Parameterized Complexity News

Newsletter of the Parameterized Complexity Community

www.fpt.wikidot.com September 2013

Welcome

Frances Rosamond, Editor, Charles Darwin University
Welcome to the Parameterized Complexity Newsletter. Congratulations to award winners and graduates. This newsletter focuses on psychology and cognitive science. We have an article about Bayesian Models by Johan Kwisthout and Iris van Rooij (Radboud U.), and an article by Tarek Besold (U. Osnabrueck) and Robert Robere (U. Toronto). Johan, Iris and Mark Blokpoel (Radboud) and Todd Wareham (Memorial U. Newfoundland) gave tutorials about using parameterized complexity analysis in cognitive science at CogSci2013 in July. There will be a Dagstuhl in 2014 (see below). Many thanks to Johan and Iris for greatly expanding the Psychology and Cognitive Science Section of the wiki.

Also thanks to Robert Bredereck (TU Berlin) for adding a Table of Races for Computational Social Choice. Each voting problem can and should be viewed under several parameterizations. Voting is by nature multivariate. Parameterized complexity now has a BLOG. See article by Neeldhara Misra on how to contribute.

Klaus Jansen DFG Award

Congratulations to **Klaus Jansen** for a three-year DFG award for the project, *Lower Bounds on the running time for scheduling and packing problems under the exponential time hypothesis* (Laufzeitschranken für Scheduling- und Packungsprobleme unter Annahme der Exponential- zeithypothese) with a PhD position for three years (around 200.000 EURO).

George B. Mertzios EPSRC Award

Congratulations to **George Mertzios**(Durham Univ.) for an EPSRC Award, the UK research funding body, for *Algorithmic Aspects of Intersection Graph Models* with funding for a one-year postdoc psition.

Figure 1: Robert Robere and Tarek R. Besold

Tarek Besold & Robert Robere

Congratulations to **Tarek R. Besold** (U. Osnabrueck) and **Robert Robere** (U. Toronto) who are pushing the frontiers at the interface between parameterized complexity and artificial intelligence. They received Best student Paper Award at Artificial General Intelligence: AGI. Their two complementary papers, conceptual background and worked out example are:
- The award paper is this one: `http://link.springer.com/chapter/10.1007\%2F978-3-642-39521-5$_$2`
- More ideas behind this line of work:

Contents of this issue:

http://link.springer.com/chapter/10.1007\%2F978-3-642-39521-5$_$18. See their article in this news.

IPEC Excellent Student Paper Awards

Congratulations to the 2013 IPEC Excellent Student Paper Awardees and appreciation to the Program Committee, with Co-Chairs Gregory Gutin (Royal Holloway, U. London) and Stefan Szeider (Vienna U. of Technology). Awardees are

- *On Sparsification for Computing Treewidth* by **Bart M.P. Jansen** (U. Utrecht)
- *Amalgam Width of Matroids* by **Lukas Mach** (DIMAP, U. Warwick) and **Tomas Toufar** (Charles U., Prague)
- *Subgraphs Satisfying MSO Properties on z-Topologically Orderable Digraphs* by **Mateus de Oliveira Oliveira** (KTH, Stockholm). A summary will be in the next newsletter.

Photos taken by the ALGO photographer and IPEC Report will be featured in the next newsletter.

FLoC–Hurry, 30th deadline

Call for Workshops - FLoC 2014 - The Sixth Federated Logic Conference - July 2014, Vienna, Austria
Email Stefan@Szeider.net, Workshop Chair
FLoC 2014 will be part of the Vienna Summer of Logic, the *largest logic event in history*, with over 2000 expected participants. FLoC 2014 will host eight conferences (CAV, CSF, ICLP, IJCAR, ITP, CSL-LICS, RTA-TLCA, SAT) and many workshops.

Researchers and practitioners are invited to submit proposals for workshops on topics in the field of computer science, related to logic in the broad sense. The deadline for the submission of workshop proposals is September 30, 2013. Further information can be found at *http://vsl2014.at/floc-ws/*.

When Almost is Not Even Close Enough: Remarks on the Approximability of HDTP

by Tarek R. Besold, U. Osnabrueck and Robert Robere, U. Toronto

The goal of Artificial General Intelligence (AGI) is to recreate a human level intelligence in an artificial system. The standard approach is to isolate individual problems solved by a typical human level intelligence, find a suitable mathematical model for the problem, and then tailor algorithms which operate on the model to solve the problem. An important issue here is that of *model evaluation*: how are we sure that the mathematical model we have developed for studying a problem is the "correct" one? Using parameterized complexity theory, in this paper we focus on one aspect of model evaluation, namely, that of *model efficiency*: how can we be sure the mathematical model we have chosen for studying a problem is algorithmically tractable?

In cognitive science, the idea of using complexity theory to evaluate models of human intelligence is not a new one (this is formalized by the *Tractable Cognition Thesis*, see [6]): our article seeks to (re-)introduce this thesis into the broader context of artificial intelligence. We present the *Tractable Cognition Thesis* (TAGT):

Tractable Cognition Thesis. *Models of cognitive capacities in artificial intelligence and computational cognitive systems have to be fixed-parameter tractable for one or more input parameters that are small in practice (i.e., have to be in FPT).*

As an application of the TAGT we study the problem of *analogy making*, which we will loosely define as follows: given two "conceptual domains" A and B, can we produce an analogy (i.e. a "structure preserving" map) between A and B? Analogy and metaphor have been extensively studied in both the artificial intelligence and the cognitive science literature, giving rise to systems such as Hofstadter's Copycat [4], the Structure Mapping Engine [1] and MAC/FAC [2]. In our case study, we focus on a recent addition to the family of analogical models: *Heuristic Driven Theory Projection* (HDTP) [3, 5]. HDTP chooses to represent the input conceptual domains A and B as formal algebra A, B both defined on an identical "signature", which is the set of allowable types, relation symbols, and function symbols allowed to appear in A and B. An analogy in HDTP is then defined using different types of *substitutions*, or operations, applied jointly on A and B. For example, suppose that A represents the Bohr model of the atom, with a nucleus and revolving electron, and B represents our solar system, with the sun and revolving planets. The algebra A may contain a term like *revolve*(nucleus; electron) and B may contain *revolve*(sun; earth). Then, a *generalization* here could be the term *revolve*$(X;\ Y)$, along with *variable substitutions*

$X \rightarrow nucleus \setminus sun;\ Y \rightarrow electron \setminus earth.$

HDTP prescribes a set of four allowable substitutions:
1. variable substitutions, described above,
2. permutations, which arbitrarily reorders the variables appearing inside a function,
3. renaming, which renames variables, and
4. argument insertions, which insert new arguments into function symbols.

The parameters of interest here are the number used of each substitution type. We give a strong hardness result, stating that HDTP is polynomial time solvable if we allow only renamings and variable substitutions, but be-

comes W[1]-hard if we allow even a *single* permutation. We also prove a W[2]-hardness result for another mechanism proposed for analogy making in HDTP which reduces "higher order" generalizations to lower-order ones. To complement our results, we show that a modification of our reduction is sufficient to show that HDTP is hard to approximate for any polynomial time algorithm within a factor of $O(n^{1-\epsilon})$ for any $\epsilon > 0$.

[1] Brian Falkenhainer, Kenneth Forbus, and Dedre Gentner. The structure-mapping engine: Algorithm and examples. Artificial Intelligence, 41(1):1 63, 1989.

[2] Dedre Gentner and Kenneth Forbus. MAC/FAC: A Model of Similarity-based Retrieval. Cognitive Science, 19:141 205, 1991.

[3] Helmar Gust, Kai-Uwe Kuhnberger, and Ute Schmid. Metaphors and Heuristic Driven Theory Projection (HDTP). Theoretical Computer Science, 354:98 117, 2006.

[4] Douglas Hofstadter and Melanie Mitchell. The copycat project: a model of mental fuidity and analogy-making. In K. Holyoak and J. Barnden, editors, Advances in Connectionist and Neural Computation Theory, volume 2: Analogical Connections, pages 31 112, New York, NY, USA, 1994. Ablex.

[5] Angela Schwering, Ulf Krumnack, Kai-Uwe Kuhnberger, and Helmar Gust. Syntactic principles of Heuristic-Driven Theory Projection. Journal of Cognitive Systems Research, 10(3):251 269, 2009.

[6] Iris van Rooij. The tractable cognition thesis. Cognitive Science, 32:939 984, 2008.

Parameterized Complexity and Bayesian Models

by Johan Kwisthout and Iris van Rooij, Radboud University Nijmegen, Donders Institute for Brain, Cognition and Behaviour

Bayesian models are becoming more and more popular. Their use as an engineering tool (e.g., in decision support systems or as classifiers) has been widespread already since the 1990s, but in recent years Bayesian models have enjoyed an enormous popularity in cognitive science as well. In the latter domain, Bayesian techniques are being used to model mental processes that underly cognitive behavior, either at the 'brain' level or at the 'mind' level. Yet, such models raise a theoretical challenge for explaining the computational efficiency of human brains: The NP-hardness of general Bayesian inference seems at odds with cognitive brain processing in *practice*, which occurs on a timescale of seconds or even milliseconds. In our research, we use parameterized complexity analysis to systematically address this challenge.

By and large, few parameterized complexity results are known for computational problems involving Bayesian networks. Fixed-parameter tractability of computing a posterior *probability* has been established *avant la lettre* for bounded treewidth (t) of the underlying graph and bounded cardinality (c) of the stochastic variables (7). Computing the mode of a posterior distribution has a $O(c^{\frac{(\log(p)}{\log(1-p)}} \cdot c^t \cdot n)$ algorithm, where p denotes the probability of the mode of that distribution (2; 5); it is para-NP-hard for $\{t, c\}$ alone (3) and $\{p, c\}$ alone (5). Deciding whether the conditional probabilities of a network can be tuned to match some constraint on the distribution of a variable of interest is NP-hard in general, para-NP-hard for bounded treewidth, and W[1]-hard for the number of tunable conditional probabilities as parameter (4). Learning the structure of a Bayesian network from data is NP-hard in general, but is fixed-parameter tractable for parameter set $\{t, d\}$, where t denotes the treewidth and d denotes the maximum degree of the super-structure (8). These complexity results and others have been used to constrain computational models of cognition (1; 9).

For the *approximate* case there are even fewer parameterized complexity results. Such results would be particularly useful in those cases where the exact Bayesian computation is not fixed-parameter tractable for a set of parameters, but the corresponding approximate Bayesian computation is fixed-parameter tractable. One such example is given by the so-called *Most Simple Explanation* problem (6). We showed that this problem is NP-hard to compute both exactly and approximately, but is fixed-parameter tractable to approximate (but not to compute exactly) for a particular parameter constraining the probability distribution (see (6) for details).

To summarize, given the evident import of parameterized complexity results for Bayesian models in domains such as cognitive science, and the paucity of such results so far, there are many opportunities to be explored. This is especially true in the case of approximate Bayesian computations. That few complexity results are known to date for approximate Bayesian computation is surprising, given the apparent success of Bayesian approximation algorithms in practical situations. Explaining why and under which circumstances such algorithms work well would constitute a major scientific advance with important applications in multiple domains of inquiry.

[1] Blokpoel, M., Kwisthout, J., van der Weide, T.P., Wareham, T., and van Rooij, I. (2013). A computational-level explanation of the speed of goal inference. To appear in *Journal of Mathematical Psychology*.

[2] Bodlaender, H. L., van den Eijkhof, F., and Van der Gaag, L. C. (2002). *On the complexity of the MPA problem in probabilistic networks*. In van Harmelen, F. (Ed.), *Proceedings of the 15th European Conference on Artificial Intelligence*, pp. 675–679.

[3] De Campos, C.P. (2011). *New complexity results for MAP in Bayesian networks*. In Walsh, T. (Ed.), *Proceedings of the 22nd International Joint Conference on Artificial Intelligence*, pp. 2100–2106.

[4] Kwisthout, J. (2009). *The computational complexity of probabilistic networks*. Ph.D. thesis, University of Utrecht.

[5] Kwisthout, J. (2011). Most probable explanations in Bayesian networks: Complexity and tractability. *International Journal of Approximate Reasoning*, *52*, 1452–1469.

[6] Kwisthout, J. and van Rooij, I. (2013). Bridging the gap between theory and practice of approximate Bayesian inference. *Cognitive Systems Research*, *24*, 2–8.

[7] Lauritzen, S.L. and Spiegelhalter, D.J. (1988). Local computations with probabilities on graphical structures and their application to expert systems. *Journal of the Royal Statistical Society. Series B (Methodological)*, *50*(2), 157–224.

[8] Ordyniak, S. and Szeider, S. (2013). Parameterized Complexity Results for Exact Bayesian Network Structure Learning. *Journal of Artificial Intelligence Research*, *46*, 263–302.

[9] Van Rooij, I., Kwisthout, J., Blokpoel, M., Szymanik, J., Wareham, T., and Toni, I. (2011). Intentional communication: Computationally easy or difficult? *Frontiers in Human Neuroscience*, *5*(52), 1–18.

PC has a BLOG!

by Neeldhara Misra, IIS, Bangalore, BLOG Editor We would like to thank everyone who has signed up for the FPT blog at http://fptnews.org - welcome on board! If you haven't signed up already, you can sign up at http://www.fptnews.org/contribute. Remember that the blog serves several purposes: sharing open problems, event announcements, expositions, reports of events, and so forth. You can already find a report from WORKER 2013 (thanks to Bart Jansen!) at the blog. We would greatly look forward to having overviews, anecdotes, pictures, and general experiences from events of relevance (for example, ADFOCS from the recent past and IPEC in the near future). Any general updates and announcements would also be very welcome. Do send us your suggestions and we look forward to making this an active and up-to-date resource!.

Papers at Conferences/Online

We appreciate **Bart Jansen** for his heroic job posting papers on the FPT Community Wiki. See `http://fpt.wikidot.com`. There are two pages. One contains FPT-related papers which have appeared online, such as on the arXiv or on ECCC. The other is FPT papers at conferences.

Cognitive Science Dagstuhl 2014

Dagstuhl Seminar 14341: Resource-bounded Problem Solving

DATES: August 17-22, 2014
Organizers:
Yll Haxhimusa (TU Wien, Austria), Iris van Rooij (Radboud University, The Netherlands), Sashank Varma (U. Minnesota, USA), Todd Wareham (Memorial Univ, Canada)
`http://www.dagstuhl.de/en/program/calendar/semhp/?semnr=14341`

Moving Around

- **Joerg Rothe** will be visiting Palo Alto and Mountain View, CA, as he will be spending part of his sabbatical at Stanford University.
- **Michael Lampis** has accepted a post-doc at the Research Institute for Mathematical Sciences (RIMS) in Kyoto University.
- **Valia Mitsou** will be a Research Visitor at the Research Institute for Mathematical Sciences (RIMS) in Kyoto University, while she writes her dissertation for CUNY.
- **Ondřej Suchý** is now a new father! We would like a photo of Ondřej, Alena, and Vojtěch.

CONGRATULATIONS New PhDs

Bart M. P. Jansen, *The Power of Data Reduction: Kernels for Fundamental Graph Problems*, Utrecht University, 2013, 310 pages, ISBN 978-90-393-5966-2. Supervisor: Prof. Hans Bodlaender. Congratulations, Dr. Jansen.
Continue scrolling for Bart's graduation photo below.

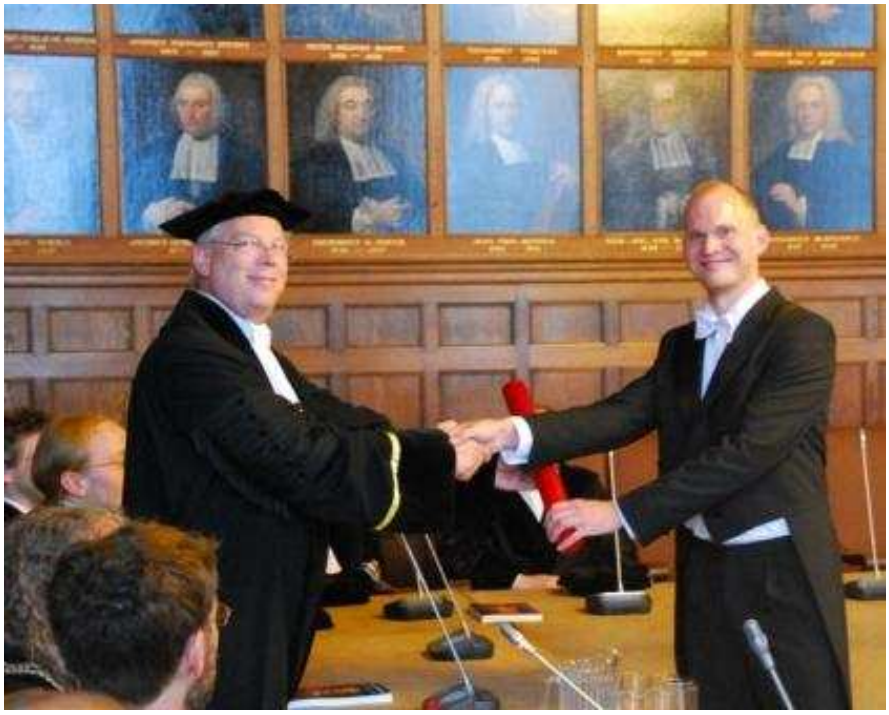

Figure 2: Bart M. P. Jansen, Ph.D.