Parameterized Complexity News

Newsletter of the Parameterized Complexity Community

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Welcome Copenhagen IWPEC09

Frances Rosamond, Editor

Welcome to the Parameterized Complexity Newsletter. We especially congratulate new graduates. The Newsletter is archived at Mike Ralph Fellows' website (www.mrfellows.net). Please post to the WIKI: `www.fpt.wikidot.com` and help keep it up-to-date. This fully-packed Newsletter features articles by Georgia Kaouri, Michael Lampis and Valia Mitsou describing new directions in treewidth, continuing work reported at ISAAC, and an article by Serge Gaspers on new uses of measure and conquer for parameterized branching algorithms. We have a report on the marvelous Corsica AGAPE Workshop by Anke Truss and Mathias Weller, and another New Ideas column by Mike Fellows, and some interesting history by Dániel Marx. Many thanks to all who have helped with this newsletter.

JCSS Exciting Invitation

Prof Ed Blum, Managing Editor of JCSS, has proposed that the *PC Newsletter* (the technical parts) become a regular feature of JCSS. The newsletter was motivated by three main impulses:

(1) building the community, including news of new PhDs, postdoc candidates, grant awards and other successes,

(2) fast dissemination of new ideas and perspectives, as the field has been moving very rapidly,

(3) keeping the f(k) and kernelization "league tables" available, as the trajectories of best known results have evolved so rapidly for so many classic problems.

These are the same issues which motivated David Johnson's famous "NP-Completeness Column" in J. Algorithms in the period 1981-87, when that subject was moving too fast for the normal pace of journal publication, and this kind of para-coverage was in order. If you have not seen Johnson's historic and influential Columns in JA, go to his website and peruse the first, and consider our field in the present moment ....It is proposed that something similar is now in order for the rapid unfolding of multivariate algorithmics and complexity.

This is a really wonderful development. Ed proposes that Mike be the Supervising Editor, Fran the Newsletter Editor, and we are proposing that each installment also have a recognized Assistant Newsletter Editor. It's all still under discussion, but Ed has checked with some of the Editors of the Journal and it seems a go.

Figure 1: Daniel Lokshtanov with his 100 from Mike Fellows. Daniel is willing to pass it on. He says: You may very well write in the Newsletter that resolving whether edge dominating set has a $o(k^2)$ (vertex) kernel gives 100 from me. Talk with Daniel at IWPEC.

Contents of this issue:

Special Issue Extension

Manuscripts are solicited for a special issue on Parameterized Complexity in the journal *Discrete Optimization*. The synergy of parameterized algorithmics and algorithms engineering is targeting new application areas of Discrete Optimization, and FPT is leading to novel algorithmic approaches. With this issue we wish to foster research in this direction by exposing both new results and promising programmatic further directions. Potential topics include (but are not limited to): * Parameterized preprocessing and kernelization, * Parameterized complexity of local search, * Color coding, * Treewidth in Discrete Optimization, * Parameterized Discrete Optimization algorithms of practical running time, * Algorithms engineering and new practical application areas of FPT algorithms. Submissions must be received before November 15, 2009 (the deadline is extended). Please contact the guest editors (Mike Fellows, Fedor V. Fomin and Gregory Gutin) for additional information.

Lessons in Magic: AGAPE Spring School (May 24–29, Corsica)

by Anke Truss and Mathias Weller, Friedrich-Schiller-Universitat, Jena Institut fur Informatik.

The AGAPE Spring School (`http://www-sop.inria.fr/mascotte/seminaires/AGAPE/`), organized by F. Havet (CR CNRS I3S, Sophia-Antipolis), M. Asté, N. Cohen, C. Jullien, P. Lachaume, I. Sau-Valls, and M. Syska was aimed at informing both students and established researchers about algorithmic techniques and complexity issues in the field of fixed-parameter and exact algorithms. The Scientific Committee, consisting of F. Havet, S. Pérennes (Sophia-Antipolis), D. Kratsch (Metz), J.-F. Lalande (Bourges), C. Paul, S. Thomassé (Montpellier), I. Todinca (Orleans), invited illustrious lecturers willing to introduce AGAPE participants to the art of their profession.

A popular quote from Arthur C. Clarke is: "Any sufficiently advanced technology is indistinguishable from magic." In this sense, magic, whether black or white, was an ongoing theme in the lectures of the school, which were mainly about fixed parameter tractability and (moderately) exponential time algorithm design. Michael Fellows gave an introductory talk starting the whole magic theme by examining the *"dark arts"* of parameterization, kernelization, and W-hardness. In a consecutive lecture by Dániel Marx , the participants were provided with the tools in the positive FPT framework, like Crown Reductions, Iterative Compression, and Color Coding.

Figure 2: Standa Zivny, Pim van't Hof, and Fernando Sanchez enjoy their coffee break. Photo kind permission of Felix Jon Reidl.

Saket Saurabh and Daniel Lokshtanov presented their research on the incompressibility of certain problems, which, in the sense of the above mentioned quotation, was (at least for some participants) indeed sufficiently advanced to be classified as magic. Under the topic "Gridology", Fedor Fomin showed how subexponential time algorithms can be derived for certain problems on planar graphs (and, more generally, on H-Minor-free graphs) by considering the branchwidth of the input.

Thore Husfeldt and Petteri Kaski gave an introduction of basic techniques in designing moderately exponential time algorithms in general, and linear and bilinear transformations in particular. More wizardry was presented as Dieter Kratsch gave a lecture about moderately exponential time branching algorithms, showing branching techniques with examplary algorithms for the Maximum Independent Set problem. The lecturer himself referred to some of the presented algorithmic tricks as *"white magic"*. Finally, Fabrizio Grandoni gave a tutorial about what has come to be known as "Measure and Conquer", a technique for refined analysis of branching algorithms.

A highlight of the spring school was the traditional open problem session led by Michael Fellows, who used this opportunity to honor a wager he made some time ago, when he bet a hundred dollars that Connected Vertex Cover would have a kernel of at most $O(k^2)$ vertices. With their work on incompressibility of certain problems, Saket Saurabh and Daniel Lokshtanov proved him wrong, thus receiving a US hundred-dollar bill, only to bet it again on the nonexistence of a $o(k^2)$ vertex kernel for Edge Dominating Set. Furthermore, Mike presented the following open questions:

1. Which of the following problems are FPT?
   (a) (Planar) Graph Topological Containment
   (b) Biclique
   (c) Even Set
   (d) Cliquewidth
2. Which problems in scheduling, AI, game theory, and social choice are FPT?

3. Which PTAS algorithms can be improved to EPTAS algorithms?

4. Can we solve the following problems in the respective times?
   (a) $O^*(2^{o(k^3)})$ for computing Treewidth
   (b) $O^*(k^{o(k)})$ or even $O^*(2^{o(k)})$ for solving Point Line Cover

5. Do the following problems have the respective-sized kernel?
   (a) linear for Feedback Vertex Set
   (b) polynomial for Directed Feedback Vertex Set
   (c) polynomial for Clique Cover

6. Is there an FPT approximationfor Dominating Set? (An FPT approximation for a minimization problem is an FPT algorithm that either finds a solution that is smaller than $g(k)$, or determines that there is no solution of size k, for an approximation function g.)

7. Can we find a kernel or improve the trivial $O^*(n^k)$ running time of k-local search for
   (a) Euclidean Traveling Salesperson
   (b) Planar Traveling Salesperson
   (c) Planar Feedback Vertex Set

8. Can we, under reasonable assumptions, determine lower bounds on running times for problems in FPT or XP? (for example, there is no $f(k)n^{o(\sqrt{k})}$ algorithm for Capacitated Dominating Set with parameter treewidth unless FPT=$M[1][1, 2]$).

More open problems came from the participants and the lecturers:

1. Can we solve Subgraph Isomorphism in $O^*(2^n)$?—Fedor Fomin

2. What is the running time of k-Leaf Power Recognition for $k > 5$?—Christophe Paul

3. What is the k-leafage number of chordal graphs?—Christophe Paul

Outside the lectures, aside from discussing interesting problems and gathering at the reception to connect to the internet, participants could swim at the nearby beach or meet for a game of miniature golf. A soccer game on the beach was announced for Tuesday evening. Due to the high number of motivated players the idea to divide the players into a fixed-parameter team and an exponential-time team was quickly dismissed, and three enthusiastic teams had a lot of fun battling for the win on difficult ground. On Wednesday afternoon there was a bus tour to a beautiful beach with the opportunity of a short hike before we returned in time for the dinner, which allowed us to taste a variety of French cheeses.

Overall, the school was an excellent opportunity to gain an overview on the various aspects of fixed-parameter and exact algorithms, to meet people and exchange ideas in a relaxing atmosphere. We want to thank the organizers, scientific committee, lecturers and the other participants for this experience.

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[2] M. Dom, D. Lokshtanov, S. Saurabh, and Y. Villanger. Capacitated domination and covering: A parameterized perspective. In M. Grohe and R. Niedermeier, editors, *IWPEC*, volume 5018 of *Lecture Notes in Computer Science*, pages 78–90. Springer, 2008.

Report from IGGA Bangalore

by Venkatesh Raman, IMSc, Chennai.

The IGGA: Introduction to Graph and Geometric Algorithms workshop held at IISc Bangalore, was attended by an audience of about 150+ people from a wide variety of backgrounds including undergraduate and PhD students, faculty from IITs, IISc, and local colleges, and people in Industry (IBM, Honeywell; look for 'introduction to graph and geometric algorithms' in Google).

There was a large audience with a wide varied background, and so I packed a lot into my presentation: including some history, Robertson-Seymour, treewidth, Courcelle, branching vertex cover, FVS, color coding, kernels upper bound and lower bound. I was skeptical of how good a job I did, but was pleasantly surprised at the feedback.

Quite a few people had not heard about this at all, and comments from people in industry, IITs were: 'Wow, this is such a cool and natural paradigm' to 'Looks like there is a lot of widely varied techniques' to 'Can you visit us and spend some time with us talking about this' and a lot more.

A couple of concrete comments/questions:

1. What is the status of testing whether a fixed graph H is a topological minor of a given graph? Is it FPT (parameterized by H) or hard? This is open.

2. Apparently Geometry people have a notion of 'core sets' which is similar to our notion of kernels and they use it for approximation, it is worth checking out.

Overall, there seems to be a lot of interest to apply FPT stuff to geometry problems, and I am surprised that this hasn't happened yet.

The main revelation was that majority of the participants didn't know about the paradigm nor how well developed it is. On the other hand, the meeting was not on parameterized complexity, and it was just a talk among 15 other talks. Overall, I am glad that I could spread the word further :)

New Directions in Directed Treewidth

by Georgia Kaouri[2], Michael Lampis[1], and Valia Mitsou,[1] City University of New York,[1] National Technical University of Athens[2]

Treewidth is one of the biggest success stories in FPT algorithms. From Courcelle's famous theorem to the numerous applications of treewidth the consensus seems to be that "Treewidth works". Naturally, when we find something that works we want to push it till it breaks. One possible direction for extending treewidth's success is digraphs: Can we generalize our treewidth techniques to also work for directed graph problems? It turns out that there is at least one simple way: digraph problems are usually FPT when parameterized by the treewidth of the underlying undirected graph, that is the graph we obtain if we ignore the directions of the arcs. Though this is welcome, it is rather unsatisfactory; throwing away a good part of the input is likely to obscure the distinction between easy and hard inputs and this is exemplified by the Hamiltonian path problem on DAGs. Solving this problem is known to be easy but there is no bound on a DAG's (undirected) treewidth.

The next step is natural: treewidth tries to measure how much a graph looks like a tree. Let's come up with a width that measures how much a digraph looks like a DAG. Several attempts have been made in this direction, starting from directed treewidth [4], to D-width [8], to DAG-width [7] and kelly-width [3] and along with these we also have directed pathwidth [1].

Why so many? There are many equivalent ways to define undirected treewidth in addition to tree decompositions, including at least two variations of cops-and-robber games, elimination orderings, partial k-trees and so on. Starting from each of these and naturally generalizing to digraphs gives a different width. The results have been very interesting as the relations between these measures are being investigated. For one thing, they seem to form a nice hierarchy (see Figure 4).

Algorithmically however, the results have not quite reached the standards set by treewidth. On the one hand, there are some problems which have been shown to be in XP for these widths, including Hamiltonian cycle and parity games. On the other hand, no FPT results are known. This has switched the focus to a search for negative results and (unfortunately) several have appeared. In [5] and [2] several problems which are in P for DAGs are shown to be NP-hard even for constant width (for all the mentioned directed widths). These results certainly narrow the scope of what one might hope to solve with the directed widths but what is perhaps even more disappointing is the result of [6] where the most major success of the directed widths, Hamiltonian cycle, is shown to be $W[2]$-hard. It seems that the widely applicable FPT results of treewidth are beyond the reach of the directed widths (surprisingly this includes even directed pathwidth).

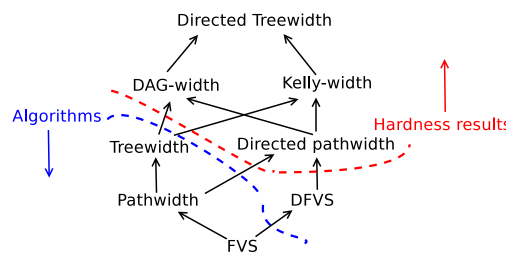

Figure 3: The ecology of digraph widths. Undirected measures refer to the underlying undirected graph. Arrows denote generalizations (for example small treewidth implies small kelly-width). The dashed lines indicate rough borders of known tractability and intractability for most studied problems (including Hamiltonian cycle).

The focus is now switching back to a search for positive results. Treewidth occupies a sweet spot in the map of width parameters: restrictive enough to be efficient and general enough to be useful. What is the right analogue which occupies a similar sweet spot (if it exists) for digraphs? One direction is to keep searching for the right width that generalizes DAGs, that is searching the area around (and probably above) DFVS (notice that the mentioned hardness results do not apply to DFVS). The other possibility is that widths which generalize DAGs, such as DFVS and all the currently known widths, may not necessarily be the right path to follow (DAGs are already much more complicated structures than trees). The search is on!

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Daniël Paulusma, editors, *WG*, volume 5344 of *Lecture Notes in Computer Science*, pages 336–347, 2008.

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[7] Jan Obdrzálek. Dag-width: connectivity measure for directed graphs. In *SODA*, pages 814–821. ACM Press, 2006.

[8] Mohammad Ali Safari. D-width: A more natural measure for directed tree width. In Joanna Jedrzejowicz and Andrzej Szepietowski, editors, *MFCS*, volume 3618 of *Lecture Notes in Computer Science*, pages 745–756. Springer, 2005.

Measure & Conquer for Parameterized Branching Algorithms

by Serge Gaspers, LIRMM – University of Montpellier 2, CNRS, France

Measure & Conquer (M&C) is a prominent technique to establish worst-case exponential upper bounds on the running times of branching algorithms. It is used to analyze many of the currently fastest branching algorithms with respect to the size of the ground set of the search procedure [1]. It has been an interesting question for quite some time if, how and to what extend this technique can be used to analyze branching algorithms for problems that are parameterized by a natural parameter, different from the instance size or the size of the ground set of the search procedure. Fernau and Raible [4], for example, challenge the community to explore the M&C paradigm within parameterized algorithms.

The idea behind M&C is to measure the progress an algorithm makes during its execution, not solely by considering the decrease of the parameter k in the recursive calls of a branching rule, but by a measure which captures more of the structure of an instance. It is thus a potential function analysis of the running time of an algorithm. As an example, consider the Independent Set problem parameterized by n, the number of vertices of the input graph G. Fomin et al. [1] define a measure $\mu(G) = \sum_{i \geq 0} \omega_i n_i$ where n_i denote the number of vertices of degree i in G and $\omega_i \in [0, 1]$ are so-called "weights" associated to vertices of different degrees. This measure allows to measure structural changes to the graph (here the decrease of the degrees of the vertices) more accurately. As $\omega_i \leq \omega_{i+1}$ in [1], this measure intuitively considers graphs with small average degree as "easier".

For a discussion on the use of M&C for problems parameterized by e.g. the solution size as in [2, 3, 5, 6], let us distinguish between local and global measures. A *global* measure is defined as $\mu(I, k) = k + \Psi(I)$ where Ψ is a function from the family of instances to $\mathbb{R}$ that depends only on global properties of the instance. Wahlström [6] uses such a measure to upper bound the running time of his 3-Hitting Set algorithm. The Ψ-function returns in this case a negative number if the instance has sets of size 2 and 0 otherwise. The algorithm only branches on sets of size 3 if it has no other choice. But then in some recursive calls, sets of size 2 appear, a situation from which the algorithm profits immediately by branching on them. The global measure allows to amortize over these good and bad branching behaviors of the algorithm.

In a *local* measure, however, weights are associated to local structures of an instance, as in the measure for Independent Set above. In general, local measures are more flexible and powerful. In particular, they do not require to cash the obtained gain at an early stage (when decreasing the degree of a vertex we do not need to branch on this vertex right away in order for the measure to capture the good local structure that has been created). However, it seemed not obvious how to use local measures to analyze algorithms for problems parameterized by solution size. The analysis of Lokshtanov and Saurabh [5] for Set Splitting seems to benefit from a tight relationship between the parameter and the instance size. In fact, the number of elements and the number of sets of the instance appear in the measure, and they can be upper bounded by k and $2k$ due the extremely small kernel the authors obtained for Set Splitting. Thus, this analysis has more the feeling of a typical M&C analysis, followed by plugging in the bounds on the kernel size. So, does M&C only work if the parameter is closely tied to the instance size?

The situation seems different for the analysis in [2], which studies the Max Internal Spanning Tree problem for subcubic graphs: given a graph $G = (V, E)$ on n vertices of maximum degree 3 and a parameter k, does G have a spanning tree with at least k internal nodes? If F is the set of edges that have already been decided to be in the spanning tree, the first measure used to analyze the algorithm is

$$\kappa_1(G, F, k) := k - \omega \cdot |X| - |Y|,$$

where Y are the vertices of degree at least 2 all of whose incident edges are in F, X is the set of vertices that have two incident edges in F and one in $E \setminus F$, and $0 \leq \omega \leq 1$. So, the vertices in $X \cup Y$ have already been decided to be internal, but we have only accounted for a measure decrease of ω for each vertex in X as the algorithm still needs to branch on these vertices. To go a little bit further, the second measure κ_2 also decreases for each vertex of degree 1 and 2 that are not incident to a vertex in $X \cup Y$: we know that neighbors of degree-1 vertices are internal in any spanning tree (if G is connected and has more than 2 vertices) and it can be shown that if u is a degree-2 vertex, then w.l.o.g. at least two vertices in the closed neighborhood of u will be internal in an optimal solution.

Given the measure, this analysis does not seem to directly profit from a close relationship between the parameter and the instance size. Moreover, this analysis yields a $2.1364^k n^{O(1)}$ running time bound, compared to a $3.4854^k n^{O(1)}$ which is obtained when we first analyze the algorithm with respect to n and then plug in a $2k$ bound on the kernel. However, it would be very interesting to see a parameterized M&C analysis for a problem that does not have a linear kernel.

Compared to the classical use of M&C, its application in parameterized algorithms poses new issues. As some of the gains come from identifying regions in the instance which will decrease the parameter k, we need to determine the loosest constraints on the weights that enable to show that an instance of measure 0 has a solution of size k which can be found in polynomial time. In [2], these regions are neighbors of degree-1 vertices and the closed neighborhood of degree-2 vertices, which may overlap with each other in many ways.

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[3] H. Fernau and D. Raible. Exact algorithms for maximum acyclic subgraph on a superclass of cubic graphs. Proc. of WALCOM 2008.

[4] H. Fernau and D. Raible. Searching Trees: An Essay. Proc. of TAMC 2009.

[5] D. Lokshtanov and S. Saurabh. Even Faster Algorithm for Set Splitting! Proc. of IWPEC 2009.

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New Ideas Column

by Mike Fellows, University of Newcastle, Australia (benefited by conversations with Daniel Lokshtanov and Saket Saurabh of University of Bergen, Norway)

The somehow magically marvelous AGAPE Summerschool on Parameterized and Exact Algorithms, held on the Island of Corse (or Corsica, to the English) in late May (reported on elsewhere in this Newsletter) led to some fresh and interesting discussions regarding the "interface" between these superficially different fields, and about possible new ways of exploring this interface (beyond soccer games).

In order to set the context, consider the classical, unparameterized problem of computing a Maximum Independent Set in a graph. Robson is the "king" of this problem, and currently claims a (very intricate) algorithm with running time $O(1.189^n p(n))$ for graphs on n vertices. Some observations:

• Notice that n is not the overall input size (let us denote this as N), but since $N = O(n^2)$, we could just as well report a running time of $O(1.211^n q(N))$, that anyway expresses the main intention: one pays exponentially in the number of vertices, modulo a multiplicative polynomial cost in the overall input size.

• But we are not very far from the foundations of parameterized complexity. Exact prefers to call the overall input size N; we like to call it n. We typically call our parameter k; they call it n. Both are focused on the exponential costs associated to the *parameter* (the measurement of interest, other than the overall input size). Parameterized problems can be trivially FPT – but then it is still interesting to *improve* the FPT. For example, the NP-hard Hamilton Circuit problem, parameterized by the number of vertices of the graph (since we're talking parameterized, we'll call it k) is trivially FPT by the algorithm that tries all permutations: $O^*(k!)$. An improvement: the problem can be solved in time $O^*(2^k)$ by dynamic programming (an old result due to Held and Karp). The $O^*(-)$ notation ignores any polynomial costs associated with the overall input size.

• Part of the "central rhetoric" of the Exact Algorithms research community is that the goal is not to find some special situations governed by some **small** *parameter* of some sort — rather, it is to assault the intractability of the classically NP-hard problem, completely. (In Australia, we would call them *rugby players*.)

• We could use the known PC results to this end, for the NP-hard problem of Maximum Independent Set. The reason is that for a graph G on n vertices, if we know either of these parameters $mis(G)$ (the size of a maximum independent set), or $vc(G)$ (the size of a minimum vertex cover), then we know the other, since n is the sum of the two.

• The best current FPT algorithm for Vertex Cover runs in time $O^*(1.28^k)$ (or so), *where k is the size of the vertex cover.* This can be used for the full-on, unparameterized, rugby-version of this NP-hard problem, Maximum Independent Set, by ramping k up to n (since $vc(G)$ will never be more than the number of vertices n), so the PC Team can offer an algorithm for the "total" MIS problem that runs in time $O^*(1.28^n)$ (via the Chen-Kanj-Xia (CKX) algorithm), by running k up to n). Unfortunately for our team, this is inferior to the result claimed by Robson. They win.

• On the other hand, Robson's algorithm pays exponentially in the number n of vertices of the graph (their trivially FPT parameterization, in our terms), whereas we pay exponentially only in terms of the size k of the vertex cover: we *pay for what we get.* If we knew in advance that the size of the maximum independent set were around $\alpha = n/3$, then we would know that the size of a minimum vertex cover is around 2n/3, and the CKX algorithm would cost $O^*((1.28^{2/3})^n)$. And then we win!

• But maybe Robson's algorithm could be adapted to pay exponentially only in the *size* of independent set that is found, rather than paying exponentially in the number of vertices of the graph — is this possible? Well, no. If this were possible, then FPT = W[1].

So the **new idea** is this (using Maximum Independent Set as a concrete example): we want a **Total Victory Map** for this NP-hard problem, mapping out *what algorithm to use* for all the possible inputs to this NP-hard problem. If we just use the simple 2-dimensional map of this problem, where n is the number of vertices and j is the size of a maximum independent set, then we currently have the following **Total Victory Map** for the Maximum Independent Set problem:

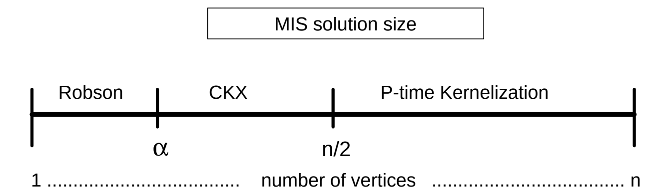

Figure 4: A small explanation of the figure: if $j \geq n/2$ then the known P-time kernelization algorithms for Vertex Cover, will lose no information (for either parameter of G), in kernelizing to the case where $j < n/2$.

All this raises many fresh questions: What do these **Total Victory Maps** (ultimately) look like for NP-hard problems? How many dimensions are relevant to such mappings? In carving up the input space optimally, in terms of total victory, how many measurements are relevant after everything possible has been dealt with by P-time pre-processing and (recursive) re-processing?

An early example of using ILP for fixed-parameter tractability

by Dániel Marx, Budapest University of Technology and Economics, Hungary, dmarx@cs.bme.hu

There is only a handful of examples in the literature of using Integer Linear Programming (ILP) for the design of FPT algorithms. A classical result of H.W. Lenstra [4] states that an integer linear program with k variables can be solved in time $f(k) \cdot n^{O(1)}$ (the function $f(k)$ is $k^{O(k)}$ in the improved algorithm due to Kannan [3]). Thus if there is a parameterized reduction from a problem P to ILP with k variables, then it follows immediately that P is FPT. The most well-known example of this technique is the algorithm of Gramm, Niedermeier, and Rossmanith [2] for the Closest String problem (conference version in 2001 [1]). They reduce the Closest String problem, parameterized by the number k of strings, to an ILP having about $k! \cdot k$ variables. This gives an FPT-time algorithm for the problem, albeit with running time *double* exponential in k.

However, there is a much earlier example of the use of this technique. Sebő [7] (submitted in 1989!) used ILP to prove the fixed-parameter tractability of a disjoint paths problem. The paper only claims that the investigated problem is polynomial-time solvable for every fixed value of k and does not give an explicit running time. However, a quick inspection shows that the running time of the algorithm is dominated by solving a 2^k variable ILP using the algorithm of Lenstra, resulting in an FPT-time algorithm.

The combinatorial optimization literature formulates the edge-disjoint paths problem the following way. Let G (the *supply graph*) and H (the *demand graph*) be two graphs on the same set of vertices. The task is to find edge-disjoint paths in G connecting the endpoints of the edges in H: for each edge $uv \in E(H)$, we need to find a path P_{uv} in G connecting u and v such that these $|E(H)|$ paths are pairwise edge disjoint. The problem is FPT parameterized by $k := |E(H)|$: the celebrated disjoint paths algorithm of Robertson and Seymour [6] solves the problem in $O(n^3)$ for every fixed k. However, without restriction on $|E(H)|$, the problem is NP-hard even in the special case when $G + H$ is planar [5], that is, not only the supply graph is planar, but adding the demand edges does not destroy planarity either.

Sebő [7] studies a version of the problem when $G+H$ is planar, the number of demands is not bounded, but the demands belong to a bounded number of parallel classes. Suppose that the demand graph H has parallel edges. If t is the number of edges of the simple graph underlying H (that is, the number of parallel classes in H), then we have to satisfy $|E(H)|$ demands structured into t parallel classes. More generally, we can consider the weighted version of the problem where each edge uv has an integer weight $w(uv)$, with the meaning that edge $uv \in E(G)$ can be used by at most $w(uv)$ paths, and edge $uv \in E(H)$ requires finding $w(uv)$ paths between u and v. As shown in [7], the duality of T-joins and T-cuts, and various other techniques from combinatorial optimization can be used to transform this weighted edge-disjoint paths problem into an ILP with 2^t variables, which implies (using the above-mentioned results of Lenstra and Kannan) that the problem is FPT parameterized by t, the number of parallel classes of demands. Interestingly, the problem is FPT even if the integer weights are given in binary form in the input, thus the number of demands can be exponentially large.

Presenting the details of the transformation would require going through too much background material. However, the core problem solved by the ILP has a nice equivalent combinatorial formulation. Let T be a tree on t vertices and let $d : V(T) \times V(T) \to \mathbb{Z}^+$ be a function assigning integers to pairs of vertices. We need to assign nonnegative integer weights to the edges of T such that for every $u, v \in V(T)$, the unique path connecting u and v in T has length at most $d(u, v)$. The goal is to maximize the total weight of the edges. This problem can be easily formulated as an ILP, but it would be interesting to find a more straightforward way of showing its fixed-parameter tractability (parameterized by the number t of vertices of T).

Acknowledgment. I thank András Sebő for drawing my attention to [7], discussing the result, and commenting on this note.

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Conferences

IWPEC 2010 will take place in Chennai, India in December 2010, co-located with FST-TCS. Some will have fond memories of the very first "pre-IWPEC" in Chennai in 2000.

SWAT 2010 will take place in Bergen, 21–23 June. Homepage is: http://org.uib.no/swat2010/. If you want to participate in the organizing commitee or have suggestions for improvements to the homepage, please inform J.Telle.

MEMICS, *Annual Doctoral Workshop on Mathematical and Engineering Methods in Computer Science.* Organized jointly by the Masaryk University and the Brno University of Technology, Czechia. November 13 – 15 in Znojmo, Czechia. Mike Fellows is one of the invited speakers.

GROW, *Fourth workshop on Graph Classes, Optimization, and Width Parameters* - Bergen, Norway, October 15–17, 2009. This is a continuation of the series of meetings: Barcelona 2001, Prague 2005, and Eugene 2007. As with each of the previous GROW workshops, a special issue of Discrete Applied Mathematics will be dedicated to papers related to GROW 2009. GROW 2009 dedicates one day to honor Dieter Kratsch on the occasion of his 50th birthday. That day's program will contain talks related to Dieter's work.

Worker 2009, *First Workshop on Kernels.* September 12-13, Bergen. The format of the workshop will be several invited lectures on the recent trends in kernelization, short reports on new results, and slots for discussions and open problems. Note that this workshop does not produce any proceedings and presentations here should not cause any problem for submitting the same material to a regular conference or journal.

Dagstuhl Seminar 09511 *Parameterized complexity and approximation algorithms*, December 13-17, 2009. Organizers: Erik Demaine (MIT - Cambridge, US), MohammadTaghi HajiAghayi (AT&T Research - Florham Park, US), Dániel Marx (Budapest Univ. of Technology and Economics, HU).

IWOCA 2009 (formerly AWOCA) held at Hradec nad Moravici, Czech Republic, had several excellent PC papers. Sue Whitesides gave the first keynote address with *Intractability in Graph Drawing and Geometry: FPT approaches.* Mike Fellows' invited address was *Towards Fully Fully Multivariate Algorithmics: Some New Results and Directions in Parameter Ecology.* The well-organized conference included castle tours, chamber concerts, banquet and garden party.

Established FPT Races

The results gradually keep improving, and the latest best results are summarized here. The table is not complete and we are awaiting information on your favorite problem for the next issue.

Problem	*f(k)*	**kernel**	**Ref**
Vertex Cover	1.2738^k	$2k$	1
Feedback Vertex Set	5^k	k^2	2
Planar DS	$2^{15.13\sqrt{k}}$	$67k$	3
1-Sided Crossing Min	1.4656^k		4
Max Leaf	6.75^k	$4k$	5
Directed Max Leaf	$2^{O(k \log k)}$		6
Set Splitting	2.6494^k	$2k$	7
Nonblocker	2.5154^k	$5k/3$	8
3-D Matching	2.77^{3k}		9
Edge Dominating Set	2.4181^k	$8k^2$	10
k-Path*	4^k	no $k^{O(1)}$	11
Convex Recolouring	4^k	$O(k^2)$	12
VC-max degree 3	1.1899^k		13
Clique Cover	$2^{\Delta k}$	2^k	14
Clique Partition		2^k	15
Cluster Editing	1.83^k	$4k$	16
Steiner Tree	2^k		17
3-Hitting Set	2.076^k	$O(k^2)$	18
Minimum Fill/ Interval Completion	$O(k^{2k}n^3m)$		19

1) J. Chen, I. Kanj and G. Xia. Improved Parameterized Upper Bounds for Vertex Cover. *MFCS 2006.*
2) J. Chen, F. Fomin, Y. Liu, S. Lu and Y. Villanger. Improved Algorithms for the Feedback Vertex Set Problems. *WADS 2007.* S. Thomassé. A quadratic kernel for feedback vertex set. *SODA 2009.*
H. L. Bodlaender. A Cubic Kernel for Feedback Vertex Set. *STACS 2007.*
3) F. Fomin and D. Thilikos. Dominating sets in planar graphs: Branch-width and exponential speed-up. *SODA 2003*, for the running time.
H. Fernau. Parameterized Algorithmics: A Graph Theoretic Approach. *HabSchrift. Wilhelm-Schickard Institut für Informatik, Universität Tübingen, 2005*, for the kernel.
4) V. Dujmovic, H. Fernau and M. Kaufmann. Fixed parameter algorithms for one-sided crossing minimization revisited. *GD 2003.*
5) P. Bonsma and Florian Zickfeld. Spanning Trees with Many Leaves in Graphs without Diamonds and Blossoms. *LATIN 2008*, for the running time.
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*, for the kernel.
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7)D. Lokshtanov and C. Sloper. *ACiD 2005.*
8) F. Dehne, M. Fellows, H. Fernau, E. Prieto, and F. Rosamond. Nonblocker: Parameterized Algorithms for Minimum

Dominating Set. *SOFSEM 2006.*
9) Y. Liu, S. Lu, J. Chen and S-H. Sze. Greedy Localization and Color-Coding: Improved Matching and Packing Algorithms. They also have a randomized result of 2.32^{3k}. *IWPEC 2006.*
10) Fedor V. Fomin, Serge Gaspers, Saket Saurabh and Alexey A. Stepanov. On Two Techniques of Combining Branching and Treewidth. *To appear in Algorithmica*, for the running time.
H. Fernau. EDGE DOMINATING SET: Efficient Enumeration-Based Exact Algorithms. *IWPEC 2006*, for the kernel.
11) J. Chen, S. Lu, S-H. Sze, F. Zhang. Improved Algorithms for Path, Matching, and Packing Problems. *SODA 2007.*
J. Kneis, D. Mölle, S. Richter and P. Rossmanith. Divide-and-Color. *WG 2006* (independently found the same algorithm).
H. Bodlaender, R. Downey, M. Fellows and D. Hermelin. On Problems Without Polynomial Kernels. *ICALP 2008.* * From Moritz Mueller: Pointed Path (the starting point of the length k path is given) has no strong subexponential kernelization ('strong' means that it doesn't increase the parameter) unless ETH fails. Or: Path has no poly kernel even when restricted to planar and connected graphs. An open problem is the subexponential kernelizability for Path, and finding methods for excluding subexponential kernelizations.
12) O. Ponta, F. Hüffner and R. Niedermeier. Speeding up Dynamic Programming for Some NP-hard Graph Recoloring Problems. *TAMC 2008.*
H. Bodlaender, M. Fellows, M. Langston, M. Ragan, F. Rosamond and M. Weyer. Kernelization for Convex Recoloring. *ACiD 2006.*
13) I. Razgon. Personal Communication.
14) J. Gramm, J. Guo, F. Hüffner, and R. Niedermeier. Data reduction, exact, and heuristic algorithms for clique cover. *ALENEX 2006.*
15) E. Mujuni and F. Rosamond. Parameterized Complexity of the Clique Partition Problem. *CATS 2008.*
16) S. Böcker, S. Briesemeister, Q. Bui and Anke Truß. PEACE: Parameterized and Exact Algorithms for Cluster Editing. Manuscript, Lehrstuhl für Bioinformatik, Friedrich-Schiller-Universität Jena, 2007
17) J. Guo. A More Effective Linear Kernelization for Cluster Editing. *ESCAPE 2007.*
A. Björklund, T. Husfeldt, P. Kaski and M. Koivisto. Fourier meets Möbius: Fast Subset Convolution. *STOC 2007.*
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.
F. Abu-Khzam. Kernelization Algorithms for d-hitting Set Problems. *WADS 2007.*
19) P. Heggernes, C. Paul, J. A. Telle, and Y. Villanger. Interval completion with few edges. *STOC 2007.*

CONGRATULATIONS Grants

Project Leader **Fred Havet**(Nice), and Local Leaders **D. Kratsch** (Metz), **I. Todinca** (Orléans), and **S. Thomassé** and **C. Paul** (Montpellier) have received a Agence Nationale de la Recherche, Programme Blanc Grant for the AGAPE Project: "Research in Fixed-Parameter and Exact Algorithmics". The budget is approx 700k Euros for a period of 4 years.

Stefan Szeider has been awarded an *ERC Starting Grant* for the project "The Parameterized Complexity of Reasoning Problems" worth 1.4M Euros. The aim of the project is to study computational reasoning (including nonmonotonic reasoning, constraint-based reasoning, and reasoning under uncertainty) in the framework of parameterized complexity theory. Theoretical research will be complemented with empirical analysis of real-world data. The project is hosted by the Vienna University of Technology, Austria, and includes two postdoc positions which will be broadly advertised. The project is planned to commence in January 2010.

Postdoc Positions Available

In addition to the positions mentioned above, a PhD position in the field of Parameterized Algorithms is available at the University of Bergen. Jan Arne Telle asks that recently graduated Master students be informed. Deadline is 20 September. See http://www.ii.uib.no/ telle/pos2.html for details.

CONGRATULATIONS ALL!

Serge Gaspers (LIRMM, Fr) has accepted a Post Doc position at the Center for Mathematical Modelling (CMM), Universidad de Chile in Santiago. CMM is an associate research unit to CNRS-France. (Spanish is not required, but Serge already speaks six languages (at least)!) Congratulations, Dr. Gaspers.

Jiong Guo (Friedrich-Schiller, Jena) has accepted a Junior Professor position at Max Planck Institute at Saarbrucken. He will join the outstanding PC talent team of Prof Kurt Mehlhorn. Congratulations, Dr. Guo, well done.

Magdalena Grüber (Mathematisch-Naturwissenschaftlichen Fakultät II der Humboldt-Universität zu Berlin) has successfully defended her Dissertation: *Parameterized Approximability*, Advisor Martin Gröhe. Congratulations, Dr. Grüber.

Moritz Müller (Freiburg) has accepted a Post Doc position with the Infinity Project at CRM Centre de Recerca Matematica, Barcelona. Congratulations, Dr. Müller.

Saket Saurabh (University of Bergen, No) has accepted a faculty position at IMSc, Chennai. The IMSc is one of the top research institutes in India, specializing in mathematics, computer science, and physics. Congratulations, Dr. Saurabh.

Somnath Sikdar (IMSc, Chennai) has accepted a Post Doc position with Prof Peter Rossmanith at RWTH, Aachen. Congratulations, Dr. Sikdar.

The Bergen website http://www.uib.no/ii/en has an appreciation of Daniel and of Saket, with pictures and, quote: (1) **Daniel Lokshtanov** is only 25 years old, but has already published 22 scientific papers. On June 22 he will defend his PhD thesis - one year ahead of time! (We reported Daniel's defense in an earlier Newsletter), and (2) With no less than four co-authored papers, postdoc **Saket Saurabh** at the Department of Informatics has set a new record at the respected ICALP conference.