Parameterized Complexity News

Newsletter of the Parameterized Complexity Community

www.fpt.wikidot.com

Vol 18, No 1. March 2022
ISSN 2203–109X

Enjoy the Newsletter

It is with the deepest sadness that this newsletter reports the death of three esteemed friends: our beloved Rolf Niedermeier, Gerhard Woeginger, and Benny Chor. Their passing is a huge loss to many of us personally as well as to us all professionally. The Memorial by Rolf's students is on the last page.

Congratulations is extended to all for many awards and prizes, graduates, new jobs, and research. Enjoy two research articles: *Parameterized Approximations via Randomized Branching* by Ariel Kulik and Hadas Shachnai and *Revising Johnson's table for the 21st century* by Ana Silva, Celina de Figueiredo, Alexsander de Melo. Please add to the *FPT Complexity* Youtube Channel. Update Wikipedia with your new results. Follow fb page @MikeFellowsFPT. Send us news via Google form https://forms.gle/sfZNzKFsbfqSywgy7 or directly to our emails. Please keep well. Take good care of yourselves. Wishing you all the best from Frances.Rosamond@uib.no, Valia Mitsou vmitsou@irif.fr, Benjamin.Bergougnoux@uib.no and the News Team.

FPT News Chief Editor retires

Dear All, I started the *FPT News, the Parameterized Complexity Newsletter* in 2005. My, how time flies. Cheering your achievements, enjoying the pictures you send, watching the development of your research and the growth of the field, meeting your families has all been greatest joy. There have been 36 editions of the *FPT News* over the past sixteen years. They can all be found at the Parameterized Complexity website (fpt.wikidot.com) along with IPEC Publicity Reports, and other items of interest to the PC community, or by using the ISSN number.

Figure 1: Frances Rosamond and Michael Fellows

Michael Fellows will retire in June as the University of Bergen has mandatory retirement when a Professor turns 70 years of age, and I will retire also. I am nostalgic letting you know that this will be my final newsletter as Chief Editor.

Besides Parameterized Complexity, Mike and I have been involved in making the mathematical foundations of computing accessible to children of all ages, as exemplified by the book "Computer Science Unplugged" by Bell, Witten and Fellows. Some of this has spilled over into the Parameterized Complexity Newsletter over the years, and conversely, most science funding agencies nowadays require that research projects involve some public science communication. There has been excellent symbiosis.

Our last conference effort before retiring, funded by

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our Norwegian Research Council grant PCPC, will be the *6th Creative Mathematical Sciences Communication* conference (CMSC'22) at the University of Bergen, 20-23 April. The CMSC conference series was initiated in Darwin, Australia. The pandemic has attracted our interest in issues of computational thinking for modern citizenship. The CMSC will hold a brainstorming session on this on Friday morning, 22 April. There will be a math theatre production created by Matthias Mnich and Verena Specht-Ronique on Friday evening. You are welcome to any or all parts of the conference. There is no registration fee. The conference website is csmc-uib.org.

Keep up the good work. Be happy.

Frances

Standa Živný, ERC Consolidator Grant

CONGRATULATIONS Standa Živný (University of Oxford) who has been awarded a five-year €2M ERC Consolidator Grant NAASP: *New Approaches to Approximability of Satisfiable Problems.* He is one of 313 scientists given awards in a €632 million EU investment to boost cutting-edge research.

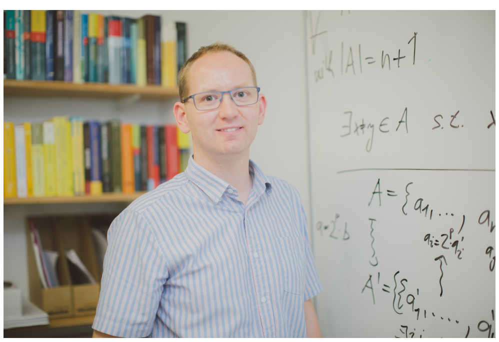

Figure 2: Standa Živný, University of Oxford.

The NAASP project aims to make advances towards our understanding of approxiability of perfectly satisfiable instances of constraint satisfaction problems (CSPs), such as the approximate graph colouring problem, whose complexity status is open since 1970s. ERC (European Research Council) Consolidator Grants are highly competitive and provide long-term funding for mid-career researchers to pursue ground-breaking, high-risk projects. NAASP is the second ERC Grant awarded to Standa; from 2017 to 2022 he held the ERC Starting Grant PowAlgDO (Power of Algorithms in Discrete Optimisation). Standa is Professor of Computer Science and Tutorial Fellow at Jesus College, University of Oxford.

Martin Koutecky, Czech Science Foundation

Figure 3: Martin Koutecký and Pavel Veselý, Charles University.

CONGRATULATIONS Martin Koutecky (Charles University) for the Czech Science Foundation project *Efficient and Realistic Models for Computational Social Choice,* investigated by Martin Koutecký and Pavel Veselý. The award is for about €300k. Parameterized complexity will be one of the primary tools.

There are several PhD positions available. The application deadline is April 7, 2022. The application and the recommendation letters should be sent electronically to: koutecky@iuuk.mff.cuni.cz. The project's webpage is https://research.koutecky.name/projects.html.

Kitty Meeks, University of Glasgow

CONGRATULATIONS Kitty Meeks (University of Glasgow) for the project *Beyond One Solution in Combinatorial Optimisation* awarded by the Engineering and Physical Sciences Research Council (EPSRC) for 1,363,670 GBP and running until 2026. Co-investigators are Dr C. Anderson, Dr. J. Enright, and Dr. B. Jani. The abstract reads: Which characteristics should be used to determine whether a patient is offered routine cancer screening? Are there two or three qualitatively different types of heart failure? Which journeys should be forbidden to restrict the spread of an infectious disease?

Data-driven approaches to answering any of these questions - as well as many others in the field of digital health - typically involve searching for a single mathematical object which is optimal with respect to some criterion. For example, we might aim to partition patients into a fixed number of groups or "clusters" in a way that minimises the maximum "difference" in the characteristics of patients assigned to the same cluster.

However, there will often be many solutions that are equally good with respect to our chosen criterion, in which case it is misleading to consider just a single example: if there are many optimal ways to split our patient group into clusters, and there is little agreement between these optimal solutions about which patients belong to the same cluster, then we should not draw conclusions based on just a single optimal solution. It is therefore important to find out more about the whole set of good solutions.

Unfortunately, in most settings, even finding a single optimal solution is a very computationally challenging problem, and finding all good solutions (or even estimating how many of these there are) is even more difficult. This project aims to advance our understanding of how to design efficient algorithms that can (at least approximately) find all good solutions, count their number, or sample a good solution uniformly at random. To do this we will develop new techniques by drawing on two areas of computational complexity - parameterised complexity and approximate counting - whose intersection has not yet been properly explored. This will make it feasible to extract information about the entire space of good representative structures in many more settings, providing complete and fully explainable answers to our original healthcare-inspired questions as well as many others.

Michael Fellows, Université Paris Dauphine Honorary Doctorate

CONGRATULATIONS Michael Fellows (University of Bergen), who will be awarded an Honorary Doctorate from the Université Paris Dauphine in June 2022.

Figure 4: Michael Ralph Fellows.

Paris Dauphine was founded in 1968 and lists 17 Honorary PhDs awarded over 44 years, to researchers including two Nobel Laureates and one Turing Award winner. The award for Parameterized Complexity will be the 18th.

Michail Lampis, Habilitation Diploma

CONGRATULATIONS Michail Lampis (Université Paris Dauphine), who has been awarded the Habilitation Diploma with his thesis, *Structural Graph Parameters, Fine-Grained Complexity, and Approximation*. The Coordinateur was Professor Vangelis Th. Paschos (Université Paris Dauphine). The Rapporteurs were Michael Fellows (University of Bergen), Christophe Paul (CNRS LIRMM), and Ioan Todinca (University d'Orleans).

Parameterized Approximations via Randomized Branching

by Ariel Kulik, *CISPA Helmholtz Center for Information Security, DE*, and Hadas Shachnai, *Technion IIT, IL*. This short article briefly outlines the ideas presented in a FOCS 2020 paper [6] by the same authors.

Figure 5: Hadas Shachnai and Ariel Kulik.

Parameterized approximation aims at approximately solving optimization problems in FPT time. This relatively new field of interest is motivated by the intuition, that combining approximation and parameterization would allow to improve the approximation guarantees obtained by polynomial-time algorithms, while surpassing the best known running times of exact FPT algorithms. Recent results affirm this intuition for some problems (e.g., [7]), yet refute it for others (e.g, [5]). In search of tools for deriving efficient parameterized approximations, we explore the power of randomization in branching algorithms, and provide the mathematical machinery required for its analysis.

Recall that a *vertex cover* of an undirected graph $G = (V, E)$ is a subset $S \subseteq V$ such that for any $(u, v) \in E$ it holds that $S \cap \{u, v\} \neq \emptyset$. In the *Vertex Cover* problem we seek a vertex cover of minimum cardinality for G. A simple polynomial-time algorithm yields a 2-approximation for the problem, which is optimal under the *unique games conjecture*. In Vertex Cover parameterized by the solution size k, we are given an integer parameter $k \geq 1$, and we wish to determine if G has a vertex cover of size k. The fastest running time of an FPT algorithm for the problem is $O^*(1.273^k)$ due to Chen et al. [2]; the existence of a $2^{o(k)} \cdot \text{poly}(n)$ algorithm is ruled out by the *exponential time hypothesis*. The fastest parameterized 1.5-approximation algorithm for Vertex Cover prior to this work, due to Brankovic and Fernau [1], has running time $O^*(1.0883^k)$. Our goal is to obtain an improved trade-off between running time and approximation ratio for the problem.

Consider the following simple algorithm for Vertex Cover. Recursively pick a vertex v of degree at least 3, and branch over the following two options: v is in the cover, or three of v's neighbors are in the cover. The first branch picks v into the cover and deletes it from the graph; the second branch picks the three neighbors into the cover and removes them from the graph. If the maximal degree is 2 or less, then find a minimal vertex cover in polynomial time. The running time of the algorithm is $O^*(1.4656^k)$ (see Chapter 3 in [3] for more details).

The randomized branching version of this algorithm replaces branching by a random selection with some probability $\gamma \in (0,1)$. In each recursive call the algorithm selects either v or three of its neighbors to the solution, with probabilities γ and $1-\gamma$, respectively (we call this algorithm below VC3$_\gamma$). If v is in a minimal vertex cover then the algorithm has probability γ to decrease the minimal cover size by one, and probability $1-\gamma$ to select three vertices to the solution, possibly with no decrease in the minimal cover size. A similar argument holds in case v is not in a minimal vertex cover. This suggests that the function $p(b,k)$ defined in equation (1) lower bounds the probability the above algorithm returns a vertex cover of size b, given a graph which has a vertex cover of size k.

$$\begin{aligned} &p(b,k) = \\ &\quad \min \begin{cases} \gamma \cdot p(b-1,k-1) + (1-\gamma)\cdot p(b-3,k) \\ \gamma \cdot p(b-1,k) + (1-\gamma)\cdot p(b-3,k-3) & k \geq 3 \end{cases} \\ &p(b,k) = 0 \qquad \forall b < 0, k \in \mathbb{N} \\ &p(b,0) = 1 \qquad \forall b \geq 0 \end{aligned} \tag{1}$$

Thus, for any $\alpha > 1$, we can obtain an α-approximation with constant probability by repeating the randomized branching process $\frac{1}{p(\alpha k,k)}$ times. While $p(b,k)$ can be evaluated using dynamic programming for any $b,k \geq 0$, finding the asymptotic behavior of $\frac{1}{p(\alpha k,k)}$ as $k \to \infty$, which dominates the running time of our algorithm, is non-trivial.

Recurrence relations. The recurrence in (1) can be viewed as representing two branching states (v is in a minimum vertex cover or not); a branching state has two possible outcomes, each associated with a probability, a decrease in b (the "budget") and a decrease in the parameter k. To analyze faster randomized branching algorithms for Vertex Cover, we first generalize the recurrence relation in (1). Our generalization allows for an arbitrary number $N \in \mathbb{N}_+$ of branching states, where each state $1 \leq j \leq N$ has an arbitrary number $r_j \in \mathbb{N}_+$ of possible outcomes. We represent the probabilities as well as the values of the decrease in the budget and parameter of the outcomes of state j using three r_j-dimensional vectors: $\bar{\gamma}^j$, $\bar{b}^j$ and $\bar{k}^j$.

Formally, the generalized recurrence relation defines a function $p : \mathbb{Z} \times \mathbb{N} \to [0,1]$ satisfying the following equation.

$$p(b,k) = \min_{\{1 \leq j \leq N \mid \ \bar{k}^j \leq k\}} \sum_{i=1}^{r_j} \bar{\gamma}_i^j \cdot p(b - \bar{b}_i^j, k - \bar{k}_i^j) \tag{2}$$

with the initial conditions $p(b,k) = 0$ for $b < 0, k \in \mathbb{N}$, and $p(b,0) = 1$ for all $b \geq 0$. We require that $N \in \mathbb{N}$, and for any $1 \leq j \leq N$ the following hold: $\bar{b}^j \in \mathbb{N}_+^{r_j}$, $\bar{k}^j \in \mathbb{N}^{r_j} \setminus \{\bar{0}\}$ and $\bar{\gamma}^j \in \mathbb{R}_+^{r_j}$ with $\sum_{i=1}^{r_j} \bar{\gamma}_i^j = 1$. We say that $\bar{k}^j \leq k$ if $\bar{k}_i^j \leq k$ $\forall 1 \leq i \leq r_j$. We refer to the recurrence relation in (2) as the *composite recurrence* of $\{(\bar{b}^j, \bar{k}^j, \bar{\gamma}^j) | 1 \leq j \leq N\}$, and to each of the triplets $(\bar{b}^j, \bar{k}^j, \bar{\gamma}^j)$ as *terms*.

As in the case of recurrences in a single variable, we associate with each term a *branching number*. We say that a vector $\bar{q} \in \mathbb{R}_{\geq 0}^r$ is a *distribution* if $\sum_{i=1}^r \bar{q}_i = 1$ and use $D\left(\bar{c} \| \bar{d}\right) = \sum_{i=1}^r \bar{c}_i \ln \frac{\bar{c}_i}{\bar{d}_i}$ to denote the *Kullback-Leibler divergence* of the distributions $\bar{c}$ and $\bar{d}$.

Definition 1. *Let $\bar{b} \in \mathbb{N}_+^r$, $\bar{k} \in \mathbb{N}^r$ and $\bar{\gamma} \in \mathbb{R}_{\geq 0}^r$ with $\sum_{i=1}^r \bar{\gamma}_i = 1$. Then for $\alpha > 0$, the* α-branching number *of the term $(\bar{b}, \bar{k}, \bar{\gamma})$ is the optimal value M^* of the following minimization problem over $\bar{q} \in \mathbb{R}_{\geq 0}^r$:*

$$M^* = \min \left\{ \frac{D\left(\bar{q} \| \bar{\gamma}\right)}{\sum_{i=1}^r \bar{q}_i \cdot \bar{k}_i} \;\middle|\; \begin{array}{l} \sum_{i=1}^r \bar{q}_i \cdot \bar{b}_i \leq \alpha \sum_{i=1}^r \bar{q}_i \cdot \bar{k}_i \\ \bar{q} \text{ is a distribution} \end{array} \right\} \tag{3}$$

If the optimization above does not have a feasible solution then $M^* = \infty$.

Our main result is the following.

Theorem 2. *Let p be the composite recurrence of $\{(\bar{b}^j, \bar{k}^j, \bar{\gamma}^j) | \ 1 \leq j \leq N\}$, and $\alpha > 0$. Denote by M_j the α-branching number of $(\bar{b}^j, \bar{k}^j, \bar{\gamma}^j)$, and let $M = \max\{M_j | 1 \leq j \leq N\}$. If $M < \infty$ then*

$$\lim_{k \to \infty} \frac{\ln p\left(\lfloor \alpha k \rfloor, k\right)}{k} = -M.$$

Theorem 2 asserts that $p(\alpha k, k) \approx \exp(-M)^k$. Furthermore, it shows that the asymptotics of $p(\alpha k, k) \approx \exp(-M)^k$ is dominated by the "worst" term in p. The latter is analogous to the property of branching numbers of classic recurrences in a single variable and can be similarly exploited towards the design of improved algorithms.

The proof of the theorem utilizes a connection between composite recurrences and a stochastic process. The analysis of this process relies on the *method of types*, a powerful technique developed mostly within the context of information theory, and can be viewed as an adaptation of Sanov's Theorem to our setting.

Analyzing algorithm VC3$_\gamma$. We can use Theorem 2 to compute the asymptotics of $p(\alpha k, k)$, where p is the function defined in (1). For a fixed $\alpha \in (1,2)$, this requires choosing γ and then solving (3) for each of the two terms. Finding the value of γ for which the overall running time is optimal, along with the computation of this running time, is a quasi-convex numerical optimization problem, which can be solved by existing tools. For $\alpha = 1.5$ the computation leads to $\lim_{k \to \infty} \frac{1}{k} \ln p(\alpha k, k) \approx 0.0428$. Hence, by choosing the optimal γ, algorithm VC3$_\gamma$ finds a 1.5-approximate solution for Vertex Cover with constant probability in time $O^*(1.0436^k)$. This already improves upon the result of [1]. By applying simple improvements over VC3$_\gamma$, the running time for a 1.5-approximation can be further improved to $O^*(1.01657^k)$.

There is a simple intuition explaining the speedup achieved by randomized branching. Previous works either considered approximative preprocessing [4] or used approximative (worsening) steps within branching approximation algorithms for Vertex Cover [1]. While these techniques use the approximative step explicitly at given stages of the algorithm execution, in randomized branching the approximative step takes the form of an incorrect branching decision, which may add unnecessary vertices to the solution. As incorrect branching is not restricted to a specific stage, a degree of freedom is added to the number of *good paths* within the branching tree. This degree of freedom in turn increases the probability of finding an approximate solution.

References

[1] L. Brankovic and H. Fernau.A novel parameterised approximation algorithm for minimum vertex cover *Theoretical Computer Science* 511: 85-108, 2013.

[2] J. Chen, I.A. Kanj and G. Xia. mproved upper bounds for vertex cover. *Theoretical Computer Science*. 411(40-42): 3736-3756, 2010.

[3] M. Cygan , F.V. Fomin, Ł. Kowalik, D. Lokshtanov, D. Marx, M. Pilipczuk, M. Pilipczuk, and S. Saurabh. Parameterized algorithms. Springer, 2015.

[4] M.R. Fellows, A. Kulik, F.A. Rosamond, and H. Shachnai. Parameterized approximation via fidelity preserving transformations. *Journal of Computer and System Sciences* 93: 30-40, 2018.

[5] C.S. Karthik, B. Laekhanukit, and P. Manurangsi. On the Parameterized Complexity of Approximating Dominating Se. *Journal of the ACM* 66(5): Article 33, 2019.

[6] A. Kulik and H. Shachnai. Analysis of two-variable recurrence relations with application to parameterized approximations. In *2020 IEEE 61st Annual Symposium on Foundations of Computer Science (FOCS)*, 762-773, 2020.

[7] D. Lokshtanov, S. Saurabh, and V. Surianarayanan. A Parameterized Approximation Scheme for Min k-Cut. In *2020 IEEE 61st Annual Symposium on Foundations of Computer Science (FOCS)*, 798-809, 2020.

Quantum Parameterized Complexity

by Michael Bremner, Ji Zhengfeng, Ryan Mann, Luke Mathieson, Mauaro Morales, Alexis Shaw (University of Technology Sydney, Australia; Tsinghua University, Beijing, China; University of Bristol, UK).

Parameterized complexity theory was developed in the 1990s to enrich the complexity-theoretic analysis of problems that depend on a range of parameters. In this paper we establish a quantum equivalent of classical parameterized complexity theory, motivated by the need for new tools for the classifications of the complexity of real-world problems. We introduce the quantum analogues of a range of parameterized complexity classes and examine the relationship between these classes, their classical counterparts, and well-studied problems. This framework exposes a rich classification of the complexity of parameterized versions of QMA-hard problems, demonstrating, for example, a clear separation between the Quantum Circuit Satisfiability problem and the Local Hamiltonian problem.

Out and About - Moving Around

Robert Bredereck (robert.bredereck@tu-clausthal.de) has started his position as Junior Professor (with tenure) for "Foundations of Artificial Intelligence and Algorithms" at TU Clausthal, certainly also continuing the spread of parameterized algorithmics in spirit of Rolf...

Benjamin Merlin Bumpus, who did his PhD in Glasgow with Kitty Meeks, has joined Bart Jansen as a postdoc in Eindhoven for 2 years: September 2021 – September 2023. He is working on Bart's ERC Starting Grant *ReduceSearch*.

Konrad Dabrowski has accepted a permanent position as Lecturer at the University of Newcastle, UK. The position comes with comes with funding for a PhD student. Please note the deadline of 30th March 2022 and that the funding is only available for students with UK home fee status; this usually includes UK students and EU students with settled (and possibly pre-settled) status.

Paloma Lima has moved to an Assistant Professor position at the IT University of Copenhagen. She took up the position in January 2022.

Diptapriyo Majumdar has completed his postdoc at Royal Holloway University of London and moved to an Assistant Professor position at the Indraprastha Institute of Information Technology (IIIT) Delhi. Diptapriyo completed his PhD under Venkatesh Raman at IMSc Chennai, India, with the thesis, *Classical and Approximate Kernels for Structural Parameterizations of some Graph Parameters.*

Lars Rohwedder is now assistant professor in Maastricht. He did some fundamental work on parameterized algorithms for integer programming and on approximation algorithms for scheduling. Lars is a former PhD student of Klaus Jansen (Univ. Kiel).

Revising Johnson's table for the 21st century

by Ana Silva (UFC, Brazil), Alexsander A. de Melo (UFRJ, Brazil), and Celina M. H. de Figueiredo (UFRJ, Brazil).

Figure 6: Celina M. H. de Figueiredo, Ana Silva and Alexsander A. de Melo.

What does it mean today to study a problem from a computational point of view? In [3], we focus on parameterized complexity and on Column 16 "Graph Restrictions and Their Effect" of D. S. Johnson's Ongoing guide, where several puzzles were proposed in a summary table with 30 graph classes as rows and 11 problems as columns. After 35 years, several of the 330 entries remain unclassified into Polynomial-time solvable or NP-complete. We revise Johnson's summary table according to the granularity provided by the parameterized complexity for NP-complete problems.

Graph Restrictions and Their Effect 35 Years Later. The 1979 book *Computers and Intractability, A Guide to the Theory of NP-completeness* by Michael R. Garey and David S. Johnson is considered the single most important book by the computational complexity community and it is known as The Guide, which we cite by [GJ]. The Guide was followed by *The NP-completeness Column: An Ongoing Guide* where, from 1981 until 2007, D. S. Johnson continuously updated The Guide in 26 columns published first in the *Journal of Algorithms* and then in the *ACM Transactions on Algorithms*. The Guide has an appendix where 300 NP-complete problems are organized into 13 categories according to subject matter. In particular, the first "A1 Graph Theory" contains 65 problems, and the second "A2 Network Design" contains 51 problems. Category "A13 Open Problems" lists 12 problems in NP, which at the time were not classified into Polynomial-time solvable or NP-complete. Surprisingly, since then, 5 of those problems have been classified into Polynomial-time solvable and 5 into NP-complete. Garey and Johnson were amazingly able to foresee a list of challenging problems which would evenly split into tractable and intractable. The goal of [3] is to propose an answer to the question: *What does it mean today to study a problem from a computational complexity point of view?* In search of an answer, we focus on parameterized complexity and on Column 16 "Graph Restrictions and Their Effect", which we cite by [OG].

The Parameterized Complexity of Hard Problems. We consider the parameterized complexity of hard problems to revise Johnson's summary table into a new table (Table 1), a proposed summary table of what it means today to study a problem from a computational complexity point of view. This is of course just a sample of what it means, since we could even consider other classifications (e.g., the approximability complexity theory and the space complexity theory). We have kept the same 30 classes but have drawn the horizontal lines so that the PARTIAL k-TREES subclasses appear together, and we may focus on the remaining rows, where the NP-complete entries appear. In [3], we discuss in detail Table 1, also presenting the basic definitions of parameterized complexity, in order to draw the reader's attention to the granularity provided by the parameterized complexity for the NP-complete problems into XP, FPT, W_1, W_2, and pN. This is to show how rich the original problems posed by Garey and Johnson are, and how their initial classification continues to develop into ever evolving complexity classes, with the NP-complete class being now just the beginning of a very interesting story.

We additionally cite two recent developments for problems restricted to chordal graphs: MaxCut on interval graphs [1], and StTree and DomSet on path graphs [2].

In Table 1, we use abbreviations for references [T] = Restriction trivializes the problem, [GJ] = the Guide, [OG] = the Ongoing guide, and [RJ] = our Revising Johnson paper [3], please refer to this reference for the entry. The parameterized puzzle is to classify every O entry, every O? entry and every N entry into FPT = Fixed parameter tractable, W_1= W[1]-hard, W_2= W[2]-hard, and pN = paraNP-complete, where the considered parameterization is with respect to the natural parameter of each corresponding problem.

We invite the FPT community to give better classifications for the trivial XP entries, and to answer all the O? (open) entries. We highlight the O* entry, which constitutes the sole problem in Johnson's table for which we know the classical complexity (it is NP-complete), but for which we could not find an FPT classification.

References

[1] Celina M. H. de Figueiredo, Alexsander Andrade de Melo, Fabiano de S. Oliveira, and Ana Silva. Maximum cut on interval graphs of interval count four is NP-complete. In *MFCS 2021*, volume 202 of *LIPIcs*, pages 38:1–38:15. Schloss Dagstuhl, 2021. https://doi.org/10.4230/LIPIcs.MFCS.2021.38.

[2] Celina M. H. de Figueiredo, Raul Lopes, Alexsander Andrade de Melo, and Ana Silva. Parameterized algorithms for Steiner tree and dominating set: Bounding the leafage by the vertex leafage. In *WALCOM 2022, Lecture Notes in Com-*

Graph Class	Member	IndSet	Clique	CliPar	ChrNum	ChrInd	HamCir	DomSet	MaxCut	κ-StTree	GraphIso
Partial k-trees	P [OG]	P [RJ]	P [T]	P [RJ]	P [RJ]	P [RJ]	P [RJ]	P [RJ]	P [RJ]	P [RJ]	P [RJ]
Trees/Forests	P [T]	P [GJ]	P [T]	P [GJ]	P [T]	P [GJ]	P [T]	P [GJ]	P [GJ]	P [T]	P [GJ]
Almost Trees (k)	P [OG]	P [OG]	P [T]	P [RJ]	P [RJ]	P [RJ]	P [RJ]	P [RJ]	P [RJ]	P [RJ]	P [RJ]
Bandwidth-k	P [OG]	P [OG]	P [T]	P [RJ]	P [RJ]	P [RJ]	P [RJ]	P [RJ]	P [OG]	P [RJ]	P [OG]
Series Parallel	P [OG]	P [OG]	P [T]	P [RJ]	P [RJ]	P [RJ]	P [RJ]	P [OG]	P [GJ]	P [OG]	P [GJ]
Outerplanar	P [OG]	P [OG]	P [T]	P [OG]	P [OG]	P [OG]	P [T]	P [OG]	P [GJ]	P [OG]	P [GJ]
Halin	P [OG]	P [OG]	P [T]	P [OG]	P [RJ]	P [RJ]	P [T]	P [OG]	P [GJ]	P [RJ]	P [GJ]
k-Outerplanar	P [OG]	P [OG]	P [T]	P [OG]	P [RJ]	P [RJ]	P [OG]	P [OG]	P [GJ]	P [RJ]	P [GJ]
Planar	P [GJ]	FPT [RJ]	P [T]	FPT [T]	pN [RJ]	O	FPT [RJ]	FPT [RJ]	P [GJ]	FPT [RJ]	P [GJ]
Grid	P [OG]	P [GJ]	P [T]	P [GJ]	P [T]	P [GJ]	FPT [RJ]	FPT [RJ]	P [T]	FPT [RJ]	P [GJ]
$K_{3,3}$-Free*	P [OG]	FPT [RJ]	P [T]	FPT [T]	pN [RJ]	O?	FPT [RJ]	FPT [RJ]	P [OG]	XP [T]	P [RJ]
Thickness-k	pN [OG]	FPT [RJ]	P [T]	FPT [T]	pN [RJ]	pN [RJ]	FPT [RJ]	XP [T]	FPT [RJ]	XP [T]	FPT [RJ]
Genus-k	P [OG]	FPT [RJ]	P [T]	FPT [T]	pN [RJ]	O?	FPT [RJ]	FPT [RJ]	FPT [RJ]	FPT [RJ]	P [OG]
Degree-k	P [T]	FPT [RJ]	P [T]	FPT [T]	pN [RJ]	pN [RJ]	FPT [RJ]	FPT [RJ]	FPT [RJ]	FPT [RJ]	P [OG]
Perfect	P [RJ]	P [OG]	P [OG]	P [OG]	P [OG]	pN [RJ]	FPT [RJ]	W_2 [RJ]	FPT [RJ]	W_2 [RJ]	FPT [RJ]
Chordal	P [OG]	P [OG]	P [OG]	P [OG]	P [OG]	O?	FPT [RJ]	W_2 [RJ]	FPT [RJ]	W_2 [RJ]	FPT [RJ]
Split	P [OG]	P [OG]	P [OG]	P [OG]	P [OG]	O?	FPT [RJ]	W_2 [RJ]	FPT [RJ]	W_2 [RJ]	FPT [RJ]
Strongly Chordal	P [OG]	P [OG]	P [OG]	P [OG]	P [OG]	O?	FPT [RJ]	P [OG]	FPT [RJ]	P [OG]	FPT [RJ]
Comparability	P [OG]	P [OG]	P [OG]	P [OG]	P [OG]	pN [RJ]	FPT [RJ]	W_2 [RJ]	FPT [RJ]	W_2 [RJ]	FPT [RJ]
Bipartite	P [T]	P [GJ]	P [T]	P [GJ]	P [T]	P [GJ]	FPT [RJ]	W_2 [RJ]	P [T]	W_2 [RJ]	FPT [RJ]
Permutation	P [OG]	P [OG]	P [OG]	P [OG]	P [OG]	O?	P [RJ]	P [OG]	FPT [RJ]	P [OG]	P [OG]
Cographs	P [T]	P [OG]	P [OG]	P [OG]	P [OG]	O?	P [OG]	P [OG]	P [RJ]	P [OG]	P [OG]
Undirected Path	P [OG]	P [OG]	P [OG]	P [OG]	P [OG]	O?	FPT [RJ]	XP [T]	FPT [RJ]	XP [T]	FPT [RJ]
Directed Path	P [OG]	P [OG]	P [OG]	P [OG]	P [OG]	O?	FPT [RJ]	P [OG]	FPT [RJ]	P [OG]	P [RJ]
Interval	P [OG]	P [OG]	P [OG]	P [OG]	P [OG]	O?	P [OG]	P [OG]	FPT [RJ]	P [OG]	P [OG]
Circular Arc	P [OG]	P [OG]	P [OG]	P [OG]	FPT [RJ]	O?	P [RJ]	P [OG]	FPT [RJ]	P [RJ]	P [RJ]
Circle	P [OG]	P [GJ]	P [OG]	XP [RJ]	pN [RJ]	O?	FPT [RJ]	W_1 [RJ]	FPT [RJ]	P [OG]	P [RJ]
Proper Circ. Arc	P [OG]	P [OG]	P [OG]	P [OG]	P [OG]	O?	P [OG]	P [OG]	FPT [RJ]	P [RJ]	P [RJ]
Edge (or Line)	P [OG]	P [GJ]	P [T]	O* [RJ]	pN [RJ]	pN [RJ]	FPT [RJ]	FPT [RJ]	P [RJ]	XP [T]	FPT [RJ]
Claw-Free	P [T]	P [OG]	FPT [RJ]	pN [RJ]	pN [RJ]	pN [RJ]	FPT [RJ]	FPT [RJ]	FPT [RJ]	XP [T]	FPT [RJ]

Table 1: The parameterized NP-Completeness Column: An Ongoing Guide table revised for the 21st century.

puter Science, volume 13174. Springer, 2022. https://doi.org/10.1007/978-3-030-96731-4_21.

[3] Celina M. H. de Figueiredo, Alexsander A. de Melo, Diana Sasaki, and Ana Silva. Revising Johnson's table for the 21st century. *Discret. Appl. Math.*, 2021. https://doi.org/10.1016/j.dam.2021.05.021.

CONGRATULATIONS New PhDs

Aridam Biswas, *Algorithms for NP-hard Problems in the sublinear space regime* (Homi Bhabha National Institute (HBNI) India).
Advisor:Professor Venkatesh Raman, Institute for Mathematical Science, Chennai, India.
Cngratulations, Dr. Biswas. Dr. Biswas has taken up a post-doc position at TU Illemenau.

Ariel Kulik, *Submodular Maximization with Assignment Constraints and Parameterized Approximations* (Technion, Haifa, Israel).
Advisor: Professor Hadas Shachnai, hadas@cs.technion.ac.il.
Congratulations, Dr. Kulik. Dr. Kulik is working at CISPA Helmholtz Center for Information Security with Daniel Marx since September 2021.

Tweet with Neeldhara@neeldhara

See new Tweets with great tips and have interesting conversation with **Neeldhara Misra**, Indian Institute of Technology, Gandhinagar.

Figure 7: Neeldhara @neeldhara.

Add your presentation to the FPT Complexity Youtube Channel

Send your presentations to the FPT COMPLEXITY Youtube Channel. Contact **Jungho Ahn** (junghoahn@kaist.ac.kr), student of Sang-il, who has volunteered to organize an FPT COMPLEXITY Youtube channel and has already gathered quite a large playlist. Please inform Jungho of videos that you would like posted.

Some videos about parameterized complexity can also be found on the Youtube channel of IMSC and the Youtube channel of MathNet Korea organized by Sang-il Oum (KAIST).

JOBS page on FPT website

Jobs, postdocs, other news on the FPT website. The FPT wiki at `fpt.wikidot.com` is always open and available for you to add your news on the WELCOME Page, jobs on the JOBS page, and other updates and information.

Social Choice Seminar Series For upcoming seminars on social choice and time slots where you can volunteer to give a talk, see this website.

Graph-Theoretic Concepts in Computer Science (WG2022).

48th International Workshop on Graph-Theoretic Concepts in Computer Science (WG2022). The WG2022 conference is the 48th edition of the WG series and will take place from Wednesday 22nd June to Friday 24th June 2022 in Tuebingen, Germany.

Parameterized Approximation Algorithms Workshop - PAAW 2022.

Organizers: Andreas-Emil Feldmann and Michael Lampis (feldmann.a.e@gmail.com, michail.lampis@dauphine.fr).

The third Parameterized Approximation Algorithms Workshop (PAAW) will take place as a satellite event of ICALP 2022 on Monday July 4th 2022 in Paris. The aim of PAAW is to bring together researchers interested in the intersection between parameterized complexity and approximation algorithms. The format will be a mix between invited and contributed talks presenting new and exciting results in FPT approximation. Since the workshop features no formal proceedings, contributions that have already appeared (or are set to appear) in other venues are more than welcome! A formal call for contributions will be posted in a few weeks, but anyone interested in presenting at PAAW may feel free to contact the organizers.

Due to the ongoing pandemic PAAW will take place in a hybrid format. Speakers are expected to attend in person, but we will make an effort to also make the workshop accessible to online participants. Check this website for more information about PAAW 2022.

New FPTers

CONGRATULATIONS to **Valia Mitsou** (Research Institute on the Foundations of Computer Science (IRIF) and Paris Diderot University) and **Michail Lampis** (Université Paris Dauphine) on baby Nestor, little Parisian / Greek.

CONGRATULATIONS to **Pål Grønås Drange** (University of Bergen) and **Hannah Hansen** on the birth of their son Charlie, who is curious and interested in everything.

CONGRATULATIONS to **Bart Jansen** (University of Eindhoven) whose son Abel Yngve Jansen was born 15th January 2022, joining sister Milou who has started to walk and learn to play games of hide and seek with her Dad.

CONGRATULATIONS to **Matthias Mnich** (TU Hamburg) whose effervescent daughter Eszter just recently got a brother.

Thanks, Rolf, for all Your Invitations

Many readers know Rolf from his book "Invitation to Fixed-Parameter Algorithms", which gave a welcoming and smooth introduction to the research area that we love. This was by far not the only invitation extended by Rolf over the years. Listing all of them here would be intractable. Let us instead deconstruct that intractability by kernelizing to a couple of salient ones.

Rolf's journey into the world of computer science started at TU Munich in 1986, where he obtained his undergraduate degree. He then continued at the University of Tübingen, where he obtained his PhD degree in 1996, and after spending one year as a postdoc at Charles University in Prague, started an independent research group on parameterized algorithms. He then joined the University of Jena in 2004, where he obtained his first position as professor and, finally, TU Berlin in 2010 where he established and chaired the "Algorithmics and Computational Complexity" research group.

During this time, he invited many of us to join him in working on his seminal contributions for example in the improvement of depth-bounded search trees, the establishment of kernelization as a framework for parameterized algorithms, and in the quest to turn parameterized algorithms into practical implementations. Rolf was a master in the art of parameterization and an early advocate of parameterization by distance from triviality and data-driven parameterization.

Rolf also invited many research areas such as computational social choice, computational biology, and temporal graph theory to make use of the toolbox of parameterized algorithms. Conversely, he invited researchers from parameterized algorithms to consider the rich world of problems from these areas. Rolf was a co-organizer of numerous Dagstuhl workshops, including the first two Dagstuhl seminars on Parameterized Algorithms in 2001 and 2003, "Adaptive, Output Sensitive, Online and Parameterized Algorithms" in 2009, "Application-Oriented Computational Social Choice" and "Algorithms and Complexity in Phylogenetics" in 2019, and "Temporal Graphs: Structure, Algorithms, Applications" in 2021. He was the local organizer for the "Workshop on Graph-Theoretic Concepts in Computer Science (WG 2007)" at Dornburg castle near Jena, "Workshop on Challenges in Algorithmic Social Choice (CASC 2014)" at Eisenhardt castle, Bad Belzig, and the "Symposium on Theoretical Aspects of Computer Science (STACS 2019)" at TU Berlin.

During his time in Tübingen, Jena, and Berlin, Rolf created an inspiring, comforting, and pleasant research environment for numerous PhD students, postdocs, and colleagues. Many long-term visitors followed Rolf's invitations: Piotr Faliszewski, Mike Fellows and Fran Rosamond, Danny Hermelin, Iyad Kanj, George Mertzios, and Gerhard Woeginger to name some of them.

Beyond his tireless dedication to academia, Rolf's invitated us also to many of the other things he was fond of: classical music, tea, cake, hikes, and bike tours. At his famous retreat trips he managed to combine academic productivity and recreation in a familial atmosphere. He invited people to laugh with him, liked to share his experiences with others, was always up for a conversation and kept an open door.

All these invitations will be dearly missed.

— Rolf's students and friends

To celebrate Rolf's achievements, we invite the reader to rediscover some of his classic texts.

References

[1] R. Niedermeier, *Invitation to Fixed-Parameter Algorithms*. Oxford University Press, 2006.

[2] R. Niedermeier, "Reflections on multivariate algorithmics and problem parameterization," in *Proceedings of the 27th International Symposium on Theoretical Aspects of Computer Science (STACS '10)*, vol. 5 of *LIPIcs*, pp. 17–32, Schloss Dagstuhl - Leibniz-Zentrum für Informatik, 2010.

[3] J. Guo and R. Niedermeier, "Invitation to data reduction and problem kernelization," *SIGACT News*, vol. 38, no. 1, pp. 31–45, 2007.

[4] R. Niedermeier, "Some prospects for efficient fixed parameter algorithms," in *Proceedings of the 25th Conference on Current Trends in Theory and Practice of Informatics (SOFSEM '98)*, vol. 1521 of *Lecture Notes in Computer Science*, pp. 168–185, Springer, 1998.

Figure 8: Rolf at his 50th birthday

Memory of Gerhard Woeginger

We are deeply grieved by the death of our dear friend and colleague, Gerhard J. Woeginger, who died in April after a long illness. Gerhard was a professor at RWTH Aachen University, where he chaired the algorithms and complexity group in the department of computer science.

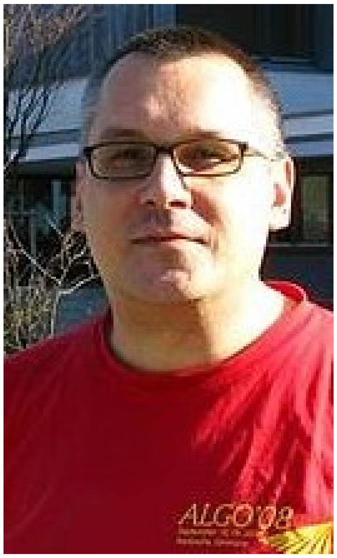

Figure 9: Gerhard Woeginger

Gerhard was born in Graz, Austria in 1964. He obtained a diploma from the Graz University of Technology (TU Graz) in 1987, and completed his Ph.D. at TU Graz 1991 under the supervision of Franz Rendl. He worked on the faculty of TU Graz from 1991 to 2001, where he completed his habilitation in 1995. He then moved to the University of Twente from 2001 to 2004, to TU Eindhoven, from 2004 to 2016, and finally to RWTH Aachen in 2016.

He was program chair of the European Symposium on Algorithms in 1997, of the algorithms track of the International Colloquium on Automata, Languages and Programming in 2003, of the European Conference on Operational Research in 2009, and of several other conferences.

In 1996, Woeginger won the Start-Preis, the highest Austrian award for scientists under the age of 35. He won a Humboldt Research Award in 2011. In 2014, he was elected to the Academia Europaea. Gerhard supervised about ten PhD students. Please see the memorial at https://www.cursor.tue.nl/en/news/2022/april/week-1/in-memoriam-gerhard-woeginger/.

In Memory of Benny Chor

Please see the guest post on Benny Chor's life and works by Oded Goldreich at http://blog.computationalcomplexity.org/2021/06/benny-chor-1956-2021.html. Benny Chor was born on December 23rd 1956 and grew-up in Tel-Aviv, Israel. He studied Mathematics in the Hebrew University, receiving a B.Sc. in 1980 and an M.Sc. in 1981. He then switched to studying Computer Science at MIT, and graduated in 1985 with a PhD thesis titled

Two Issues in Public Key Cryptography – RSA Bit Security and a New Knapsack Type System

which received an ACM Distinguished Dissertation award. After post-doctoral periods at MIT and Harvard, he took a faculty position at the Computer Science Department of the Technion (1987-2001), and then at Tel-Aviv University, where he served as the chairman of the department for two years. He died on June 10th 2021, from a terminal disease.

Although Benny was a very articulated and verbal person, I find it impossible to describe his personality in words. The point is that words cannot capture the experience of interacting with him, which was always sheer fun. Still, I guess I should say something personal as a close friend of his. So I will just mention that he lived happily with Metsada, whom he met in the summer of 1981, and that they lovingly raised three kids: Arnon, Omer and Aya. Actually, let me also mention his life-long close relationship with his brother, Kobi.

The above paragraphs were written by Oded. Fran and Mike would like to add that Benny was a dear friend. Benny visited us in Australia and we took him surfing with us. He was a great communicator and did *Computer Science Unplugged* workshops for children, inspiring many.

Figure 10: Benny Chor