Parameterized Complexity News

Newsletter of the PC Community November 2011

Welcome

Frances Rosamond, Editor
Congratulations to Serge Gaspers and Mohammad Taghi Hajiaghayi for multiple awards, to Yoichi Iwata for the IPEC Excellent Student Paper award, and to others on new positions. This newsletter includes useful citation statistics by Mike Fellows. Neeldhara Misra has agreed to be Column Editor of a regular column about blogs. Magnus Wahlström, Stefan Kratsch and Danny Hermelin have each contributed outstanding articles on latest results. There is an excellent report on WorKer, including Open Problems. The Table of Races is quite large, and so I have placed it at the end of the newsletter. Please help keep it updated at our community wiki **www.fpt.wikidot.com**. We also report new available positions, conferences, and call for papers.

Serge Gaspers – TWO awards!

Congratulations to **Serge Gaspers** who was forced to choose between two Australian awards. Serge was awarded the prestigious University of New South Wales (UNSW) Vice-Chancellor Award, and also the Australian Research Council Discovery Early Career Researcher Award (DECRA). Serge has chosen the DECRA, with funding of 375,000AUD over 3 years. Serge will be mentored by Prof. Toby Walsh at UNSW, School of Computer Science and Engineering. The success rate of DECRA was only about 12%.

Figure 1: Serge Gaspers

The title of Serge's project is: Solving intractable problems: from practice to theory and back.

Mohammad Taghi Hajiaghayi

Congratulations to **Mohammad Taghi Hajiaghayi**, the Univ. Maryland. During 2011 he has been awarded the prestigious Office of Naval Research (ONR) Young Investigator Award, an NSF CAREER Award, and a Google Faculty Research Award with total more than 1M dollars. A PostDoc position is available starting Jan 1, 2012 or later, in his algorithms theory group, especially in Algorithmic Game Theory, Fixed Parameter Algorithms, and Approximation Algorithms. Contact `Hajiaghayi@gmail.com`. The subject of the e-mail should be "POSTDOC2011."

Contents of this issue:

Welcome . . . 1
Serge Gaspers –TWO awards! . . . 1
Mohammad Taghi Hajiaghayi . . . 1
IPEC Excellent Student Paper Award . . . 2
www.fpt.wikidot.com . . . 2
Some Notes on the Performance of the Field, by Mike Fellows . . . 2
The AND-conjecture may be necessary, by Magnus Wahlström . . . 3
The Theory Blogosphere, by Neeldhara Misra . . . 4
Hierarchies of Inefficient Kernelizabilty, by Danny Hermelin . . . 5
Co-nondeterministic compositions, by Stefan Kratsch . . . 5
WorKer 2011 – A Report and Open Problems, by Serge Gaspers, Sebastian Ordyniak, and Stefan Szeider . . . 6
CATS PC Tutorial - Feb 3 . . . 8
APEX papers due Dec 7 . . . 8
ISAAC 2011 Japan - December . . . 8
Computational Social Choice - Auckland . . . 8
Special Issue: Call for Papers . . . 9
Promotions and Moves . . . 9
Positions Available . . . 9
Computer Science Outreach . . . 10
Table of Races . . . 10

IPEC Excellent Student Paper Award

Congratulations to **Yoichi Iwata** for winning an IPEC Excellent Student Paper Award for his paper, *A Faster Algorithm for Dominating Set Analyzed by the Potential Method*.

Figure 2: Yoichi Iwata

Yoichi is a Master's student in the Dept of CS, Grad. School of Information Science and Technology, Univ. of Tokyo. He has also won programming contests. The award was presented at the 2011 IPEC at ALGO 2011, Max Planck Institute for Informatics, Saarbrucken.

---

www.fpt.wikidot.com

Please visit the new pages that Bart Jansen has added to the wiki. See *FPT papers online* at `http://fpt.wikidot.com/fpt-papers-online`. Bart welcomes information, and adds papers as they appear. He uses `http://feedworld.net/toc/` to track what has been added to arXiv.

The *Parameterized Complexity Newsletter* is archived on the wiki. Anyone wishing to receive the newsletter by email can sign onto Fran's mailing list here: `http://mrfellows.net/mailman/listinfo/fptnews_mrfellows.net` under the heading "Subscribing to Fptnews".

The current setting is that everybody who subscribes receives an email where (s)he needs to confirm the subscription, without needing Fran's approval. If you have changed email address, please un-subscribe and then re-subscribe with your new address.

Some Notes on the Performance of the Field

by Michael Fellows, Charles Darwin University, Australia.

The following data was gathered using the fairly easy-to-use citation analysis engine **Publish or Perish**, that runs on top of Google Scholar data. By *MVA papers* is meant any paper that could have been published at IPEC. In the early part of the last ten years, there were some papers that clearly were about parameterized algorithms, but avoided mentioning this, but most of these cases have become known. But still, some uncertainties remain, and there is no claim that this data is exact.

I think we can be proud of the performance, expansion, and practical relevance of the field over a significant span of time. I think we can increasingly quantitatively document a fundamental paradigm shift to a multivariate view of algorithms and complexity. I expect this data to be useful to grant proposals (and progress reports), job applications, and so on. Enjoy!

Siam J. Computing
Average number of citations per paper, for papers published since 1995 (incomplete analysis, as only the top-cited 1000 in the period were analyzed) = 55
Average in that period and sample for MVA papers = 90
Note: for the period 2001-2011 (where the sample is still incomplete) the average per paper citation rate is 26, averaging over all papers published.

Journal of the ACM
Average number of citations per paper, for papers published since 2004 = 16
Average in that period for MVA papers = 31
Note: for the period 2001-2011 (where the sample is still incomplete) the average per paper citation rate is 26, averaging over all papers published.

Journal of Computer and System Sciences
Average number of citations per paper, for papers published since 2001 = 17
Average in that period for MVA papers = 26

Algorithmica
Average number of citations per paper, for papers published since 2001 (incomplete analysis, as only the top-cited 1000 were analyzed) = 11
Average in that period for MVA papers = 31

Information and Computation
Average number of citations per paper, for papers published since 2001 (incomplete analysis, as only the top-cited 1000 were analyzed) = 13
Average in that period for MVA papers = 20

Theoretical Computer Science
Average number of citations per paper, for papers published since 2001 (incomplete analysis, as only the top-cited 1000 were analyzed, as supplied by Google Scholar to the Publish-or-Perish engine) = 38
Average in that period for MVA papers = 49

Theory of Computing Systems
Average number of citations per paper, for papers published since 2001 = 8
Average in that period for MVA papers = 12

Information Processing Letters
Average number of citations per paper, for papers published since 2001 (incomplete analysis, as only the top-

cited 1000 were analyzed, as supplied by Google Scholar to the Publish-or-Perish engine) = 15
Average in that period for MVA papers = 18

ACM Transactions on Algorithms
Average number of citations per paper, for papers published since the journal began = 14
Average in that period for MVA papers = 17

Comment 1. The numbers look very good for the field, which shows every sign of continued exponential growth, in all ways: funding, papers per year accepted to SODA, researchers active in the area, etc. In fact, I think a case can be made that the shift to multivariate algorithmics is one of cleanest examples of a Kuhnian paradigm shift, that Kuhn could ever have hoped to find. Mathematically, it is stark, simple and productive.

Back to the numbers: consider the JCSS data. It looks like, in the ten year period 2001-2011, that papers in the area of parameterized/multivariate algorithmics have a per paper citation rate 53 % higher than papers on average in that period.

But this isn't quite a fair comparison, because of two things:
(1) The exponential growth of the field means that the publication dates of papers in the field in that window are skewed towards "more recent". This function is fairly well estimated. The field has been doubling every 3.7 years since its inception.
(2) As a paper destined for citations ages, citations come in. It takes a while for them to build up, and the average per year citation-rate of a paper as a function of its age, is a more mysterious function, probably moderately exponential for a period, and then flattening.

Based on the above, particularly the "fairly sure" estimate of the function in (1), and a guestimate of (2) consistent with the average performance data, I estimate the *headwind distortion* at an approximate ratio of 5/3.

In other words, the JCSS average number of cites per paper for the ten year period is nominally 17 per paper on average *versus* 26 per MVA paper. But adjusting for the headwind, the comparison is probably more like: 17 on average *versus* 43 for MVA papers.

Comment 2. It is interesting that the numbers bear out common perceptions, such as "What are the top two journals?". Most would say *JACM* or *SIAM J. Computing* are tied for top rank, and the data says (for the truncated sample, since Google Scholar stops supplying raw data at 1000 items), both have an average per paper citation rate, for papers published in the ten year period 2001–2011 of 26. But what's with *Theoretical Computer Science* which comes in at 38? But *TCS* publishes many more papers than *JACM* or *SIAM J. Computing*, so the top-1000 sample is from a more selective lot.

The AND-conjecture may be necessary

by Magnus Wahlström, Max Planck Institut für Informatik, Saarbrücken, Germany. The result is joint with Stefan Kratsch, Universiteit Utrecht, The Netherlands.

At WorKer this year in Vienna, Mike raised a question originally asked by Bart Jansen: Are there parameterized problems which are AND-compositional but (under some complexity conjecture) provably not OR-compositional? In other words, can we prove that we gain extra power from the AND-conjecture, compared to what we get from OR-compositions? (For definitions, see Bodlaender et al. [2].)

We sketch the simple construction of such a problem. We need two slightly unusual concepts. First, a co-NP kernel is a non-deterministic kernel without false negatives – i.e., a non-deterministic polynomial-time computation, where every computation path outputs a poly(k)-sized instance, and where one such output is a negative instance if and only if the input is negative. Second, an AND-kernel is the polynomial-time reduction of an instance of size n, parameter k, into a conjunction over poly(n) instances of size poly(k). (The kind of "cheating" kernels given for k-LEAF-OUT-BRANCHING [3] and CLIQUE parameterized by maximum degree [5] could thus be called OR-kernels.)

The key is now that the Fortnow-Santhanam results [3] exclude even co-NP distillations (see [2]), and that an AND-kernel implies a co-NP kernel, by simply (nondeterministically) selecting one of the produced instances as the kernel. Thus, an OR-compositional problem cannot have an AND-kernel unless the polynomial hierarchy collapses.

Consider now the problem CLIQUE IN EVERY COMPONENT: The input is a graph G and an integer k, and the question is whether every connected component of G contains a k-clique. The parameter is the size of the largest connected component of G. The problem is easily AND-compositional, and NP-hard in its unparameterized version (with a single component), thus does not have a polynomial kernel under the AND-conjecture. However, it has a trivial AND-kernel, which (by above) implies that it is not OR-compositional unless the polynomial hierarchy collapses. Thus, the Fortnow-Santhanam results cannot be used to exclude a polynomial kernel for CLIQUE IN EVERY COMPONENT, although the AND-conjecture can.

[1] H. L. Bodlaender, R. G. Downey, M. R. Fellows, and D. Hermelin. On problems without polynomial kernels. *J. Comput. Syst. Sci.*, 75(8):423–434, 2009.

[2] H. Dell and D. van Melkebeek. Satisfiability allows no nontrivial sparsification unless the polynomial-time hierarchy collapses. In *STOC*, pages 251–260, 2010.

[3] H. Fernau, F. V. Fomin, D. Lokshtanov, D. Raible, S. Saurabh, and Y. Villanger. Kernel(s) for problems with

no kernel: On out-trees with many leaves. In *STACS*, pages 421–432, 2009.

[4] L. Fortnow and R. Santhanam. Infeasibility of instance compression and succinct PCPs for NP. *J. Comput. Syst. Sci.*, 77(1):91–106, 2011.

[5] D. Hermelin, S. Kratsch, K. Soltys, M. Wahlström, and X. Wu. Hierarchies of inefficient kernelizability. *CoRR*, abs/1110.0976, 2011.

The Theory Blogosphere

Neeldhara Misra, Column Editor, Institute for Mathematical Sciences, Chennai, India.

In recent times, a number of preliminary ideas, proof expositions, opinions, and developments have made their way to the public domain through blogs written by eminent experts. The medium has provided for an excellent channel of communication, and has come close to providing the flavor of a "real world" discussion. Many theoretical computer scientists happen to be avid bloggers as well, and this has led to a CS blogosphere that is evolving at an exciting pace. This column is a brief peek into the world of CS blogs, and it is hoped that this will inspire contributions from the parameterized community!

Gödel's Lost Letter and P=NP This is a blog on P=NP and other questions in the theory of computing, authored by Dick Lipton. It is named after after the famous letter that Gödel wrote to von Neumann which essentially stated the question decades before Cook and Karp. This blog is just shy of being three years old, and with over 200 posts, much of the content of the blog has been organized into a book, which can be found at `http://rjlipton.wordpress.com/2010/09/17/my-book-on-pnp-is-now-available/`.

A particularly interesting post explored the question of whether emptiness checking of the intersection of finite automata can be done in a manner that beats having to construct the product automata. Specifically, given automata $A_1, \ldots, A_k$, what are the consequences of having an algorithm that ran in time $n^{o(k)}$ and determined whether or not there was an input they all accepted? Among various implications, it was established that $NDTIME(n) \subseteq DTIME(2^{\varepsilon n})$, for any $\varepsilon > 0$. Subsequently, Dániel Marx pointed out in the comments that a stronger result can be obtained by employing a parameterized reduction from clique, which rules out algorithms running in time $f(k) \cdot n^{o(k)}$, assuming the ETH. The full post may be found here: `http://rjlipton.wordpress.com/2009/08/17/on-the-intersection-of-finite-automata/`.

Computational Complexity Actively updated since 2002, *Computational Complexity* is among the earliest theory blogs. It is jointly authored by Lance Fortnow and Bill Gasarch. The blog features, in the words of the authors, "computational complexity and other fun stuff in math and computer science". One of the most popular posts on the blog involved an open problem challenge, with a financial incentive (not unlike the open problem sessions at WorKer).

The question is easily stated. The $n \times m$ grid is c-colorable if there is a way to c-color the vertices of the $n \times m$ grid so that there is no rectangle with all four corners the same color. (The rectangles pertinent to this problem are the axis-parallel ones.) The blog stated that "the first person to email me a 4-coloring of 17x17 in LaTeX will win $289.00." It was also stated that if 17x17 is not 4-colorable, then nobody will collect the $289.00. The slides from a talk that provide the context for the problem may be found at `http://www.cs.umd.edu/~gasarch/papers/gridtalk.pdf`, while the corresponding paper is here: `http://www.cs.umd.edu/~gasarch/papers/grid.pdf`. Various follow-ups and attempts have been posted, even on other blogs, but at the time of this writing, the problem remains open. The original blog post is here: `http://blog.computationalcomplexity.org/2009/11/17x17-challenge-worth-28900-this-is-not.html`.

Shtetl-Optimized This is the very popular blog of Scott Aaronson, with the first post dating back to late 2005 — the trivia in the introductory post also explains the name of the blog. Shtetl-Optimized is full of commentary, humor, news, opinions and the frequent techno-expository post. The blog is also the home of the lecture series *Quantum Computing Since Democritus* and *Great Ideas in Theoretical Computer Science*. In the latter series, the notes on "NP-completeness in practice" refer to parameterized complexity as a fundamental coping strategy.

0xDE This is the blog of David Eppstein, around since mid-2005. The updates reflect his interests in computational geometry and graph algorithms, and photography too! One of his recent posts explores the intriguing question of how one might identify an infinite graph as being chordal. The definition evidently gets tricky quickly: properties that are easily seen to be equivalent for finite graphs lose the equivalence in the world of infinite graphs. For instance, a doubly-infinite path does not have any simplicial vertices, but satisfies the property that very cycle of length greater than three has a chord — while these properties are equivalent in the case of finite graphs. An alternative definition based on the theory of well-orderings is proposed and justified, and the details can be found at `http://11011110.livejournal.com/234995.html#cutid1`.

For those who would like to keep track of new blog posts, the content from nearly forty active blogs is conveniently "aggregated" at one central place, and can be found at `http://feedworld.net/toc/`.

Hierarchies of Inefficient Kernelizabilty

by Danny Hermelin, Max Planck Institut für Informatik, Saarbrücken, Germany.

The recently introduced lower bounds framework for kernelization has proven to be very useful in many settings, allowing the exclusion of polynomial kernels for numerous problems under the assumption of coNP $\not\subseteq$ NP/poly. However this framework has two main drawbacks: It does not scale easily to exclude kernels of size significantly larger than polynomial (*e.g.* subexponential kernels), and moreover, it does not exclude Turing-kernels of even linear size. The latter is because Turing-kernelizations are allowed to make a number of oracle queries which depends on the total input length, breaking down the complexity-theoretic argument underlying the existing lower bound framework.

The latter drawback is not merely a theoretical objection. First of all, Turing-kernelization is arguably just as applicable as regular kernelization in many practical settings. Furthermore, there are known examples of problems that do not admit polynomial kernels but still have Turing-kernels of polynomial size. For instance, Fernau, Fomin, Lokshtanov, Raible, Saurabh, and Villanger showed in a 2009 STACS paper that the LEAF OUT BRANCHING(k) problem has no polynomial kernel, yet it admits a $O(k^3)$ kernel as soon as the root of the out-branching has been fixed. As another example, consider the CLIQUE(Δ) problem (the clique problem parameterized by the maximum degree of the graph): It is very easy to exclude the existence of a polynomial kernel for CLIQUE(Δ) (using disjoint union composition), but simply making one initial selection of a vertex that is to be included in the clique reduces the instance down to size Δ.

Attempting at obtaining lower bounds for Turing kernelizations, Kratsch, Sołtys, Wahlström, Wu, and myself abandoned the existing working hypothesis of coNP $\not\subseteq$ NP/poly and adopted a different approach. We first observed that polynomial Turing kernels are preserved under polynomial parametric transformations (PPTs), a type of reduction introduced by Bodlaender, Thomassé, and Yeo to exclude regular polynomial kernelizations. We then identified a hierarchy of problems in EXPT (*i.e.* problems solvable in $2^{\mathrm{poly}(k)} \cdot \mathrm{poly}(n)$ time) which we believe are hard kernelize, even under the relaxed notion of Turing kernelization. Roughly speaking, these problems are reparameterizations of the weft-t satisfiability problems used to define the W- and M-hierarchies, where the original parameter is multiplied by a factor of $\log n$. Considering the PPT-closure of all these problems leads to two hierarchies of classes: The WK-hierarchy and the MK-hierarchy. These hierarchies refine EXPT, intertwining together to form a tower of inclusions similar to the one formed by the W- and M-hierarchies:

$$\mathrm{MK}[1] \subseteq \mathrm{WK}[1] \subseteq \mathrm{MK}[2] \subseteq \mathrm{WK}[2] \subseteq \cdots \subseteq \mathrm{EXPT}.$$

The class MK[1] corresponds to problems with polynomial kernels. Thus, the fundamental hardness class of our hierarchies is WK[1], which we hope will play the same role for Turing kernelizabilty as W[1] plays for FPT-time algorithms. Indeed, it includes within it all problems for which regular polynomial kernels have been excluded, where many of these turn out to actually be complete for this class. For instance, the k-halting problem for non-deterministic Turing machines parameterized by $k \log n$ is complete for this class, and the same problem restricted to machines with binary tapes is complete when parameterized by k. Other examples include reparameterizations of many W[1]-complete problems such as CLIQUE($k \log n$), and several EXPT problems under the standard parameterization of solution size such as CONNECTED VERTEX COVER(k) and UNIQUE COVERAGE(k).

Thus, the new working conjecture for kernelization theory that we propose is the conjecture that WK[1] $\not\subseteq$ Turing-PK, where Turing-PK is the class of all parameterized problems with polynomial Turing kernelizations. Our belief in this conjecture stems from the intuition behind the more established W[1] $\neq$ FPT conjecture, and from the fact that so many problems turn out to be complete for WK[1]. Of course we have no idea of how to prove this conjecture, but we hope it provides an accessible platform for showing some kind of evidence for the non-existence of polynomial Turing-kernelizations.

Co-nondeterministic compositions

by Stefan Kratsch, Universiteit Utrecht, The Netherlands.

At WorKer 2010 in Leiden, Rod Downey posed the interesting question of whether the following problem admits a polynomial kernel: Given a graph G and an integer k, does G contain a clique *or* an independent set of size at least k? Apart from the theoretical interest in this nice variant of two favorite problems, such a kernel would greatly speed up the computation of Ramsey numbers. The problem is FPT by a more general result of Khot and Raman [4] for finding induced subgraphs which are members in certain hereditary graph classes.

Unfortunately, recent work [5] shows that the problem has no polynomial kernel unless NP $\subseteq$ coNP/poly. On the bright side, however, the way of getting this result turned out to be quite interesting as the used composition requires co-nondeterminism. Roughly, this means that given t instances, if one of them is YES then each computation path must return a YES instance. Otherwise, if all instances are NO, then at least one path of the composition must give a NO instance.

It is already implicit in the work of Fortnow and Santhanam [3] (and using results of Bodlaender et al. [2]) that co-nondeterminism can be allowed for both polynomial kernels and compositions while still implying the same collapse of the polynomial hierarchy. This was observed in unpublished work of Chen and Müller. Intuitively it comes from the fact that to show NP $\subseteq$ coNP/poly we build a coNP-machine to accept some NP-hard language, using a polynomial kernel and a composition as subroutines. There is no immediate reason why the subroutines should not be allowed co-nondeterminism as well!

The composition for our "Ramsey problem" appears to be the first to actually make use of this additional power for compositions. It is used, when composing t instances, to find a so-called host graph on roughly t vertices which describes how the graphs of the instances will be connected: each graph is assigned one vertex of the host graph H, and we take the join of two graphs iff their two corresponding vertices are adjacent in H. The constraints on the host graph are that, for some integer ℓ, it does not contain cliques or independent sets of size greater than ℓ, and that each vertex is contained in a clique or an independent set of size ℓ. Modulo some details, this can be seen to give the desired behavior. It remains to actually find such a host graph such that $\ell = t^{o(1)}$, to exclude all polynomial kernels. As an example, the disjoint union of $\sqrt{t}$ cliques of size $\sqrt{t}$ each gives $\ell = \sqrt{t}$.

Work of Barak et al. [1] provides graphs with t vertices and excluding cliques and independent sets of size exceeding $\ell = t^{o(1)}$. However, with the large value of ℓ it seems even harder to find the covering; it is much easier to do this when $\ell \sim \log t$. Instead, a lemma about gaps between consecutive Ramsey numbers (kindly provided by Pascal Schweitzer) allows us to find graphs which are small enough to have no larger cliques or independent sets, but large enough to get the covering as a consequence of the exceeded Ramsey numbers. We get $\ell = \mathcal{O}(\log t)$, thus excluding polynomial kernels for the "Ramsey problem" assuming NP $\nsubseteq$ coNP/poly.

Co-nondeterminism can help finding compositions and hence prove more lower bounds. One way to use it, is to create less regular ways of composing the given instances, to lower the dependence on their number. Similarly, we may venture to find co-nondeterministic kernelizations in order to exclude the possibility of a composition.

[1] B. Barak, A. Rao, R. Shaltiel, and A. Wigderson. 2-source dispersers for sub-polynomial entropy and Ramsey graphs beating the Frankl-Wilson construction. In J. M. Kleinberg, editor, *STOC*, pages 671–680. ACM, 2006.

[2] H. L. Bodlaender, R. G. Downey, M. R. Fellows, and D. Hermelin. On problems without polynomial kernels. *J. Comput. Syst. Sci.*, 75(8):423–434, 2009.

[3] L. Fortnow and R. Santhanam. Infeasibility of instance compression and succinct PCPs for NP. *J. Comput. Syst. Sci.*, 77(1):91–106, 2011.

[4] S. Khot and V. Raman. Parameterized complexity of finding subgraphs with hereditary properties. *Theor. Comput. Sci.*, 289(2):997–1008, 2002.

[5] S. Kratsch. Co-nondeterminism in compositions: A kernelization lower bound for a Ramsey-type problem. *CoRR*, abs/1107.3704, 2011. To appear in SODA 2012.

WorKer 2011 – A Report and Open Problems

by Serge Gaspers, Sebastian Ordyniak, and Stefan Szeider, Vienna University of Technology.

WorKer 2011, the 3rd Workshop on Kernelization, took place at the Vienna University of Technology in Austria from 2–4 September 2011. After successful workshops in Bergen 2009 and Leiden 2010, this third workshop aimed at consolidating the results achieved in recent years and discussing future research directions.

A special aspect this year was to take a closer look at related work from different research areas, in particular from Practical Preprocessing, Property Testing, and Knowledge Compilation. Therefore invited leading researchers from these three areas gave keynote talks: Armin Biere (Johannes Kepler University, Linz, Austria), Sourav Chakraborty (Chennai Mathematical Institute, India), and Pierre Marquis (Université d'Artois & CRIL-CNRS, France). These talks were complemented by five more traditional keynote talks on kernelization by Mike Fellows, Fedor Fomin, Bart Jansen, Daniel Lokshtanov, and Anders Yeo. New developments in this vibrant and rapidly developing area were presented in twelve contributed talks. With a total of 58 international participants the workshop provided opportunities to engage in joint research and discussions on open problems and future research directions. For the full program, the slides of the talks, and pictures taken during the workshop and the workshop dinner at a local Heurigen, see the workshop webpage `http://www.kr.tuwien.ac.at/drm/worker2011`.

In the following we state questions presented at the workshop's *open problem session*.

Bart Jansen considered the q-Coloring problem parameterized by VC, which has as input a graph G and a vertex cover X of G, the parameter is $k = |X|$, and the question is whether the chromatic number of G is at most q. The problem has a kernel with $O(k^q)$ vertices which can also be encoded in $O(k^q)$ bits, but for every $q \geq 4$ the q-Coloring problem parameterized by VC does not have a kernel of bitsize $O(k^{q-1-\epsilon})$ for any $\epsilon > 0$ unless NP $\subseteq$ coNP/poly. Which kernel size is tight? The question is strongly related to kernel size bounds for the q-NAE-SAT problem (satisfiability with q literals per clause, where a clause is satisfied if not all its literals evaluate to the same truth value) parameterized by the number of variables [7].

Mike Fellows reported that there are a large number of open problems in different areas, that basically ask whether some parameterization of the problem is in XP. For these problems, it is still interesting to ask if one can at least show W-hardness. One example is Unit Task Length Precedence-Constrained Scheduling with k Processors. The question of whether this problem is in XP (that is, "solvable in polynomial-time for every fixed k") is on the famous list of open problems in the concluding pages of [4] – and one of the few problems on that list that still remains open. However, Bodlaender and Fellows [1] showed that the problem is W[2]-hard with respect to the parameter k, and thus even if the problem is in XP, this is unlikely to be in any way that is useful for $k \geq 3$. The point here is that W-hardness is still significant for concrete problems not known to be in XP.

Gregory Gutin posed the following problem which was first stated in [5] for graphs and hypergraphs. For a graph G, let $\alpha(G)$ be the maximum size of an independent set. Let d be a constant and let G be a d-degenerate graph. It is easy to prove that $\alpha(G) \geq n/(d+1)$, where n is the number of vertices in G. What is the parameterized complexity of the following problem: decide whether for a d-degenerate graph G we have $\alpha(G) \geq n/(d+1) + k$, where k is the parameter? If d is the maximum degree of G, then the problem is fpt and has a linear kernel as observed in [6]. It is also observed in [6] that, in this case, if d is part of input, then the problem is W[1]-hard.

Marcin Pilipczuk asked whether one can complement the recent kernelization results of Kratsch and Wahlström [8, 9] and rule out, under the usual assumptions, polynomial kernels for some graph separation problems. Our candidates to study are Multiway Cut parameterized above lower bounds, Subset Feedback Vertex Set parameterized by solution size, or sufficient generalizations of these problems. Note that Multicut and Directed Multiway Cut, parameterized by the solution size, were proven to be OR-compositional very recently [3].

In Weihe's train problem [10] one is given a set of trains and a set of stations, each train is associated to the set of stations where it regularly stops on its route. The problem is to select a minimum number of stations covering each train. This problem is equivalent to the Red-Blue Dominating Set problem in a bipartite graph with trains and stations forming the two partite sets (genes and diseases could be modeled the same way). Weihe uses two reduction rules: (1) if $N(t) \subseteq N(t')$ for two trains t, t', then remove t', and (2) if $N(s) \subseteq N(s')$ for two stations s, s', then remove s. These led to a huge empirical success for practical preprocessing of problems concerning European rail networks (with input graphs on the order of 50,000 vertices). The very same model arises in the important Feature Set problem in Computational Medicine and Computational Biology. Mike Fellows asked for explanations of these successes from a theoretical point of view. It is not exactly the same thing as polynomial many:one kernelization, although it is a great example of *pre-processing in practical computing*. The two reduction rules described above reduce the typical inputs to instances that consist of a union of disjoint components of bounded size (like at most 50 vertices each in the case of the train graphs). What's going on here, and how does it generalize?

In Bart Jansen's second question, he asked about the parameterized complexity of the q-Path problem in interval+kv graphs. More precisely, the input is a graph G, a set $X \subseteq V(G)$ such that $G \setminus X$ is an interval graph, and an integer q. The parameter is $k = |X|$, and the question is whether G has a path of length q. Is this problem in FPT? Is it in XP?

Mike Fellows then posed another open question which was communicated to him by Bart Jansen: Are there parameterized problems that are AND-composable but not OR-composable? For more on this topic, see the article by Magnus Wahlström in this Newsletter.

Michał Pilipczuk considered a kind of "parameterized knowledge compilation problem" for the Steiner Tree problem. In the Steiner Tree problem one is given a graph G, a set $T \subseteq V(G)$ of terminals and an integer k, and the question is whether G has a subtree with $k + |T|$ nodes spanning T. Can you preprocess a Steiner Tree instance in FPT time, with a suitable parameter such as $k + |T|$, such that queries about specific terminals can be answered efficiently?

Arash Rafiey asked whether the following problem has FPT or XP algorithms. The input is a bipartite graph G with vertex partition (V, U) and an integer parameter k. The question is whether there is an ordering of the vertices in U such that the neighborhood of each vertex in V consists of at most k intervals. The class of convex bipartite graphs is exactly the class of graphs that are Yes-instances for $k = 1$ and they can be recognized in polynomial time.

The final question was raised by Mike Fellows. The intuition behind the kernel lower bound machinery is that a problem with a composition algorithm does not have a polynomial kernel because the composition of kernelized instances contains too little information to distinguish all the inputs. Mike asked whether a similar reasoning applies to higher levels of the parameterized hierarchy. For example, the naturally parameterized Bandwidth problem is trivially AND-composable, and is known to be W[t]-hard for all $t \geq 1$ [2]. Is the problem in W[P]? This question has remained open for nearly 20 years. Mike claims that the central issue seems to be very similar, possibly related.

The workshop was organized by Serge Gaspers, Sebastian Ordyniak, and Stefan Szeider, and funded by the Vienna Center for Logic and Algorithms (VCLA), the Wolfgang Pauli Institute (WPI), and the European Research Council (ERC).

[1] H.L. Bodlaender, M.R. Fellows. W[2]-hardness of precedence constrained K-processor scheduling. *Oper. Res. Lett.* 18(2):93–97 (1995).

[2] H.L. Bodlaender, M.R. Fellows, M.T. Hallett. Beyond NP-completeness for problems of bounded width: hard-

ness for the W-hierarchy. In *Proc. of STOC 1994*, 449–458 (1994).

[3] M. Cygan, S. Kratsch, M. Pilipczuk, M. Pilipczuk, M. Wahlström. Clique cover and graph separation: new incompressibility results. *arXiv* abs/1111.0570.

[4] M.R. Garey, D.S. Johnson. Computers and intractability. A guide to the theory of NP-completeness. W.H. Freeman and Company, New York (1979).

[5] G. Gutin, M. Jones, A. Yeo. Kernels for below-upper-bound parameterizations of the hitting set and directed dominating set problems. *Theoretical Comput. Sci.* 412:5744–5751 (2011).

[6] G. Gutin, E.J. Kim, M. Lampis, V. Mitsou. Vertex cover problem parameterized above and below tight bounds. *Theory Comput. Syst.* 48:402–410 (2011).

[7] B.M.P. Jansen, S. Kratsch. Data Reduction for Graph Coloring Problems. In *Proc. of FCT 2011*, LNCS 6914, 90–101 (2011).

[8] S. Kratsch, M. Wahlström. Compression via matroids: a randomized polynomial kernel for Odd Cycle Transversal. In *Proc. of SODA 2012*, to appear.

[9] S. Kratsch, M. Wahlström. Representative sets and irrelevant vertices: new tools for kernelization. *arXiv* abs/1111.2195.

[10] K. Weihe. Covering trains by stations or the power of data reduction. In *Proc. of ALEX 1998*, 62–75 (1998).

CATS PC Tutorial - Feb 3

There will be a Parameterized Complexity – Multivariate Complexity Analysis Tutorial sponsored by CATS (Computing: Australasian Theory Symposium) (ACSW Week), FRIDAY 3 FEBRUARY, Melbourne. See `http://fpt.wdfiles.com/local--files/courses-in-pc/CATS.htm`. Speakers include Mike Fellows (Charles Darwin Univ.), Mike Langston (Univ. Tennessee and Oak Ridge National Labs), Franz J. Brandenburg (Univ. Passau), Ljljana Brankovic (Univ. Newcastle, AU), and Gabor Erdelyi (Univ. Siegen). Contact Frances Rosamond, `frances.rosamond@cdu.edu.au`.

APEX papers due Dec 7

The APEX (Approximation, Parameterized and EXact algorithms) workshop is supported by the French National Agency for Research (ANR). It aims to bring together researchers working on the design and analysis of algorithms (exact, moderately exponential, approximation and low memory,...) for combinatorial optimization problems. APEX is co-located with STACS 2012 in Paris.

Papers are solicited in all areas of approximation and exact algorithms, including but not limited to: - exact and parameterized algorithms - approximation and online algorithms - massive data computation - low memory and streaming algorithms - analysis and experimental evaluation of algorithms Submissions deadline: December 7, 2011 Conference: February 28, 2012 `http://apex.lip6.fr`

Invited speakers include Henning Fernau, Universitaet Trier and Martin Skutella, TU Berlin.

ISAAC 2011 Japan - December

The 22nd International Symposium on Algorithms and Computation (ISAAC 2011) will be held in Yokohama, Japan, December 5 – 8, 2011. The list of accepted papers includes papers related to parameterized complexity.

- Cristina Bazgan, Morgan Chopin and Michael Fellows: Parameterized Complexity of the Firefighter Problem
- Victor Campos, Sulamita Klein, Rudini Sampaio and Ana Silva: Two Fixed-Parameter Algorithms for the Cocoloring Problem
- Martin Dörnfelder, Jiong Guo, Christian Komusiewicz and Mathias Weller: On the Parameterized Complexity of Consensus Clustering
- Sylvain Guillemot: Parameterized Algorithms for Inclusion of Linear Matchings
- Jiong Guo, Sepp Hartung, Rolf Niedermeier and Ondřej Suchý: The Parameterized Complexity of Local Search for TSP, More Refined
- Sheng-Ying Hsiao: Fixed-Parameter Complexity of Feedback Vertex Set in Bipartite Tournaments
- Pranabendu Misra, Ramanujan M. S., Venkatesh Raman and Saket Saurabh: A Polynomial Kernel for FEEDBACK ARC SET on Bipartite Tournaments
- Chunhao Wang and Qian-Ping Gu: Computational Study on Bidimensionality Theory Based Algorithm for Longest Path Problem

Among them, we are pleased to announce that Sheng-Ying Hsiao won the Best Student Paper Award of ISAAC 2011. The invited talks will be given by Sanjeev Arora and Dorothea Wagner. Website: `http://www.is.titech.ac.jp/isaac11/`

Computational Social Choice - Auckland

The Centre for Mathematics in Social Sciences in Auckland (New Zealand) is organizing the 3rd Summer Workshop, February 20-22, 2012. The topic of this meeting is

Algorithmic, Logical and Game-theoretic Aspects of Social Choice. This is an excellent venue to share your work and collaborate with others who share your passion and research interests in this broadly defined interdisciplinary area. Contact Arkadii Slinko, `slinko@math.auckland.ac.nz`

Special Issue: Call for Papers

Manuscripts are solicited for a special issue in the journal *Theoretical Computer Science* on “Exact & Parameterized Computation - Moderately Exponential & Parameterized Approximation”

Potential topics include (but are not limited to) the following: - Moderately exponential algorithms for NP-hard problems - Parameterized algorithms - New tools for exact computation - Hardness in fixed parameter computation - Moderately exponential and/or parameterized approximation algorithms for NP-hard problems - Structure in moderately exponential and/or parameterized approximation - New tools for exponential or parameterized approximation - Relations between polynomial approximation and parameterized computation - Probabilistic techniques in exponential approximation

Submissions must be received before December 31, 2011. Please contact Guest Editor, Vangelis Th. Paschos `paschos@lamsade.dauphine.fr`

Promotions and Moves

Holger Dell is now a Postdoctoral Fellow at the University of Wisconsin - Madison, hosted by Dieter van Melkebeek. His research is supported by a Feodor Lynen Research Fellowship of the Alexander von Humboldt Foundation `holger@cs.wisc.edu`.

Rudolf Fleischer has accepted a position with the German University of Technology in Oman (GUtech). The university has been established in collaboration with RWTH Aachen University.

Sylvain Guillemot has accepted a postdoc position at Iowa State. He will be working with David Fernndez-Baca.

Matthias Mnich has moved from Berkeley to accept a PostDoc, jointly at the Cluster of Exellence Multimodal Computing and Interaction with Jiong Guo at Universität des Saarlandes, Saarbrücken, and the Max-Planck-Institut fuer Informatik.

Moritz Müller has moved from Barcelona to become a member of the Kurt Gödel Research Center for Mathematical Logic (KGRC) in Vienna.

Jesper Nederlof will join the research group of Hans Bodlaender at Univ. Utrecht as a PostDoc, starting February 1.

Positions Available

Those with positions to offer are invited to announce at `http://fpt.wikidot.com/jobs:positions-available-and-people-looking`. Another Jobs resource is the Center of Computational Intractability at Princeton `http://intractability.princeton.edu/jobs/`.

Hungarian Academy of Sciences, Budapest

Postdoc positions at the Computer and Automation Research Institute supported by the ERC Starting Grant PARAMTIGHT: “Parameterized complexity and the search for tight complexity results” held by Dàniel Marx. The goal of the project is to systematically push the boundaries of algorithmic and hardess results, mostly in the framework of parameterized complexity, with the aim of obtaining tight results that give an optimal understanding of the complexity of a problem. Contact `dmarx@cs.bme.hu`

Two Positions at UQ, Australia

The University of Queensland (Brisbane, Australia) offers two continuing positions in mathematics (the Australian equivalent of tenure track). UQ Mathematics has strong groups in discrete mathematics and algorithms, and interest in parameterized algorithmics. This includes a large established group in combinatorics (including design theory, graph theory and algebraic combinatorics), and also a smaller but growing group in computational geometry and topology. Applications close on Thursday 17 November (Australian time). Contact Benjamin Burton `bab@maths.uq.edu.au`

Tenure-track assistant professorship at LAMSADE-Paris

Tenure-track assistant professorship with associated CNRS Chair at LAMSADE, University Paris-Dauphine in The Laboratoire d’Analyse et Modelisation de Systemes pour l’Aide a la Decision (Director Prof. Paschos).

The successful candidate will join the project, *Efficient solution of hard Combinatorial Optimization problems: new models concepts and tools*, and work mainly on “Exact computation with provably time complexity upper bounds” on “Moderately exponential time approximation algorithms” and on “Parameterized algorithms”.

Other themes where outstanding applications will also be considered are: Polynomial approximation, On-line computation, Reoptimization, Algorithmic games.

Applications are due by February 2012. Please contact Prof. Vangelis Th. Paschos (paschos@lamsade.dauphine.fr) or Prof. Cristina Bazgan (bazgan@lamsade.dauphine.fr).

Computer Science Outreach

Thore Husfeldt's Sorting Network at Copenhagen's "Culture Night."

Figure 3: Sorting on the stairs

See Thore Husfeldt's interesting story of the Sorting Network that he and his students built when IT Univ. of Copenhagen joined the city-wide "Culture Night" (http://thorehusfeldt.net/2011/10/19/sorting-networks-activity/.)

The Sorting Network is an excellent outdoor, group activity that demonstrates parallel computing. Items can include ordering distances from planets to the sun (science), molecular weights or densities (chemistry), fractions (math), notes and scales (music), eras or events (history), or priorities (social studies).

There are at least two lovely things about sorting networks. (Mike and Fran generally carry one in their luggage, even on international trips, and have nice experiences putting on workshops with it.)

(1) Does it matter if "smaller goes left, and larger goes right" or v.v.? Some people have to think about this. The isomorphism involved is a little bit profound and nontrivial.

(2) Two-in / two-out at every comparator. Same if run backwards. If a sorting network works for all inputs in one direction, then why not when run backwards?

More information about the Sorting Network can be found at http://csunplugged.org/.

Table of Races

The results are improving ever more rapidly. Saket Saurabh is keeping the Table updated on the wiki at www.fpt.wikidot.com. Kernel sizes are measured in the number of vertices.

REFERENCES for the Table of Races

1) Jianer Chen, Iyad A. Kanj, Ge Xia: Improved upper bounds for vertex cover. Theor. Comput. Sci. 411(40-42): 3736-3756 (2010)

2) Yixin Cao, Jianer Chen, Yang Liu: On Feedback Vertex Set New Measure and New Structures. SWAT 2010: 93-104 Stéphan Thomassé: A $4k^2$ kernel for feedback vertex set. ACM Transactions on Algorithms 6(2): (2010)

3) Frederic Dorn: Dynamic Programming and Fast Matrix Multiplication. ESA 2006: 280-291 Jianer Chen, Henning Fernau, Iyad A. Kanj, Ge Xia: Parametric Duality and Kernelization: Lower Bounds and Upper Bounds on Kernel Size. SIAM J. Comput. 37(4): 1077-1106 (2007)

4) Henning Fernau, Fedor V. Fomin, Daniel Lokshtanov, Matthias Mnich, Geevarghese Philip, Saket Saurabh: Ranking and Drawing in Subexponential Time. IWOCA 2010: 337-348 Vida Dujmovic, Henning Fernau, Michael Kaufmann: Fixed parameter algorithms for one-sided crossing minimization revisited. J. Discrete Algorithms 6(2): 313-323 (2008)

5) Jean Daligault, Gregory Gutin, Eun Jung Kim, Anders Yeo: FPT algorithms and kernels for the Directed k-Leaf problem. J. Comput. Syst. Sci. 76(2): 144-152 (2010) V. Estivill-Castro, M. Fellows, M. Langston and F. Rosamond. Fixed-Parameter Tractability is Polynomial-Time Extremal Structure Theory I: The Case of Max Leaf. ACiD, (2004)

6) Jean Daligault, Gregory Gutin, Eun Jung Kim, Anders Yeo: FPT algorithms and kernels for the Directed k-Leaf problem. J. Comput. Syst. Sci. 76(2): 144-152 (2010) Jean Daligault, Stéphan Thomassé: On Finding Directed Trees with Many Leaves. IWPEC 2009: 86-97

7) Jesper Nederlof, Johan M. M. van Rooij: Inclusion/Exclusion Branching for Partial Dominating Set and Set Splitting. IPEC 2010: 204-215 Daniel Lokshtanov, Saket Saurabh: Even Faster Algorithm for Set Splitting! IWPEC 2009: 288-299

8) Frank K. H. A. Dehne, Michael R. Fellows, Henning Fernau, Elena Prieto, Frances A. Rosamond: NONBLOCKER: Parameterized Algorithmics for minimum dominating set. SOFSEM 2006: 237-245

10) Mingyu Xiao, Ton Kloks, Sheung-Hung Poon: New parameterized algorithms for edge dominating set CoRR abs/1104.4160: (2011). To appear in MFCS 2011

11a) Jianer Chen, Joachim Kneis, Songjian Lu, Daniel Mölle, Stefan Richter, Peter Rossmanith, Sing-Hoi Sze, and Fenghui Zhang: Randomized Divide-and-Conquer: Improved Path, Matching, and Packing Algorithms. SIAM J. Comput. 38: 2526-2547 (2009) Hans L. Bodlaender, Rodney G. Downey, Michael R. Fellows, Danny Hermelin: On problems without polynomial kernels. J. Comput. Syst. Sci. 75(8): 423-434 (2009)

11b) Andreas Björklund, Thore Husfeldt, Petteri Kaski, Mikko Koivisto: Narrow sieves for parameterized paths

and packings CoRR abs/1007.1161: (2010)
Hans L. Bodlaender, Rodney G. Downey, Michael R. Fellows, Danny Hermelin: On problems without polynomial kernels. J. Comput. Syst. Sci. 75(8): 423-434 (2009)
12) Oriana Ponta, Falk Hüffner, Rolf Niedermeier: Speeding up Dynamic Programming for Some NP-Hard Graph Recoloring Problems. TAMC 2008: 490-501
Hans L. Bodlaender, Michael R. Fellows, Michael A. Langston, Mark A. Ragan, Frances A. Rosamond, Mark Weyer: Quadratic Kernelization for Convex Recoloring of Trees. COCOON 2007: 86-96
13) Mingyu Xiao: A Note on Vertex Cover in Graphs with Maximum Degree 3. COCOON 2010: 150-159
14) Jens Gramm, Jiong Guo, Falk Hffner, Rolf Niedermeier: Data reduction and exact algorithms for clique cover. ACM Journal of Experimental Algorithmics 13: (2008)
15) Egbert Mujuni, Frances A. Rosamond: Parameterized Complexity of the Clique Partition Problem. CATS 2008: 75-78
16) Sebastian Böcker: A Golden Ratio Parameterized Algorithm for Cluster Editing. To appear in IWOCA 2011
Yixin Cao, Jianer Chen: Cluster editing: kernelization based on edge-cuts. IPEC 2010: 60-71
17) Andreas Björklund, Thore Husfeldt, Petteri Kaski, Mikko Koivisto: Fourier meets mbius: fast subset convolution. STOC 2007: 67-74
Jesper Nederlof: Fast Polynomial-Space Algorithms Using Mbius Inversion: Improving on Steiner Tree and Related Problems. ICALP (1) 2009: 713-725
Michael Dom, Daniel Lokshtanov, Saket Saurabh: Incompressibility through Colors and IDs. ICALP (1) 2009: 378-389 18) M. Wahlström. Algorithms, Measures and Upper Bounds for Satisfiability and Related Problems.PhD Thesis, Department of Computer and Information Science, Linköpings universitet, Sweden, 2007. Faisal N. Abu-Khzam: A kernelization algorithm for d-Hitting Set. J. Comput. Syst. Sci. 76(7): 524-531 (2010)
19) Yngve Villanger, Pinar Heggernes, Christophe Paul, Jan Arne Telle: Interval Completion Is Fixed Parameter Tractable. SIAM J. Comput. 38(5): 2007-2020 (2009)
20) Fedor V. Fomin, Yngve Villanger: Subexponential Parameterized Algorithm for Minimum Fill-in CoRR abs/1104.2230: (2011) Assaf Natanzon, Ron Shamir, Roded Sharan: A Polynomial Approximation Algorithm for the Minimum Fill-In Problem. SIAM J. Comput. 30(4): 1067-1079 (2000)
21) Marek Cygan, Marcin Pilipczuk, Michal Pilipczuk, Jakub Onufry Wojtaszczyk: On Multiway Cut parameterized above lower bounds. To appear in IPEC 2011
22) Dániel Marx, Igor Razgon: Fixed-parameter tractability of multicut parameterized by the size of the cutset. STOC 2011: 469-478
23) Marek Cygan, Jesper Nederlof, Marcin Pilipczuk, Michal Pilipczuk, Johan M. M. van Rooij, Jakub Onufry Wojtaszczyk: Solving connectivity problems parameterized by treewidth in single exponential time CoRR abs/1103.0534: (2011). To appear in FOCS 2011
Stéphan Thomassé: A $4k^2$ kernel for feedback vertex set. ACM Transactions on Algorithms 6(2): (2010)
24) Bruce A. Reed, Kaleigh Smith, Adrian Vetta: Finding odd cycle transversals. Oper. Res. Lett. 32(4): 299-301 (2004)
Stefan Kratsch, Magnus Wahlström: Compression via Matroids: A Randomized Polynomial Kernel for Odd Cycle Transversal. http://arxiv.org/abs/1107.3068
25) Jiong Guo, Jens Gramm, Falk Hüffner, Rolf Niedermeier, Sebastian Wernicke: Compression-based fixed-parameter algorithms for feedback vertex set and edge bipartization. J. Comput. Syst. Sci. 72(8): 1386-1396 (2006)
Stefan Kratsch, Magnus Wahlström: Compression via Matroids: A Randomized Polynomial Kernel for Odd Cycle Transversal. http://arxiv.org/abs/1107.3068
26) Marek Cygan, Jesper Nederlof, Marcin Pilipczuk, Michal Pilipczuk, Johan M. M. van Rooij, Jakub Onufry Wojtaszczyk: Solving connectivity problems parameterized by treewidth in single exponential time CoRR abs/1103.0534: (2011). To appear in FOCS 2011. Michael Dom, Daniel Lokshtanov, Saket Saurabh: Incompressibility through Colors and IDs. ICALP (1) 2009: 378-389
27) Jianer Chen, Yang Liu, Songjian Lu, Barry O'Sullivan, Igor Razgon: A fixed-parameter algorithm for the directed feedback vertex set problem. J. ACM 55(5): (2008)
28) Marek Cygan, Marcin Pilipczuk, Michal Pilipczuk, Jakub Onufry Wojtaszczyk: An Improved FPT Algorithm and Quadratic Kernel for Pathwidth One Vertex Deletion. IPEC 2010: 95-106 29) Marek Cygan, Marcin Pilipczuk, Michal Pilipczuk, Jakub Onufry Wojtaszczyk: Subset Feedback Vertex Set Is Fixed-Parameter Tractable. ICALP (1) 2011: 449-461
30) Pinar Heggernes, Pim van 't Hof, Benjamin Lévêque, Daniel Lokshtanov, Christophe Paul: Contracting Graphs to Paths and Trees CoRR abs/1104.3677: (2011). To appear in IPEC 2011
31) Isolde Adler, Stavros G. Kolliopoulos, Philipp Klaus Krause, Daniel Lokshtanov, Saket Saurabh, Dimitrios M. Thilikos: Tight Bounds for Linkages in Planar Graphs. ICALP (1) 2011: 110-121
32) Fedor V. Fomin, Serge Gaspers, Saket Saurabh, Stéphan Thomassé: A Linear Vertex Kernel for Maximum Internal Spanning Tree. ISAAC 2009: 275-282
33) Fedor V. Fomin, Daniel Lokshtanov, Fabrizio Grandoni, Saket Saurabh: Sharp Separation and Applications to Exact and Parameterized Algorithms. LATIN 2010: 72-83. Gregory Gutin, Igor Razgon, Eun Jung Kim: Minimum leaf out-branching and related problems. Theor. Comput. Sci. 410(45): 4571-4579 (2009)

TABLE OF RACES

Problem	*f(k)*	Vertices in kernel	Ref
Vertex Cover	1.2738^k	$2k$	1
Connected Vertex Cover	2^k	no $k^{O(1)}$	26, randomized algorithm
Multiway Cut	2^k	not known	21
Almost-2-SAT	4^k	not known	21
Multicut	$2^{O(k^3)}$	not known	22
Pathwidth One Deletion Set	4.65^k	$O(k^2)$	28
Undirected Feedback Vertex Set	3.83^k	$4k^2$	2, deterministic algorithm
Undirected Feedback Vertex Set	3^k	$4k^2$	23, randomized algorithm
Subset Feedback Vertex Set	$2^{O(k \log k)}$	not known	29
Directed Feedback Vertex Set	$4^k k!$	not known	27
Odd Cycle Transversal	3^k	$k^{O(1)}$	24, randomized kernel
Edge Bipartization	2^k	$k^{O(1)}$	25, randomized kernel
Planar DS	$2^{11.98\sqrt{k}}$	$67k$	3
1-Sided Crossing Min	$2^{O(\sqrt{k} \log k)}$	$O(k^2)$	4
Max Leaf	3.72^k	$3.75k$	5
Directed Max Leaf	3.72^k	$O(k^2)$	6
Set Splitting	1.8213^k	k	7
Nonblocker	2.5154^k	$5k/3$	8
Edge Dominating Set	2.3147^k	$2k^2 + 2k$	10
k-Path	4^k	no $k^{O(1)}$	11a, deterministic algorithm
k-Path	1.66^k	no $k^{O(1)}$	11b, randomized algorithm
Convex Recolouring	4^k	$O(k^2)$	12
VC-max degree 3	1.1616^k	13	
Clique Cover	2^{2^k}	2^k	14
Clique Partition	2^{k^2}	k^2	15
Cluster Editing	1.62^k	$2k$	16, weighted and unweighted
Steiner Tree	2^k	no $k^{O(1)}$	17
3-Hitting Set	2.076^k	$O(k^2)$	18
Interval Completion	$O(k^{2k} n^3)$	not known	19
Minimum Fill-In	$2^{O(\sqrt{k} \log k)}$	$2k^2 + 2k$	20
Contraction to Paths	$2^{k+o(k)}$	$5k + 3$	30
Contraction to Trees	$4^k/4.98^k$	no $k^{O(1)}$	30, randomized/deterministic algorithm
Planar Disjoint Path	$2^{O(2^k)}$	not known	31
Max Internal Spanning Tree	8^k	$3k$	32
Directed Max Internal Spanning Tree	$16^{k+\log k}$	$O(k^2)$	33