Leibniz Universität Hannover

Institut für Theoretische Informatik

79. Theorietag

(17. November 2020)

Gesellschaft für Informatik

Theorie Tag

Program and Workshop Information

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2 Overview of Talks

Invited Talk: Sketches of Dynamic Complexity

Thomas Zeume (Uni Bochum)

Main Reference Thomas Schwentick, Nils Vortmeier and Thomas Zeume. *Sketches of Dynamic Complexity.* Sigmod Records 2020.

In many modern data management scenarios, data is subject to frequent changes. In order to avoid costly re-computing query answers from scratch after each small update, one can try to re-use auxiliary data that has been computed before. A logical perspective on dynamic query answering is studied in dynamic complexity theory, where the focus is on updating query results as well as auxiliary data with first-order formulas. The use of first-order formulas for specifying updates is motivated by the database query language SQL, whose core is first-order logic, as well as by diverse characterizations of first-order logic in terms of, for instance, constant-depth circuits and relational algebra expressions.

In this talk, I will gently introduce dynamic complexity theory and summarize recent results with a focus on the dynamic complexity of the reachability query.

This talk builds on the survey article "Thomas Schwentick, Nils Vortmeier, Thomas Zeume. Sketches of Dynamic Complexity. Sigmod Records 2020." and on joint work with Samir Datta, Raghav Kulkarni, Anish Mukherjee, Nils Vortmeier and Thomas Schwentick.

Understanding the Relative Strength of QBF CDCL Solvers and QBF Resolution

Benjamin Böhm (Uni Jena)

Main Reference Olaf Beyersdorff and Benjamin Böhm. *Understanding the Relative Strength of QBF CDCL Solvers and QBF Resolution.* Electron. Colloquium Comput. Complex. 2020.

QBF solvers implementing the QCDCL paradigm are powerful algorithms that successfully tackle many computationally complex applications. However, our theoretical understanding of the strength and limitations of these QCDCL solvers is very limited. In this paper we suggest to formally model QCDCL solvers as proof systems. We define different policies that can be used for decision heuristics and unit propagation

and give rise to a number of sound and complete QBF proof systems (and hence new QCDCL algorithms). With respect to the standard policies used in practical QCDCL solving, we show that the corresponding QCDCL proof system is incomparable (via exponential separations) to Q-resolution, the classical QBF resolution system used in the literature. This is in stark contrast to the propositional setting where CDCL and resolution are known to be p-equivalent.
This raises the question what formulas are hard for standard QCDCL, since Q-resolution lower bounds do not necessarily apply to QCDCL as we show here. In answer to this question we prove several lower bounds for QCDCL, including exponential lower bounds for a large class of random QBFs.
We also introduce a strengthening of the decision heuristic used in classical QCDCL, which does not necessarily decide variables in order of the prefix, but still allows to learn asserting clauses. We show that with this decision policy, QCDCL can be exponentially faster on some formulas.
We further exhibit a QCDCL proof system that is p-equivalent to Q-resolution. In comparison to classical QCDCL, this new QCDCL version adapts both decision and unit propagation policies.

Approximating Upper Edge Dominating Set (Zur Approximierbarkeit von Upper EDS)

Henning Fernau (Uni Trier)

Joint work with Jérôme Monnot and David Manlove.

We study the problem of finding a minimal edge dominating set of maximum size in a given graph $G = (V, E)$, called Upper EDS. We show that this problem is not approximable within a ratio of $n^{\varepsilon - \frac{1}{2}}$, for any $\varepsilon \in (0, \frac{1}{2})$, assuming $\mathsf{P} \neq \mathsf{NP}$, where $n = |V|$. On the other hand, for graphs of minimum degree at least 2, we give an approximation algorithm with ratio $\frac{1}{\sqrt{n}}$, matching this lower bound. We further show that Upper EDS is APX-complete in bipartite graphs of maximum degree 4, and NP-hard in planar bipartite graphs of maximum degree 4.

Exploiting c-Closure in Kernelization Algorithms for Graph Problems

Tomohiro Koana (TU Berlin)

Main Reference Tomohiro Koana, Christian Komusiewicz and Frank Sommer. *Exploiting c-Closure in Kernelization Algorithms for Graph Problems.* ESA 2020.

A graph is c-closed if every pair of vertices with at least c common neighbors is adjacent. The c-closure of a graph G is the smallest number such that G is c-closed. Fox et al. [ICALP '18] defined c-closure and investigated it in the context of clique enumeration. We show that c-closure can be applied in kernelization algorithms for several classic graph problems. We show that Dominating Set admits a kernel of size $k^{O(c)}$, that Induced Matching admits a kernel with $O(c^7 \cdot k^8)$ vertices, and that Irredundant Set admits a kernel with $O(c^{\frac{5}{2}} \cdot k^3)$ vertices. Our kernelization exploits the fact that c-closed graphs have polynomially-bounded Ramsey numbers, as we show.

Computing Dense and Sparse Subgraphs of Weakly Closed Graphs

Frank Sommer (Uni Marburg)

Main Reference Tomohiro Koana, Christian Komusiewicz, und Frank Sommer. *Computing Dense and Sparse Subgraphs of Weakly Closed Graphs.* CoRR abs/2007.05630 (2020). URL: https://arxiv.org/abs/2007.05630

A graph G is weakly γ-closed if every induced subgraph of G contains one vertex v such that for each non-neighbor u of v it holds that $|N(u) \cap N(v)| < \gamma$. The weak closure $\gamma(G)$ of a graph, recently introduced by Fox et al. [SIAM J. Comp. 2020], is the smallest number such that G is weakly γ-closed. This graph parameter is never larger than the degeneracy (plus one) and can be significantly smaller. Extending the work of Fox et al. [SIAM J. Comp. 2020] on clique enumeration, we show that several problems related to finding dense subgraphs, such as the enumeration of bicliques and s-plexes, are fixed-parameter tractable with respect to $\gamma(G)$. Moreover, we show that the problem of determining whether a weakly γ-closed graph G has a subgraph on at least k vertices that belongs to a graph class $\mathcal{G}$ which is closed under taking subgraphs admits a kernel with at most γk^2 vertices. Finally, we provide fixed-parameter algorithms for Independent Dominating Set and Dominating Clique when parameterized by $\gamma + k$ where k is the solution size.

Length-Bounded Cuts: Proper Interval Graphs and Structural Parameters

Klaus Heeger (TU Berlin)

Main Reference Matthias Bentert, Klaus Heeger and Dusăn Knop. *Length-Bounded Cuts: Proper Interval Graphs and Structural Parameters.* CoRR abs/1910.03409 (2019). URL: https://arxiv.org/abs/1910.03409

In the presented paper we study the Length-Bounded Cut problem for special graph classes as well as from a parameterized-complexity viewpoint. Here, we are given a graph G, two vertices s and t, and positive integers b and l. The task is to find a set of edges F of size at most b such that every s-t-path of length at most l in G contains some edge in F.

Bazgan et al. [Networks, 2019] conjectured that Length-Bounded Cut admits a polynomial-time algorithm if the input graph G is a proper interval graph. We confirm this conjecture by showing a dynamic-programming based polynomial-time algorithm.

We strengthen the W[1]-hardness result of Dvořák and Knop [Algorithmica, 2018] for Length-Bounded Cut parameterized by pathwidth. Our reduction is shorter, and the target of the reduction has stronger structural properties. Consequently, we give W[1]-hardness for the combined parameter pathwidth and maximum degree of the input graph. Finally, we prove that Length-Bounded Cut is W[1]-hard for the feedback vertex number. Both our hardness results complement known XP algorithms.

Parameterised Complexity of Logic-Based Argumentation in Schaefer's Framework

Yasir Mahmood (Uni Hannover)

Logic-based argumentation is a well-established formalism modeling nonmonotonic reasoning playing a major role in AI for decades, now. Informally, a set of formulas is the support for a given claim if it is consistent, subset-minimal, and implies the claim. In such a case, the pair of the support and the claim together is called an

argument.
We study the propositional variants of the following three computational tasks studied in argumentation: ARG (exists a support for a given claim with respect to a given set of formulas), ARG-Check (is a given set a support for a given claim), and ARG-Rel (similarly as ARG plus requiring an additionally given formula has to be contained in the support as well). ARG-Check is complete for the complexity class DP, and the other two problems are known to be complete for the second level of the polynomial hierarchy (Parson et al., 2003) and, accordingly, are highly intractable.
Analyzing the reason for this intractability, we perform a two-dimensional classification: first, we consider all possible propositional fragments of the problem within Schaefer's framework, and then study different parameterizations for each of the fragment. We identify a list of reasonable structural parameters (size of the claim, support, knowledge-base) that are connected to the aforementioned decision problems. Eventually, we thoroughly draw a fine border of parameterized intractability for each of the problems showing where the problems are fixed-parameter tractable and when this exactly stops. Surprisingly, several cases are highly intractable (paraNP and beyond).

Peeling Close to the Orientability Threshold – Spatial Coupling in Hashing-Based Data Structures

Stefan Walzer (TU Ilmenau)

Main Reference Stefan Walzer. *Peeling Close to the Orientability Threshold: Spatial Coupling in Hashing-Based Data Structures.* CoRR abs/2001.10500 (2020). URL: https://arxiv.org/abs/2001.10500

In cuckoo hash tables each *key* x in a set S of m keys is associated with a random set $e(x) \subseteq [n]$ of *buckets* by hash functions. Each key must be placed into one of its associated buckets, but each bucket can only hold one key. A successful placement of all keys is called an *orientation*. Sometimes an orientation can be found greedily using *peeling*, meaning we repeatedly look for a bucket that only one unplaced key is associated with and placing that key in that bucket.
Many constructions exhibit sharp thresholds with respect to orientability and peelability, i.e. as the load factor $c = \frac{m}{n}$ grows past a critical value, the probability of these properties drops from almost 1 to almost 0. In the standard case where for

each key x the set $e(x) \subseteq [n]$ of associated buckets is a *fully random* set of size k, the threshold c_k^* for orientability significantly exceeds the threshold for peelability. This talk presents for every $k \geq 3$ and every $z > 0$ a different distribution on sets of size k such that if the sets $e(x)$ are chosen independently from that distribution, both the peelability and the orientability threshold approach c_k^* as $z \to \infty$. In particular the reach of the greedy placement algorithm is extended to load factors arbitrarily close to 1.

Our construction is simple: The n vertices are linearly ordered and each hyperedge selects its k elements uniformly at random from a random range of $\frac{n}{z+1}$ consecutive vertices. We thus exploit the phenomenon of *threshold saturation* via *spatial coupling* discovered in the context of low-density parity-check codes. Once the connection to data structures is in plain sight, a framework by Kudekar, Richardson and Urbanke (2015) does the heavy lifting in our proof.