Parameterized Complexity News

Newsletter of the PC Community May 2012

Welcome

Frances Rosamond, Editor

Welcome to the Parameterized Complexity Newsletter. Congratulations to award winners and graduates. We have excellent articles: Mahdi Parsa writes about game theory, and Uéverton dos Santos Souza writes about answer set programming and bounded treewidth. Please keep the wiki `http://fpt.wikidot.com` updated with latest results and publications.

IPEC 2012 Call for Papers

The **7th International Symposium on Parameterized and Exact Computation IPEC 2012** `http://ipec2012.isoftcloud.gr/` will be co-located with ALGO in Ljubljana, Slovenia. Accepted papers will be published in Springer *LNCS*.

Paper submission: June 19, 2012

Symposium: September 12-14, 2012

Invited Speakers: Dániel Marx (Computer and Automation Research Institute, Hungarian Academy of Sciences (MTA SZTAKI)), Andreas Björklund (Lund University).

Workshop: Saket Saurabh: Subexponential Parameterised Algorithms.

Excellent Student Paper Awards: A paper is eligible for the award if all authors are students at the time of submission. A student is someone who has not been awarded a PhD.

The AND-Conjecture

Andrew Drucker, MIT, has shown that the AND-conjecture is true (assuming that the polynomial hierarchy doesn't collapse). `http://intractability.princeton.edu/blog/2012/03/theory-lunch-february-17/` and `http://people.csail.mit.edu/andyd/dist_stability_note.pdf`. Andy has promised an article for our next newsletter. See the related, "The AND-Conjecture may be Necessary" by Magnus Wahlström, MPI (Nov 2011 Newsletter).

Yiannis Koutis

Congratulations to **Yiannis Koutis**, Computer Science Dept. at the Univ. Puerto Rico, Rio Piedras. Yiannis has been awarded a prestigious NSF CAREER AWARD for his proposal about spectral graph theory and linear time algorithms. Together with another internal grant, he will be managing about 600K over the next 5 years.

Figure 1: IMSc Short Course Jan 2012

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IMSc January Short Course

A Short Course was held at the Institute for Mathematical Sciences in Chennai (IMSc) in January. This was also the occasion of Neeldhara Misra's defense lecture.

Morgan Chopin

Congratulations to **Morgan Chopin** for a DAAD Fellowship to visit Rolf Niedermeier at Technical Univ. Berlin. Morgan is the student of Cristina Bazgan, Univ. Dauphine, Paris.

Papers at Conferences/Online

We appreciate **Bart Jansen** for maintaining two pages on the FPT Community Wiki. See `http://fpt.wikidot.com`. One contains FPT-related papers which have appeared online, such as on arXiv or on ECCC. The other is FPT papers at conferences. For example, **ten out of the 71 Track A papers at ICALP 2012 are about parameterized complexity**. Congratulations, everyone! See the *Quick Summary of Parameterized Complexity – 2012* by Bart and Fran at the top of the wiki Welcome Page.

Conferences/Meetings

There are now four Parameterized Complexity International Conferences.

(1) **International Symposium on Parameterized and Exact Computation (IPEC)**, now in its 7th year, is the main conference and focuses on all aspects of parameterized complexity and algorithmics.

(2) **Workshop on Kernelization (WorKer)** focuses on kernelization. This year, WorKer will take place at Dagstuhl Seminar 12241, "Data Reduction and Problem Kernels." This event is dedicated to the 60th birthday of Michael Fellows. Please send photos of yourself with Mike to Frances.Rosamond–at–cdu.edu.au.

(3) **Approximation, Parameterized and Exact Algorithms (APEX)** is supported by the French National Agency for Research (ANR). APEX was co-located with STACS 2012 in Paris.

(4)**Workshop on Applications of Parameterized Algorithms and Complexity (APAC)**. APAC 2012 is collocated with ICALP in Warwick, UK.

AMS Special Session on PC

There will be a Special Session on Parameterized Complexity at the American Mathematical Society Annual Meeting in San Diego. The session will take place on Friday and Saturday, 11/12 January 2013. Organizers are Mike Fellows, Anil Nerode and Rod Downey.

Shonan PC, Japan

The new Japanese computer conference center, Shonan, modeled on Dagstuhl, will host "Parameterized Complexity and the Understanding, Design and Analysis of Heuristics," May 5-11, 2013. Contact: Gregory Gutin.

Pablo Moscato

Keynote speaker at the IX Congress of the Chilean Inst of Operations Research was **Pablo Moscato**, Univ. Newcastle, Australia. At UoN, Pablo is Co-Director of the Priority Research Centre for Bioinformatics, Biomarker Discovery and Information-based Medicine. He is a Chief Investigator for the ARC Centre of Excellence in Bioinformatics.

Figure 2: Pablo Moscato

At the Congress, Pablo also gave a Tutorial on Memetic Algorithms, including links to parameterized complexity related to the design of local search and recombination operators that prove optimality of the final solution under some restrictions. Pablo's group has big results in Alzheimer's Disease. See `http://www.skynews.com.au/health/article.aspx?id=735768\&vId=3164045`.

Vienna Center

The Vienna Center for Logic and Algorithms `http://www.VCLA.at`, Faculty of Informatics, Vienna Univ of Technology (TU Vienna), held its official opening in January. Stefan Szeider was Co-chair. Fedor V. Fomin, Univ. Bergen, was an invited speaker.

Parameterized Complexity and Nash Equilibrium

by Vlad Estivill-Castro and Mahdi Parsa, Griffith Univ, Australia.

One of the key solution concepts in game theory is the Nash equilibrium, a set of strategies, one for each player (two or more), such that no player has anything to gain by changing only his or her own strategy unilaterally.

Nash proved that every finite game has an equilibrium (Nash equilibrium) maybe with mixed strategies. But Nash's existence proof does not suggest how to compute an equilibrium. This fact motivates the question: when can we compute Nash equilibria efficiently?

Since Nash's paper was published, many researchers developed algorithms for finding Nash equilibria [4, and references therein]. However, all of them are known to have worst-case running times that are exponential.

So, the question that naturally arises is: what is the inherent complexity of finding Nash equilibria in n-player games?

Attempts to turn the Nash problem into a decision problem, either by imposing restrictions on the kind of Nash equilibrium that is desired, or by asking questions about properties of potential Nash equilibria, resulted in variants of Nash problems that are computationally hard [3], [4, and references therein].

A review of the literature in game theory reveals that many decision problems regarding the computation of Nash equilibria can be answered in $n^{O(k)}$ time, where n is the size of the game (input size) and k is a parameter that is related to a property of the Nash equilibria in the problem. The $n^{O(k)}$ time complexity indicates these problems are in the class **XP**. Thus, applying parameterized complexity techniques may result in tractability.

An important class of decision problems are related to the *support* of Nash equilibria. The support of a mixed strategy is the set of strategies assigned positive probability. It is an important concept, because if we know the support, then the corresponding Nash equilibria can be found in polynomial time for two-player games. Therefore, we focus on whether we can achieve fixed-parameter tractability in these classes of problems.

Computation of Nash equilibria in two-player games

Our first attempt is to determine the parameterized complexity of finding Nash equilibria where all the strategies in the support are played with the same probability. These are called *uniform* Nash equilibria. It seems that a uniform mixed strategy is probably the simplest way of mixing pure strategies.

k-UNIFORM NASH

> ***Instance***: A two-player game $\mathcal{G}$.
> ***Parameter***: An integer k.
> ***Question***: Does there exist a uniform Nash equilibrium with support size k?

k-UNIFORM NASH is **W[2]**-complete even for games where all payoffs are either 0 or 1 [4].

Our second attempt is to determine the parameterized complexity of Nash equilibria with smallest support size.

k-MINIMAL NASH SUPPORT

> ***Instance***: A two-player game $\mathcal{G}$.
> ***Parameter***: An integer k.
> ***Question***: Does there exist a Nash equilibrium such that each player uses at most k strategies with positive probability?

k-MINIMAL NASH SUPPORT is **W[2]**-hard [4]. It is a natural relaxation of k-UNIFORM NASH, as we remove the requirements on the uniformity of the distribution and the strict bound on the support size.

Our last problem regarding computing Nash equilibria with mixed strategies is NASH EQUILIBRIUM IN A SUBSET. We seek an algorithm that can tell us whether there exists *any* equilibrium where a player plays on a certain set of strategies. This could be useful in eliminating possibilities in the search for Nash equilibria.

NASH EQUILIBRIUM IN A SUBSET

> ***Instance***: A two-player game $\mathcal{G}$. A subset of strategies $E_1 \subseteq \{1, \ldots, m\}$ for the row player and a subset of strategies $E_2 \subseteq \{1, \ldots, n\}$ for the column player.
> ***Parameter***: $k = \max\{|E_1|, |E_2|\}$
> ***Question***: Does there exist a Nash equilibrium of $\mathcal{G}$ where all strategies not included in E_1 and E_2 are played with probability zero?

NASH EQUILIBRIUM IN A SUBSET is fixed parameter tractable [4].

Computation of dominant strategies

A strategy for a player is (strictly) *dominant* if, regardless of what any other player does, the strategy earns a better payoff than any other, but if it is simply not worse, then it is called *weakly dominant*. This is a more elementary notion than Nash equilibrium and it can be used as a preprocessing technique for computing Nash equilibria.

Many decision problems regarding computation of domination are **NP**-complete [2]. We studied these problems in the parameterized framework. We first tried to find the smallest mixed strategy that dominates a given strategy. A strategy may fail to be dominated by a pure strategy, but may be dominated by a mixed strategy.

MINIMUM MIXED DOMINATING STRATEGY SET

> ***Instance***: The row player's payoffs of a two-player game $\mathcal{G}$ and a distinguished pure strategy i of the row player.
> ***Parameter***: An integer k.
> ***Question***: Is there a mixed strategy $\mathbf{x}$ for the row player that places positive probability on at most k pure strategies, and dominates the pure strategy i?

MINIMUM MIXED DOMINATING STRATEGY SET is **W[2]**-hard [1]. It can be solved in polynomial time in games where the payoffs are limited to 0 and 1 [4]. It is FPT for games where the payoff matrices have at most r nonzero entries in each row and each column [4].

Our next problem is related to the concept of *iterated domination*. It is well-known that iterated strict dominance is path-independent, that is, the elimination process will always terminate at the same point, and the elimination procedure can be executed in polynomial time [2]. In contrast, iterated weak dominance is path-dependent. It is known that testing whether a given strategy is eliminated in some path is **NP**-complete [1].

ITERATED WEAK DOMINANCE (IWD)
Instance: A two-player game and a distinguished pure strategy i.
Parameter: An integer k.
Question: Is there a path of at most k-step of iterated weak dominance that eliminates the pure strategy i?

ITERATED WEAK DOMINANCE is **W[2]**-hard [4].

Our last problem is related to the sub-game problem. Finding the smallest sub-game of a given game $\mathcal{G}$=(A, B) using iterated elimination of strict dominated strategies can be performed in polynomial time. However, whether a distinguished sub-game of $\mathcal{G}$=(A, B) can be reached (using strict domination) is **NP**-complete [2].

SUB-GAME
Instance: Games $\mathcal{G}$= ($A_{n\times n}$, $B_{n\times n}$) and $\mathcal{G}'$ = ($A'_{k\times k}$, $B'_{k\times k}$).
Parameter: An integer k.
Question: Is there a path of iterated strict dominance that reduces the game $\mathcal{G}$ to the game $\mathcal{G}'$?

SUB-GAME is **W[1]**-hard [2].

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A Parameterized Approach for And-Or Graphs and X-of-Y graphs

by Uéverton dos Santos Souza, Fábio Protti and Maise Dantas da Silva, Federal University of Rio de Janeiro, Brazil. Uéverton recently completed his Master's thesis with Supervisors Protti and Dantas da Silva, and is now working towards the Ph.D. with them.

We study *and/or graphs* and *x-y graphs*, two data structures that have been used to model problems in computer science. An and/or graph is an acyclic digraph containing a source (a vertex that reaches all other vertices by directed paths). Every vertex v has a label $f(v) \in$ {`and`,`or`}, (weighted) edges represent dependency relations between vertices. A vertex labeled `and` depends on all of its out-neighbors (conjunctive dependency), while a vertex labeled `or` depends on only one of its out-neighbors (disjunctive dependency). X-y graphs are defined as a natural generalization of and/or graphs: every vertex v_i of an x-y graph has a label x_i-y_i to mean that v_i depends on x_i of its y_i out-neighbors.

And/or graphs have modeled problems in AI [11, 13], and other fields to model cutting problems [10], interference tests [7], failure dependencies [2], robotic task plans [3], assembly/disassembly sequences [5], game trees [8], software versioning [4], and evaluation of boolean formulas [9]. With respect to x-y graphs, they correspond to the *x-out-of-y model* of resource sharing in distributed systems [1].

Special directed hypergraphs *F-graphs* are equivalent to and/or graphs [6]. An F-graph is a directed hypergraph where hyperarcs are called *F-arcs* (for *forward arcs*), which are of the form $E_i = (S_i, T_i)$ with $|S_i| = 1$. An F-graph H can be easily transformed into an and/or graph.

We analyze the complexity of MIN-AND/OR and MIN-X-Y, which consist of finding solution subgraphs of optimal weight for and/or and x-y graphs, respectively. A solution subgraph H of an and/or-graph must contain the source and obey the following rule: if an `and`-vertex (resp. `or`-vertex) is included in H then all (resp. one) of its out-edges must also be included in H. Analogously, if a vertex v_i is included in a solution subgraph H of an x-y graph then x_i of its y_i out-edges must also be included in H.

In 1974, Sahni [12] showed that MIN-AND/OR is NP-hard via a reduction from 3-SAT. Therefore, MIN-X-Y is also NP-hard. We prove that MIN-AND/OR remains NP-hard even for a very restricted family of and/or graphs where edges have weight one and `or`-vertices have out-degree at most two (apart from other property related to some in-degrees), and that deciding whether there is a solution subtree with weight exactly k of a given x-y tree is also NP-hard. We also show that: (i) the parameterized problem MIN-AND/OR(k, r), which asks whether there is a solution subgraph of weight at most k where every `or`-vertex has at most r out-edges with the same weight, is FPT; (ii) the parameterized problem MIN-AND/OR$^0(k)$, whose domain includes and/or graphs allowing zero-weight edges, is W[2]-hard; (iii) the parameterized problem MIN-X-Y(k) is W[1]-hard. The question of classifying the parameterized problem MIN-AND/OR(k) for and/or graphs whose edges have *positive* weights remains open.

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The Theory Blogosphere

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

We continue our journey into the theory blogosphere.

My Brain is Open is the blog of Shiva Kintali `http://kintali.wordpress.com`. The latest posts include coverage of the Turing Centennial Celebration — a 3-day event hosted by Princeton Univ, celebrating Turing's time there. Snippets from the film *Breaking The Code* are posted.

The CSTheory Community Blog. Some of the talks from FSTTCS (IIT Bombay, Dec 2011) are described in a post by Jagadish. Complete notes are at: `http://cstheory.blogoverflow.com/2012/02/fsttcs-2011-conference-report/`.

Simultaneously Satisfying Linear Equations Over F_2 by R. Crowston, M. Fellows, G. Gutin, M. Jones, F. Rosamond, S. Thomasse, A. Yeo. Input is a set of m equations containing n variables $x_1, \ldots, x_n$ of the form $\prod_{i \in I} x_i = b$. The x_is and b take values from $\{-1, 1\}$. Each equation has a positive weight. The objective is to find an assignment of variables such that the total weight of the satisfied equations is maximized. There is always an assignment satisfying half the equations, so the above guarantee version of the question is addressed. The authors show that the problem MAX-LIN[k] is FPT and admits a kernel of size $O(k^2 \log k)$, and give an $O(2^{O(k \log k)}(nm)^c)$ algorithm.

Rainbow Connectivity: Hardness and Tractability by P. Ananth, M. Nasre, and K. K. Sarpatwar. A path in an edge colored graph is a *rainbow path* if no two edges on the path have the same color. *Rainbow connected* means there exists a (geodesic) rainbow path between every pair of vertices. The rainbow connectivity of a graph is the smallest number of colors required to edge color the graph such that G is rainbow connected. The following problem is shown to be FPT: Given G, determine the maximum number of pairs of vertices that can be rainbow connected using two colors. The authors also address the more direct question of finding (strong) rainbow connectivity numbers, and derive hardness results in almost all cases.

Obtaining a Bipartite Graph by Contracting Few Edges by P. Heggernes, P. van't Hof, D. Lokshtanov, C. Paul. Given a graph G, can we obtain a bipartite graph by contracting k edges? This is a variant of the much-studied OCT problem, and it is established that the contraction variant is FPT, parameterized by k. The question of whether the problem has a polynomial kernel remains open.

Shtetl-Optimized. Towards the end of last year, the blog covered two recent improvements in the time required to multiply two n-by-n matrices. The Coppersmith and Winograd algorithm required $O(n^{2.376})$. While being the best known for a couple of decades, this has been improved *twice* in the space of two years, first in a PhD thesis by Andrew Stothers (2010), and then in a paper by Virginia Vassilevska Williams (2011), to $O(n^{2.374})$ and $O(n^{2.373})$ respectively: `http://www.scottaaronson.com/blog/?p=839`

The Geomblog This is the blog of Suresh Venkat, and his latest piece is about the *multiplicative weight update method*. He makes a case for why it should be taught as a standard algorithm tool that naturally follows from divide and conquer and prune-and-search, instead of being treated as an "advanced" method. The post begins by motivating randomized splitting for prune-and-search, and leads up to the intriguing conclusion that the MWU method can be thought of as a zombie binary search... and the post wraps up with the hope that you think of zombies whenever you think of MWU! More at `http://geomblog.blogspot.com/2012/05/multiplicative-weight-updates-as-zombie.html`.

Elsevier and The Cost Of Knowledge. Not strictly speaking a blog, `http://thecostofknowledge.com/` is a protest against Elsevier's business practices. A number of popular bloggers express their support. The website has a blog for updates and a list of 11503 signatures (and counting).

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

Celebrating our Colleagues in Industry

Siamak Tazari has accepted an engineering position in the NYC office of Google. He says, "It was a very tough decision for me (to leave academia) and a very long process."

While at MIT, Siamak co-taught, "Algorithms for Planar Graphs and Beyond." The lectures are online at `http://courses.csail.mit.edu/6.889/fall11/lectures/`. In particular, Lectures 5-7, 9, 10, 16, 17, 22 and 24 are by Siamak. `siamak.tazari--at--googlemail.com`.

Siamak has been an important part of our parameterized community and we look forward to seeing him at future conferences and workshops. We would like to hear more from Siamak and others who have moved into industry about what the transition is like, how our community can better serve them, and what we can do to enhance the academia-industry relationship.

Moving Around

Sebastian Ordyniak has accepted a postdoc with Petr Hlineny at Masaryk University in Brno, Czech Republic (starting in July).

CONGRATULATIONS New PhDs

Wolfgang Dvorák, *Computational Aspects of Abstract Argumentation*, Technische Universität Wien, 2012. Supervisor: Prof. Stefan Woltran. Congratulations, Dr. Dvorák.

Anna Kasprzik, *Formal tree languages and their algorithmic learnability*, Department of Theoretical Computer Science, University of Trier, 2012. Supervisor: Prof. Dr. Henning Fernau. Congratulations, Dr. Kasprzik.

Neeldhara Misra, *Kernels for the F-Deletion problem*, Institute of Mathematical Sciences, Chennai, India, and Homi Bhabha National Institute. Supervisor: Prof. Venkatesh Raman and Prof. Saket Saurabh. Congratulations, Dr. Misra.

Mahdi Parsa, *Parameterized Complexity Applied in Algorithmic Game Theory*, School of ICT, Griffith University, 2011. Supervisor: Prof. Vladimir Estivill-Castro. Congratulations, Dr. Parsa.

Geevarghese Philip, *The Kernelization Complexity of Some Domination and Covering Problems*, Institute of Mathematical Sciences, Chennai, India, and Homi Bhabha National Institute. Supervisor: Prof. Venkatesh Raman. Congratulations, Dr. Geevarghese Philip. Philip is now a postdoc at MPI, Saarbrucken.

M. Praveen, *Parameterized Complexity of Some Problems in Concurrency and Verification*, The Institute of Mathematical Sciences, Chennai, India, and Homi Bhabha National Institute. Supervisor: Prof. Kamal Lodaya. Congratulations, Dr. Praveen. M. Praveen is now a Postdoctoral Researcher at ERCIM with the the DAHU team. He is supported by a grant from the ERCIM "Alain Bensoussan" Fellowship Programme. This programme is supported by the Marie Curie Co-funding of Regional, National and Internal Programmes (COFUND) of the European Commission.

Positions Available

Univ. of Siegen. A PhD position at the interface of Computational Social Choice and Scheduling. Contact Gabor Erdelyi (erdelyi@wiwi.uni-siegen.de).

Wedding Saket Saurabh

Congratulations to Saket and Sushmita on their beautiful wedding. It was attended by Mike Fellows and Frances Rosamond, Serge Gaspers, Daniel Lokshtanov, Venkatesh Raman, and about 600 other people. It was marvelous.

Figure 3: Sushmita and Saket