Parameterized Complexity News

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Always Parameterize!

Welcome

Frances Rosamond, Editor, *University of Bergen.* `Frances.Rosamond@uib.no`

Congratulations to many award and prize-winners, graduates, new jobs, and wonderful research. Bart Jansen provides an insightful graph showing the dynamic expansion of the field. It may be useful in grant applications. Featured are two excellent articles, *Graver basis optimization methods: n-Fold Integer Programming for FPT* by Martin Koutecký, and *Fixed-Parameter Algorithms in Operations Research: Opportunities and Challenges by* René van Bevern. We invite you to participate in the very first *Parameterized Algorithms and Computational Experiments Challenge* (PACE) (`https://pacechallenge.wordpress.com`). We hope the libraries developed will be useful for Masters projects. Let me know if you would like to join the PACE discussion on SLACK. PACE winners will be announced at the 11th IPEC in Aarhus in August (note that ALGO has changed from its usual Sept date). Does the Newsletter need a new logo to represent *multivariate algorithmics*? Send your suggestions.

David S. Johnson: in memoriam

David S. Johnson, a leading expert in computational complexity and the design and analysis of algorithms, died March 8, 2016. A memorial is at `http://www.cs.columbia.edu/2016/david-johnson-in-memoriam/`.

We are all familiar with Garey and Johnson's 1979 classic, *Computers and Intractability: A Guide to the Theory of NP-Completeness,* the black paperback with a cartoon. Johnson was the 2010 Knuth Prize winner for his contributions to theoretical and experimental analysis of algorithms. The first PACE implementation challenge is respectfully dedicated to David Johnson in recognition of his work in establishing the DIMACS Challenge.

IPEC 2016: 24–26 August, Aarhus

The 11th **IPEC** at ALGO in Aarhus, Denmark.

Important Dates:

Abstract submission deadline: June 12, 2016

Paper submission deadline: June 15, 2016

Notification date: July 25, 2016

Symposium: August 24-26, 2016

Final version due: September 30, 2016

The Nerode Prize, Excellent Student Paper Awards, and PACE Challenge winners will be awarded at IPEC.

Publication Growth over decades

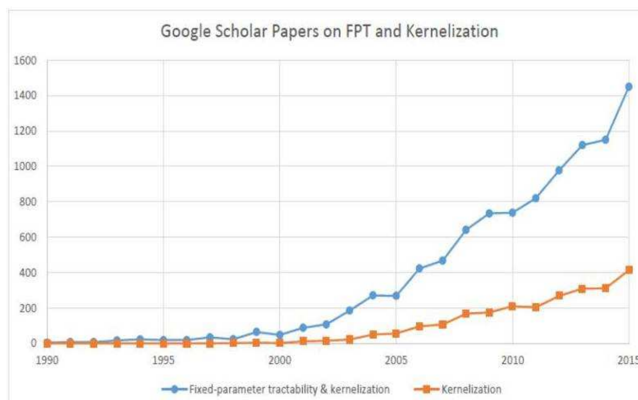

Figure 1: Publication Growth

by Bart M. P. Jansen, *Eindhoven Univ of Technology, The Netherlands*, `bmpjansen@gmail.com`

The chart visualizes the growth of parameterized complexity and kernelization over the last decades. The chart shows, for each year from 1990 to 2015, the number of papers that Google Scholar knows about and which first appeared in that particular year, excluding citations and patents. The blue line shows the number of papers re-

Contents of this issue:

lating to FPT or kernelization; these are papers whose content matches "fixed-parameter tractable" (or one of a handful variations thereof), "parameterized complexity", or "kernelization", but whose content excludes "emulation" (to filter out some false-positives that I identified manually). The orange line represents papers relating to kernelization, whose content matches "kernelization" or "kernel" but not "emulation", "system kernel", "unix", "biometric", "semantic", "semantics", "learners", "singular" or "MS-DOS" (again to filter out some obvious false-positives).

René van Bevern – Russian Federation Award

Congratulations to **René van Bevern**, *Novosibirsk State Univ, Russian Federation* for a three-year grant *Fixed-parameter algorithms for NP-hard routing and scheduling problems* from the Russian Foundation for Basic Research. The project is running from 2016–2018.

Marek Cygan – Kaggle Santa's Sleigh

Congratulations to **Marek Cygan** and **Marcin Mucha**, *Univ Warsaw*, winners three years in a row in the Kaggle Santa's Stolen Sleigh optimization competition. See blog: `http://blog.kaggle.com/2016/03/03/santas-stolen-sleigh-winners-interview-3rd-place-marcin-marek/` for an excellent victory interview. Marek is on the ICALP 2016, FOCS 2016, WAOA 2016 program committees, and is a new father.

PACE: Experiments Challenge

All are encouraged to participate in the first **Parameterized Algorithms and Computational Experiments Challenge** (PACE). Benchmark instances are available.

See `https://pacechallenge.wordpress.com`.

TRACK A: Tree Decomposition: optimal solutions, heuristics, generating hard instances, and collecting real-world instances. The tree decomposition validator is `https://github.com/holgerdell/td-validate/`.

TRACK B: Feedback Vertex Set: FPT algorithms.

Important Dates:
1) Register Participation: June 1, 2016. Track A for TreeWidth send email to Holger Dell at `pace16@holgerdell.com`, and for Track B Feedback Vertex Set send email to `Christian.Komusiewicz@uni-jena.de`.
2) Deadline to submit implementations: August 1, 2016.
3) Results announced: August 24 - 26 at IPEC 2016.

2016 PACE Programme Committee:
TRACK A: Holger Dell (Saarland Univ, Simons Institute for the Theory of Computing) and Thore Husfeldt (Lund Univ, IT Univ Copenhagen).
TRACK B: Falk Hüffner (TU-Berlin) and Christian Komusiewicz (Friedrich-Schiller-Univ Jena).

PACE Steering Committee:
Holger Dell (Saarland Univ, Simons Inst for the Theory of Computing)
Thore Husfeldt (Lund Univ, IT Univ Copenhagen)
Bart M. P. Jansen (Eindhoven Univ Technology)
Petteri Kaski (Aalto Univ)
Christian Komusiewicz (Friedrich-Schiller-Univ Jena)
Amer Abdo Mouawad (Univ Bergen)
Frances Rosamond, Chair (Univ Bergen)

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n-Fold Integer Programming for FPT

by Martin Koutecký, *Charles University in Prague, Czech Republic,* `koutecky@kam.mff.cuni.cz`

Today we focus on integer programs $(IP)_{A,\mathbf{b},\mathbf{l},\mathbf{u},\mathbf{w}}$:

$$\min\{\mathbf{wx} \mid A\mathbf{x} = \mathbf{b}, \mathbf{l} \leq \mathbf{x} \leq \mathbf{u}, \mathbf{x} \in \mathbb{Z}^n\}$$

The two well known tractable fragments are when A is a totally unimodular matrix and when the dimension (number of variables) of the program is a parameter (Lenstra [4]). Since the latter result has found much use in parameterized complexity, it is natural to ask if there is another property of $(IP)_{A,\mathbf{b},\mathbf{l},\mathbf{u},\mathbf{w}}$ besides total unimodularity and fixed dimension which makes it tractable. This question has been answered affirmatively by a collective of authors in the past 10 years. We believe their results are highly relevant for the parameterized complexity community – they are useful for proving new positive results, for improving the runtime of results using Lenstra's algorithm, and they are quite elegant nad beautiful. We base the following exposition on the excellent books of Onn [7] and De Loera, Hemmecke and Köppe [5].

Augmentation and Graver bases. The essence of these techniques is a simple augmentation procedure: given an initial solution $\mathbf{x}_0$ to $(IP)_{A,\mathbf{b},\mathbf{l},\mathbf{u},\mathbf{w}}$, we repeatedly search for augmenting directions until we reach an optimal solution. To do so, we need an *optimality certificate*: a set $\mathcal{T} \subseteq \mathbb{Z}^n$ such that for a non-optimal solution $\mathbf{x}_0$ there exists a vector $\mathbf{t} \in \mathcal{T}$ and a positive integer α with (1) $\mathbf{x}_0 + \alpha\mathbf{t}$ feasible, and (2) $\mathbf{wx}_0 > \mathbf{w}(\mathbf{x}_0 + \alpha\mathbf{t})$. Two questions immediatelly arise: how big is $\mathcal{T}$ (because we possibly need to enumerate all of it to find an augmenting step), and how many augmenting steps do we need to reach the optimum?

Let us define the *Graver basis* of a matrix A, denoted $\mathcal{G}(A)$. For two vectors $\mathbf{u}, \mathbf{v} \in \mathbb{Z}^n$, we say that $\mathbf{u} \sqsubseteq \mathbf{v}$

if they lie in the same orthant and $|u_i| \le |v_i|$ for all $i = 1, \dots, n$. $\mathcal{G}(A)$ is the set of all $\sqsubseteq$-minimal elements of $\{\mathbf{x} \mid A\mathbf{x} = 0, \mathbf{x} \in \mathbb{Z}^n\}$. It is proven that $\mathcal{G}(A)$ is an optimality certificate for $(IP)_{A,\mathbf{b},\mathbf{l},\mathbf{u},\mathbf{w}}$ (for all choices of $\mathbf{b}, \mathbf{l}, \mathbf{u}, \mathbf{w}$). Moreover, if instead of taking *any* augmenting step we always take the *best* step, the number of steps needed to obtain the optimum is polynomial in n and the encoding lengths of $A, \mathbf{b}, \mathbf{l}, \mathbf{u}, \mathbf{w}$. The natural question is then in which cases can we find the best augmenting step quickly.

The most obvious case is when $|\mathcal{G}(A)|$ is polynomial. In this most favorable case many extensions are known to various objectives: f separable convex, $f(W\mathbf{x})$ concave with $W \in \mathbb{Z}^{d\times n}$ for fixed d, $f(W\mathbf{x}) + g(\mathbf{x})$ with W as before and f, g separable convex, $f(\mathbf{x}) = \|\mathbf{x}\|_p$, and for some quadratic (even non-convex) f [3]. However, few natural examples where $|\mathcal{G}(A)|$ is polynomial are known.

4-block N-Fold IP. A much more interesting (but also involved) set of cases are 4-block N-Fold Integer Programs and their specializations. Consider:

$$\left(\begin{smallmatrix} C & D \\ B & A \end{smallmatrix}\right)^{(N)} := \begin{pmatrix} C & D & D & \cdots & D \\ B & A & 0 & & 0 \\ B & 0 & A & & 0 \\ \vdots & & & \ddots & \\ B & 0 & 0 & & A \end{pmatrix}$$

for some given $N \in \mathbb{N}$ and N copies of A. We call $E^N = \left(\begin{smallmatrix} C & D \\ B & A \end{smallmatrix}\right)^{(N)}$ an N-fold 4-block matrix. Let $a := \|E\|_\infty$. It turns out that even though $|\mathcal{G}(E^N)|$ can be exponential, it is possible to find an augmenting step faster than by enumerating all possibilities. Thus we get:

Theorem 1 *Solving $(IP)_{E^N,\mathbf{b},\mathbf{l},\mathbf{u},\mathbf{w}}$ is in* XP *parameterized by the dimensions of E and a. Moreover, separable convex minimization over $(IP)_{E^N,\mathbf{b},\mathbf{l},\mathbf{u}}$ is also in* XP.

For $C = \mathbf{0}$ and $D = \mathbf{0}$ we get the problem matrix E^N_{stoch} of a two-stage stochastic IP. While $|\mathcal{G}(E^N_{\text{stoch}})|$ is still potentially exponential, the problem is significantly easier:

Theorem 2 *Solving $(IP)_{E^N_{stoch},\mathbf{b},\mathbf{l},\mathbf{u},\mathbf{w}}$ is in* FPT *parameterized by the dimensions of E and a.*

N-Fold IP. Furthemore, for $B = \mathbf{0}$ and $C = \mathbf{0}$ we get the problem matrix E^N_{nfold} of an N-fold IP; we devote the rest of the article to this scenario. The Graver basis $\mathcal{G}(E^N_{\text{nfold}})$ exhibits remarkable structure. Observe that every $\mathbf{g} \in \mathcal{G}(E^N_{\text{nfold}})$ is naturally divided into N *bricks* of fixed size corresponding to the common dimension of A and D. A crucial observation shows that there exists a constant $g(E)$ which only depends on A, D and a such that every $\mathbf{g} \in \mathcal{G}(E^N_{\text{nfold}})$ has at most $g(E)$ non-zero bricks, all coming from a set of bounded size, and thus $|\mathcal{G}(E^N_{\text{nfold}})| \le n^{g(E)}$. This naturally gives an XP algorithm for all the previously mentioned objectives. Moreover, in a breakthrough result which preceded and inspired the previous theorems, Hemmecke, Onn and Romanchuk [1] have shown that there exists a smart dynamic programming approach to find the best augmenting step in $\mathcal{G}(E^N_{\text{nfold}})$, leading to the following:

Theorem 3 *Let $D \in \mathbb{Z}^{r\times t}$ and $A \in \mathbb{Z}^{s\times t}$ and $a = \max(\|D\|_\infty, \|A\|_\infty)$. There is an algorithm solving $(IP)_{E^N_{nfold},\mathbf{b},\mathbf{l},\mathbf{u},\mathbf{w}}$ in time $\mathcal{O}(a^{\mathcal{O}(trs+t^2s)}n^3L)$ where L is the length of the input. Thus, it is in* FPT *parameterized by the dimensions of E and a. Also, minimizing certain separable convex functions over $(IP)_{E^N_{nfold},\mathbf{b},\mathbf{l},\mathbf{u}}$ is in* FPT.

Application: Scheduling. A fundamental problem in scheduling theory is *makespan minimization on identical machines* (often denoted $P||C_{max}$). When we consider the maximum job length $p_{max} =: M$ as a parameter, the problem simplifies to the following. We are given numbers n_j for $j = 1, \dots, M$ such that $n = \sum_j n_j$, where n_j is the number of jobs of length j that need to be scheduled, and we are given a number m of machines. The goal is to assign jobs to machines such that when C_i is the sum of lengths of jobs assigned to machine i (its *completion time*), $\max_{i\in\{1,\dots,m\}} C_i$ is minimized.

Let x^i_j with $j \in \{1, \dots, M\}$ and $i \in \{1, \dots, m\}$ be a variable which represents the number of jobs of length j that are scheduled to run on machine i. Let us guess $T := \max_i C_i$. Then $\mathbf{x} \in \mathbb{Z}^{nt}$ represents a solution of length at most T if the completion time of every machine is at most T:

$$\forall i \in \{1, \dots, m\} \qquad \sum_{j=1}^{M} j x^i_j \le T,$$

and if every job is scheduled on some machine:

$$\forall j \in \{1, \dots, M\} \qquad \sum_{i=1}^{m} x^i_j = n_j.$$

Observe that this is an N-Fold IP with D the $M \times M$ identity matrix and $A = (1\ 2\ 3\ \dots\ M)$. (Inequalities can be dealt with using slack variables.) Using Theorem 3 we get an algorithm running in time $\mathcal{O}(M^{\mathcal{O}(M^2)}m^3 \log n)$.

Advantages. Let us now highlight a few advantages of this approach. **(1) Simplicity:** remarkably, without using N-Fold IP, the present example was only shown in 2014 by Mnich and Wiese [6], who first need to make a non-trivial structural observation, and then use Lenstra's algorithm. **(2) Speed:** the resulting runtime of the previous approach is orders of magnitude worse, roughly $\mathcal{O}(p^p n \log m)$ where $p = M^{M^2}$. **(3) Flexibility:** in the *uniformly related machines* model every machine also has a speed $s_i \in \mathbb{N}$ such that a job of length j takes time j/s_i to execute on machine i. To model that in our IP we simply change the first set of constraint to $\forall i \ \sum_j jx_j^i \leq s_i T$ and the rest follows. Other extensions are possible. **(4) Insight:** while it is possible to use N-Fold IP in a blackbox fashion, it also provides some insight. Recall that every element $\mathbf{g} \in \mathcal{G}(E^N_{\text{nfold}})$ has at most $g(E)$ non-zero bricks, and when we always choose the best $\mathbf{g}$, polynomially many steps take us to optimum. Reinterpreting this into our scheduling example, there $\mathcal{G}(E^N_{\text{nfold}})$ is a set of swaps of jobs among machines preserving feasibility, these swaps always act on at most $g(E)$ machines, and polynomially many of (integer multiples of) these swaps lead to an optimal solution. For more details see our paper [2].

Open problems. We see many interesting open problems which roughly fall into two categories. The first regards *applying* the tools we have described here. **(1) New results.** What new FPT results can be shown using these tools? **(2) Speeding up.** Many FPT results which were shown using Lenstra's algorithm have double-exponential (or worse) time complexity. Like in our example, we believe that this can often be improved.

The second category regards *exploring* the techniques themselves. **(3) Extensions.** To which other objective functions can Theorems 1, 2 and 3 be extended? Especially Theorem 3 is not yet proven for general separable convex functions. Moreover, is it possible to improve the complexity analysis for certain matrices A, D containing large numbers, for example if we considered scheduling parameterized not by p_{max} but by the number of distinct job types? **(4) Hardness and lower bounds.** Solving 4-block N-Fold IPs is in XP, but it is not known whether it is W[1]-hard, nor can we show strong lower bounds.

References.

[1] R. Hemmecke, S. Onn, and L. Romanchuk. N-fold integer programming in cubic time. *Math. Program*, 137(1-2):325–341, 2013.

[2] D. Knop and M. Koutecký. Scheduling meets n-fold integer programming, 2016. `arxiv:1603.02611`.

[3] J. Lee, S. Onn, L. Romanchuk, and R. Weismantel. The quadratic graver cone, quadratic integer minimization, and extensions. *Math. Program*, 136(2):301–323, 2012.

[4] H. W. Lenstra, Jr. Integer programming with a fixed number of variables. *Mathematics of Operations Research*, 8(4):538–548, 1983.

[5] J. A. D. Loera, R. Hemmecke, and M. Köppe. *Algebraic and Geometric Ideas in the Theory of Discrete Optimization*, volume 14 of *MOS-SIAM Series on Optimization*. SIAM, 2013.

[6] M. Mnich and A. Wiese. Scheduling and fixed-parameter tractability. *Math. Program*, 154(1-2):533–562, 2015.

[7] S. Onn. *Nonlinear discrete optimization*. European Mathematical Society, 2010.

Fixed-Parameter Algorithms in Operations Research: Opportunities and Challenges

by René van Bevern, *Novosibirsk State University, Russian Federation*, `rvb@nsu.ru`

In the December 2015 issue of this newsletter, Gregory Gutin pointed out that FPT research is frequently motivated by its potential value to practical computing and that it's time to deliver so as to keep up the interest in FPT research. The Parameterized Algorithms and Computational Experiments Challenge (PACE) is the right step into this direction, but the imbalance between theory and applications in the field manifested itself even in the problem selection process for PACE: the set of problems that are theoretically well-understood *and* have available benchmark data turned out to be rather limited.

This newsletter contribution shares some insights from recent parameterized approaches to discrete optimization problems in operations research, more specifically, to vehicle routing and scheduling problems.

From benchmarks to parameters and back. Real-world data for experiments is often hard to obtain or distribute for legal reasons. Luckily, for many routing or scheduling problems, benchmark instances are publicly available. Often a record list of the best known heuristically obtained solutions is maintained. Thus, the search for interesting problems and parameters could start by analyzing the structure of available benchmark data. The aim: fixed-parameter algorithms that potentially break records for at least *some* instances (for example, by finding optimal solutions, which would yield a perpetual entry in the record list). Positive algorithmic results would provide interesting material for future instances of PACE. A broken record would certainly attract attention to fixed-parameter algorithms and support our claim of potential practical impact.

In the opposite direction, benchmark data can profit from multivariate complexity studies. In recent joint work with C. Komusiewicz and M. Sorge, we investigated the Mixed Capacitated Arc Routing Problem (MCARP) of computing tours of total minimum length to serve the demand of arcs and edges of a mixed graph using vehicles of bounded capacity [3]. An interesting parameter from an application point of view is the number C of weakly-connected components induced by arcs and edges with positive demand. In fact, we found $C = 1$ in almost all instances of popular benchmark sets (real and simulated snow plowing and municipal waste collection instances). Unfortunately, the problem is NP-hard even for $C = 1$ on very restricted graphs [5] and constant-factor approximability is open since more than 30 years. Therefore, our $O(2^C C^2 \cdot n^3 \log n)$-time constant-factor approximation and polynomial-time $O(\log C/ \log\log C)$-approximation was met with interest at the 15th Workshop on Algorithmic Approaches for Transportation Modeling, Optimization, and Systems (ATMOS'15) [3].

In our subsequent experiments, we did not break records, yet reached a median relative error of less than 13 % on some benchmark sets. Moreover, having shown that the approximability of MCARP mainly depends on C, it became somewhat arguable whether benchmark sets having $C = 1$ in almost all instances are suitable for evaluating the solution quality of MCARP algorithms. From known benchmark instances, we therefore derived a new set that mimics cities that are separated into few connected components by a river, which can be crossed using bridges with zero demand. These new results will be presented at the 2nd Workshop on Arc Routing Problems in Lisbon (WARP 2), May 22-24, 2016.

Uncapacitated arc routing is often tractable. While MCARP is hard for many parameters [5], there are several fixed-parameter algorithms for its special cases with uncapacitated vehicles or if additionally all arcs and edges are *required*, that is, have positive demand [3, 5, 10, 13, 14, 15, 16, 17, 27, 28]. Herein, MCARP with one uncapacitated vehicle is known as Rural Postman and, if additionally all arcs are required, as Chinese Postman.

For example, Mixed Chinese Postman is fixed-parameter tractable parameterized by the number of undirected edges [5] as well as parameterized by the number of directed arcs [13]. Rural Postman is fixed-parameter tractable with respect to the number of times that a vehicle has to traverse an arc without serving it [10]. Notably, there is a randomized fixed-parameter algorithm for Rural Postman parameterized by the number C of weakly connected components induced by the required arcs [17, 25]. This is in contrast to MCARP, which is NP-hard for $C = 1$. The few hardness results concern problem-independent parameters such as the pathwidth of the network [15] or kernelization lower bounds [27].

Many of the results listed above solved open problems we posed in the draft of a recent book chapter on the complexity of arc routing problems with R. Niedermeier, M. Sorge, and M. Weller [5]. Thus, the final version of the book chapter contains a new set of open problems.

Scheduling problems are incredibly hard. The first parameterized results on scheduling problems were intractability results [8, 12]. Marx [24] saw one reason for the little attention of the FPT community to scheduling problems in the fact that it is not obvious how to choose relevant parameters that could lead to fixed-parameter tractability. Nowadays, several fixed-parameter tractability results are known [1, 2, 4, 6, 7, 9, 18, 19, 20, 26]. Indeed, the parameter choice for these positive results tends to be much more problem-specific than, for example, for graph problems. Moreover, *parameter combinations* seem to be required in many cases.

However, there are some extreme examples like classical *shop scheduling* problems, in which each job has to be processed by multiple machines in free or given order: they remain NP-hard even if many obvious parameters are simultaneously bounded by small constants [21]. This even includes "number of numbers"-like parameters [11]. While this may simply mean that the right parameters have not been found yet, these problems are also difficult to approximate, such that both parameterized as well as approximate approaches preliminarily reached the end of the road regarding positive results. However, since these are not mere toy problems, they still want to be solved and one can hardly be satisfied having shown hardness results only. Such problems are a fertile soil for fixed-parameter approximation algorithms or schemes [23], which can yield surprisingly positive news for problems that already seem hopeless from a theoretical point of view, like in the case of MCARP [3].

Scheduling and mathematical programming. It is not surprising that fixed-parameter tractability results for scheduling problems frequently exploit tools from mathematical programming [7, 19, 20, 26] like Lenstra's theorem for solving mixed integer linear programs. It will be interesting to see an application of integer linear programming *kernelization* results [22], especially since positive kernelization results on scheduling problems are still rare [4].

Work on scheduling problems also discovered new tools from mathematical programming for the parameterized algorithms toolbox: convex programming [26] and n-fold integer programming [20]. They primarily led to tractability results with respect to the "number of numbers" or the maximum processing time as parameters. Indeed, so far, they were successfully applied only to basic parallel or single machine scheduling problems and even these immediately become W-hard with respect to various parameters and constant processing times once one adds precedence constraints [1, 8, 12]. Therefore, it seems challenging to apply these mathematical programming tools to obtain fixed-parameter algorithms for scheduling problems with side constraints like precedence constraints [1, 8, 12], machine or job availability intervals [4], machine setup times or integrated routing [7].

Interestingly, in recent joint work with A. V. Pyatkin on Routing Open Shop with unit processing times—a scheduling problem with integrated routing—Lenstra's theorem was more helpful for solving the routing part of the problem, whereas the scheduling part was solved by another new tool: Galvin's theorem on list-coloring bipartite graphs, which will presumably be helpful in other fixed-parameter algorithms for scheduling problems with unit processing times or allowed preemption.

References.

[1] R. van Bevern, R. Bredereck, L. Bulteau, C. Komusiewicz, N. Talmon, and G. J. Woeginger. Precedence-constrained scheduling problems parameterized by partial order width. arxiv:1605.00901, 2016.

[2] R. van Bevern, J. Chen, F. Hüffner, S. Kratsch, N. Talmon, and G. J. Woeginger. Approximability and parameterized complexity of multicover by c-intervals. *Inform. Process. Lett.*, 115(10):744–749, 2015.

[3] R. van Bevern, C. Komusiewicz, and M. Sorge. Approximation algorithms for mixed, windy, and capacitated arc routing problems. In *Proc. 15th ATMOS*, volume 48 of *OASIcs*. Schloss Dagstuhl–Leibniz-Zentrum fr Informatik, 2015.

[4] R. van Bevern, M. Mnich, R. Niedermeier, and M. Weller. Interval scheduling and colorful independent sets. *J. Sched.*, 18:449–469, 2015.

[5] R. van Bevern, R. Niedermeier, M. Sorge, and M. Weller. Complexity of arc routing problems. In *Arc Routing: Problems, Methods, and Applications*, MOS-SIAM Series on Optimization. SIAM, 2014.

[6] R. van Bevern, R. Niedermeier, and O. Suchý. A parameterized complexity view on non-preemptively scheduling interval-constrained jobs: few machines, small looseness, and small slack. *J. Sched.*, 2016. In press.

[7] R. van Bevern and A. V. Pyatkin. Completing partial schedules for open shop with unit processing times and routing. In *Proc. 11th CSR*, 2016. To appear.

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

[9] M. Cieliebak, T. Erlebach, F. Hennecke, B. Weber, and P. Widmayer. Scheduling with release times and deadlines on a minimum number of machines. In *Exploring New Frontiers of Theoretical Informatics*, volume 155 of *IFIP International Federation for Information Processing*, pages 209–222. Springer, 2004.

[10] F. Dorn, H. Moser, R. Niedermeier, and M. Weller. Efficient algorithms for Eulerian Extension and Rural Postman. *SIAM J. Discrete Math.*, 27(1):75–94, 2013.

[11] M. R. Fellows, S. Gaspers, and F. A. Rosamond. Parameterizing by the number of numbers. *Theory of Computing Systems*, 50(4):675–693, 2011.

[12] M. R. Fellows and C. McCartin. On the parametric complexity of schedules to minimize tardy tasks. *Theor. Comput. Sci.*, 298(2):317–324, 2003.

[13] G. Gutin, M. Jones, and B. Sheng. Parameterized complexity of the k-Arc Chinese Postman Problem. In *Proc. 22nd ESA*, volume 8737 of *LNCS*, pages 530–541. Springer, 2014.

[14] G. Gutin, M. Jones, B. Sheng, and M. Wahlström. Parameterized Directed k-Chinese Postman problem and k-Arc-Disjoint Cycles problem on Euler digraphs. In *Proc. 40th WG*, pages 250–262. Springer, 2014.

[15] G. Gutin, M. Jones, and M. Wahlström. Structural parameterizations of the Mixed Chinese Postman Problem. In *Proc. 23rd ESA*, volume 9294 of *LNCS*, pages 668–679. Springer, 2015.

[16] G. Gutin, G. Muciaccia, and A. Yeo. Parameterized complexity of k-Chinese Postman Problem. *Theor. Comput. Sci.*, 513:124–128, 2013.

[17] G. Gutin, M. Wahlström, and A. Yeo. Rural Postman parameterized by the number of components of required edges. *J. Comput. Syst. Sci.*, 2014. To appear. arXiv:1308.2599v4.

[18] M. M. Halldórsson and R. K. Karlsson. Strip graphs: Recognition and scheduling. In *Proc. 32nd WG*, volume 4271 of *LNCS*, pages 137–146. Springer, 2006.

[19] D. Hermelin, J.-M. Kubitza, D. Shabtay, N. Talmon, and G. Woeginger. Scheduling two competing agents when one agent has significantly fewer jobs. In *Proc. 10th IPEC*, volume 43 of *LIPIcs*, pages 55–65. Schloss Dagstuhl–Leibniz-Zentrum fr Informatik, 2015.

[20] D. Knop and M. Koutecký. Scheduling meets n-fold integer programming. arXiv:1603.02611, 2016.

[21] A. Kononov, S. Sevastyanov, and M. Sviridenko. A complete 4-parametric complexity classification of short shop scheduling problems. *Journal of Scheduling*, 15(4):427–446, 2011.

[22] S. Kratsch. On polynomial kernels for sparse integer linear programs. *Journal of Computer and System Sciences*, 82(5):758–766, 2016.

[23] D. Marx. Parameterized complexity and approximation algorithms. *The Computer Journal*, 51(1):60–78, 2008.

[24] D. Marx. Fixed-parameter tractable scheduling problems. In *Packing and Scheduling Algorithms for Information and Communication Services (Dagstuhl Seminar 11091)*. 2011.

[25] D. Marx and M. Pilipczuk. Everything you always wanted to know about the parameterized complexity of subgraph isomorphism (but were afraid to ask). arxiv:1307.2187, 2013.

[26] M. Mnich and A. Wiese. Scheduling and fixed-parameter tractability. *Math. Programming*, 154(1-2):533–562, 2015.

[27] M. Sorge, R. van Bevern, R. Niedermeier, and M. Weller. From few components to an Eulerian graph by adding arcs. In *Proc. 37th WG*, pages 307–318. Springer, 2011.

[28] M. Sorge, R. van Bevern, R. Niedermeier, and M. Weller. A new view on Rural Postman based on Eulerian Extension and Matching. *J. Discrete Alg.*, 16:12–33, 2012.

3rd Creative Mathematical Sciences Communication (CMSC)

The 3rd *Creative Mathematical Sciences Communication* takes place 4 - 7 October 2016, Luebeck, Germany.

See `http://www.tcs.uni-luebeck.de/cmsc`

Come to explore new ways of popularizing the rich mathematics underlying computer science including outdoor activities, art, dance, drama and all forms of storytelling. This is *Computer Science Unplugged!* (`www.csunplugged.org`) and Beyond.

Challenge yourself to communicate our research culture to young people and you will inevitably confront fresh mathematical questions that will renew your own research, and your field. The creative dynamic is bidirectional.

The previous conferences, held in Darwin, AU (2013) and in Chennai, India (2014) saw a unique interaction between computer science / mathematics researchers, educators and artists of all sorts (theatre, drawing, dance, graphic arts).

Everyone interested in innovative ways to teach / popularize algorithmics and its foundations is welcome. We encourage you to present your own efforts and discuss new ideas. Presentations and demonstrations welcome, also ideas for leading round-table discussions.

Important dates:
Abstracts due: 10 June 2016
Submissions due: 8 July 2016
Early Registration: 15 August 2016
Conference: 4-7 October 2016

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Moving Around – Congratulations to ALL.

Dr. Ljiljana Brankovic, Univ Newcastle, Australia has visited Cristina Bazgan, Dauphine Univ and is now visiting Henning Fernau, Univ Trier as part of her DFG Mercator position.

Dr. Moritz Müller has successfully aquired habilitation in mathematics at the University of Vienna. Congratulations, Moritz!

Dr. André Nichterlein, from Prof. Rolf Niedermeier's group, has accepted a DAAD-funded postdoc position at Durham Univ (UK), hosted by Dr. George Mertzios.

Prof. Toby Walsh will move from Sydney to TU Berlin in June 2016 with his ERC Advanced Grant *Allocation Made PracticaL (AMPLify).*

CONGRATULATIONS New PhDs

Jiehua Chen, *Exploiting Structure in Computationally Hard Voting Problems*, 2015, TU-Berlin. Advisor: Prof. Rolf Niedermeier. Congratulations, Dr. Chen. Dr. Chen is with Prof. Niedermeier's group at TU-Berlin.

Shenwei Huang, *Colouring on Hereditary Graph Classes*, 2015, Simon Frasier University, Canada. Advisor: Professor Pavol Hell. Congratulations, Dr. Huang. Dr. Huang has accepted a postdoc position with Serge Gaspers at UNSW Australia.

Fahad Panolan, *Dynamic Programming using Representative Families*, 2016, IMSc, Chennai. Advisor: Prof. Saket Saurabh. Congratulations, Dr. Panolan. Dr. Panolan has accepted a Post-Doc at the University of Bergen.

Manuel Sorge, *Be Sparse! Be Dense! Be Robust! Elements of Parameterized Algorithmics*, 2016, TU-Berlin. Advisor: Prof. Rolf Niedermeier. Congratulations, Dr. Sorge. Dr. Sorge is with Prof. Niedermeier's group.

Nimrod Talmon, *Algorithmic Aspects of Manipulation and Anonymization in Social Choice and Social Networks*, 2015, TU-Berlin. Advisor: Prof. Rolf Niedermeier. Congratulations, Dr. Talmon. Dr. Talmon has accepted a postdoc position at Weizmann Institute of Science, Israel (I-CORE ALGO) and his host is Robert Krauthgamer.

Jenna Thompson, *Subgraph identification and detection in complex networks*, 2016, Univ Queensland, Australia. Advisor: Prof. Benjamin Burton. Congratulations, Dr. Thompson. Dr. Thompson has accepted a position with the Australian government in Canberra.

Welcome to new FPTers

Congratulations to **Olga and Robert Ganian** on the birth of their daughter Vanessa, born 24 Nov 2015. Welcome, Vanessa.

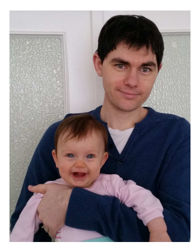

Figure 2: Happy Vanessa, proud Robert.

Congratulations to **Manju and G. Philip** on the birth of their daughter Aditi. Aditi is visiting Saarbruecken with her parents and will come to Bergen in July. Welcome, Aditi.

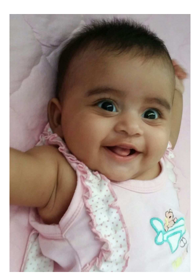

Figure 3: Aditi cheerfully encourages her parents.