochna, Peter Zeman,

Participants:

Jørgen Bang-Jensen, Florian Barbero, Julien Baste, Rémy Belmonte, Benjamin Bergougnoux, Edouard Bonnet, Nick Brettell, Katrin Casel, Steven Chaplick, Ilkyoo Choi, Hojin Choi, Vincent Cohen-Addad, Derek Corneil, Konrad Dabrowski, Feodor Dragan, François Dross, Till Fluschnik, Jakub Gajarský, Robert Ganian, Tomáš Gavenčiak, Archontia Giannopoulou, Moritz Gobbert, Alexander Grigoriev, Michel Habib, Tatiana Hartinger, Chinh Hoàng, Jisu Jeong, Mark Jones, Gwenaël Joret, Chuzhoy Julia, Dongyeap Kang, Pavel Klavik, Tereza Klimosova, Dušan Knop, Ekkehard Köhler, jan Kratochvil, Dieter Kratsch, O-joung Kwon, Michael Lampis, Ngoc Khang LE, Frédéric Maffray, George Mertzios, Martin Milanic, Valia Mitsou, Pedro Montealegre, Lalla Mouatadid, Sang-il Oum, Christophe Paul, Michal Pilipczuk, Andrzej Proskurowski, Jean-Florent Raymond, Fernando Sanchez Villaamil, Ignasi Sau Valls, Celine Scornavacca, Mordechai Shalom, Manuel Sorge, Nicolas Trotignon, Yushi Uno, Mathias Weller, Marcin Wrochna, Peter Zeman