80. Theorietag
Workshop on Algorithms and Complexity

Program and Abstracts

April 13, 2021

Organized by the Algorithmics and Computational Complexity Group of the Technische Universität Berlin.

Program

(in CEST/Berlin time)

09:00–09:05	Opening		
Session 1 (Chair: André Nichterlein)			
09:05–09:30	Yasir Mahmood	Parameterised Complexity of Team Based Logics	(p.3)
09:30–09:55	Donghyun Lim	Degrees of Second and Higher Order Polynomials	(p.4)
09:55–10:20	René van Bevern	On Weihe's data reduction algorithm: Fast kernelization of Multiple Hitting Set parameterized by Dilworth number	(p.5)
10:20–10:40	Coffee break with breakout session		
Session 2 (Chair: Matthias Bentert)			
10:40–11:05	Kriti Jethlia	The k-Colorable Unit Disk Cover Problem	(p.7)
11:05–11:30	Henning Fernau	Synchronizing Words and Monoid Factorization, Yielding a New Parameterized Complexity Class?	(p.8)
11:30–11:55	Stefan Hoffmann	Constrained Synchronization and Subset Synchronization Problems for Weakly Acyclic Automata	(p.9)
11:55–13:30	Lunch with breakout session (first 15 minutes)		
Session 3 (Chair: Malte Renken)			
13:30–14:30	Thomas Erlebach	Algorithms for Explorable Uncertainty: Parallel Queries and Untrusted Predictions	(p.10)
14:30–14:50	Coffee break with breakout session		
Session 4 (Chair: Tomohiro Koana)			
14:50–15:15	Petra Wolf	A Timecop's Chase Around the Table	(p.11)
15:15–15:40	Niclas Böhmer	A Fine-Grained View on the Hospital Residents Problem with Lower and Upper Quotas	(p.12)
15:40–16:05	Bhaskar DasGupta	Maximizing coverage while ensuring fairness: a tale of conflicting objectives	(p.13)
16:05–16:20	Coffee break with breakout session		
Session 5 (Chair: Klaus Heeger)			
16:20–16:45	Alexander Lindermayr	Double Coverage with Machine-Learned Advice	(p.14)
16:45–17:10	J. A. Gregor Lagodzinski	Quantum Graphs and (Modular) Counting	(p.15)
17:10–17:35	Hendrik Molter	Equitable Scheduling on a Single Machine	(p.16)
17:35–17:40	Closing		

Parameterised Complexity of Team Based Logics

Yasir Mahmood

(Leibniz Universität Hannover, Germany)

09:05 – 09:30

The origin of team based logics dates back to 2007 when Jouko Väänänen introduced dependence logic. The area was extended with the introduction of inclusion exclusion and independence logic. Moreover, the interaction of these logics with modal logic gave rise to modal dependence logic (as well as, modal inclusion/exclusion/independence logic). Since the beginning, it has emerged as an interesting area of study with applications in databases, social choice, statistics and many more. The problems of interest from complexity point of view are model checking, satisfiability, validity and the implication problem. The complexity of these problems is well understood in the classical setting.

In this work we analyse the parameterised complexity of the satisfiability and the model checking problems in the propositional setting. Mahmood et al., (FoIKS 2021) recently studied the parameterised complexity of propositional dependence logic. As a continuation of their work, we classify independence and inclusion logic and thereby try to complete the picture with respect to the parametrised complexity for all three logics.

Based on ongoing joint work with Jonni Virtema (LUH, Hannover).

Degrees of Second and Higher Order Polynomials

Donghyun Lim

(School of Computing, KAIST, Republic of Korea)

09:30 – 09:55

The classical theory of computational complexity measures cost in (worst-case) dependence on one integer parameter $n = |x|$ denoting the length of the input $x \in \{0,1\}^*$. Efficient computation according to Cobham means cost bounded by a polynomial in n. Function inputs $f : \{0,1\}^* \to \{0,1\}^*$, presented for example as oracles, are not captured by one natural number only, but instead by number function $\ell : \mathbb{N} \to \mathbb{N}$ with $|f(y)| \leq \ell(|y|)$. Here, efficient computation is understood as cost bounded by a so-called second-order polynomial: depending on both $n = |x|$ and ℓ [4]. These characterize the 'basic feasible functionals' [1] and have applications in complexity theory of operators in analysis [2, 5].

We consider syntax and semantics of second-order polynomials. The syntax is given by the rule $P, Q ::= 1 \mid n \mid P + Q \mid P * Q \mid \ell(P)$. The semantics $[\![P]\!] : \mathbb{N}^{\mathbb{N}} \times \mathbb{N} \to \mathbb{N}$ is the canonical interpretation as a second-order function. We prove that the syntax and the semantics coincide: $[\![P]\!] = [\![Q]\!]$ if and only if P and Q are related under a suitable notion of syntactic equivalence. Work in progress generalizes this to higher-order polynomials in terms of typed lambda calculus.

We consider a notion of degree of a second-order polynomial to be a (first-order) polynomial; we show it to be well-defined, and such that the degree of the degree coincides with the nesting depth of ℓ [3].

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On Weihe's data reduction algorithm: Fast kernelization of Multiple Hitting Set parameterized by Dilworth number*

René van Bevern

(Novosibirsk State University (NSU), Novosibirsk, Russian Federation (RF))

09:55 – 10:20

In the Hitting Set problem, one is given a collection of sets and has to find a minimum-cardinality set intersecting all sets in the input collection. In applications with noisy data like feature selection or multi-drug medication, one is rather interested in Multiple Hitting Set, where the solution has to intersect each input set a given number of times. In 1998, Weihe presented a data reduction algorithm for Hitting Set that turned out effective in practice. We observe that Weihe's algorithm actually computes linear-size problem kernels for Hitting Set parameterized by the Dilworth number of the incidence graph and thus initiate parameterized complexity studies with respect to the Dilworth number: it was introduced by Foldes and Hammer [1] and is bounded from above by the neighborhood diversity, which is frequently studied in the context of parameterized complexity theory. We generalize Weihe's kernelization to Multiple Hitting Set and speed it up using matrix multiplication, allowing for sequential subquadratic-time implementations and parallel implementations using NC^1 circuits. We experimentally compare the data reduction effect of our kernelization and additional data reduction rules for Multiple Hitting Set to those derived by Mellor et al. [2] in the context of optimal cancer medication.

This is joint work with Artem M. Kirilin (Siberian Federal University, Krasnoyarsk, RF), Daniel A. Skachkov (Moscow Institute of Physics and Technology, Moscow, RF) Pavel V. Smirnov (NSU, Novosibirsk, RF) Oxana Yu. Tsidulko (NSU, Novosibirsk, RF, Sobolev Institute of Mathematics, Novosibirsk, RF).

References

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*These results were obtained during the First Workshop of Mathematical Center in Akademgorodok, which was held during July 13–17th and August 10–14th, 2020, under support of the Ministry of Science and Higher Education of the Russian Federation, agreement No. 075-15-2019-1675. R. van Bevern, P. V. Smirnov, and O. Yu. Tsidulko were supported by Russian Foundation for Basic Research, project 18-501-12031 NNIO_a.

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The k-Colorable Unit Disk Cover Problem

Kriti Jethlia

(BITS Pilani, Hyderabad Campus, India)

10:40 – 11:05

We consider colorable variations of the Unit Disk Cover (*UDC*) problem as follows.

k-Colorable Discrete Unit Disk Cover (k-CDUDC): Given a set P of n points, and a set D of m unit disks (of radius=1), both lying in the plane, and a parameter k, the objective is to compute a set $D' \subseteq D$ such that every point in P is covered by at least one disk in D' and there exists a function $\chi : D' \to C$ that assigns colors to disks in D' such that for any d and d' in D' if $d \cap d' \neq \emptyset$, then $\chi(d) \neq \chi(d')$, where C denotes a set containing k distinct colors.

For the *k-CDUDC* problem, our proposed algorithms approximate the number of colors used in the coloring if there exists a k-colorable cover. We first propose a 4-approximation algorithm in $O(m^{7k} n \log k)$ time for this problem, where k is a positive integer. The previous best known result for the problem when $k = 3$ is due to the recent work of Biedl et al. [*Computational Geometry:Theory & Applications, 2021*], who proposed a 2-approximation algorithm in $O(m^{25} n)$ time. For $k = 3$, our algorithm runs in $O(m^{21} n)$ time, faster than the previous best algorithm, but gives a 4-approximate result. We then generalize our approach to yield a family of ρ-approximation algorithms in $O(m^{\alpha k} n \log k)$ time, where $(\rho, \alpha) \in \{(4, 7), (6, 5), (7, 5), (9, 4)\}$. We further generalize this to exhibit a $O(\frac{1}{\tau})$-approximation algorithm in $O(m^{\alpha k} n \log k)$ time for a given grid width $1 \leq \tau \leq 2$, where $\alpha = O(\tau^2)$. We also extend our algorithm to solve the *k-Colorable Line Segment Disk Cover (k-CLSDC)* and *k-Colorable Rectangular Region Cover (k-CRRC)* problems, in which instead of the set P of n points, we are given a set S of n line segments, and a rectangular region $\mathcal{R}$, respectively.

Related manuscript: `http://arxiv.org/abs/2104.00207`

Synchronizing Words and Monoid Factorization, Yielding a New Parameterized Complexity Class?

Henning Fernau

(Universität Trier, Germany)

11:05 – 11:30

The concept of a synchronizing word is a very important notion in the theory of finite automata. We consider the associated decision problem to decide if a given DFA possesses a synchronizing word of length at most k, where k is the standard parameter. We show that this problem DFA-SW is equivalent to the problem Monoid Factorization introduced by Cai, Chen, Downey and Fellows. Apart from the known $\mathsf{W}[2]$-hardness results, we show that these problems belong to $\mathsf{A}[2]$, $\mathsf{W}[\mathsf{P}]$ and WNL. This indicates that DFA-SW is not complete for any of these classes and hence, we suggest a new parameterized complexity class $\mathsf{W}[\mathsf{Sync}]$ as a proper home for these (and more) problems. We present quite a number of problems that belong to $\mathsf{W}[\mathsf{Sync}]$, or are hard or complete for this new class.

Joint work with Jens Bruchertseifer.

Constrained Synchronization and Subset Synchronization Problems for Weakly Acyclic Automata

Stefan Hoffmann

(Universität Trier, Germany)

11:30 – 11:55

We investigate the constrained synchronization problem for weakly acyclic, or partially ordered, input automata. We show that, for input automata of this type, the problem is always in NP. Furthermore, we give a full classification of the realizable complexities for constraint automata with at most two states and over a ternary alphabet. We also investigate two problems related to subset synchronization, namely if there exists a word mapping all states into a given target subset of states, and if there exists a word mapping one subset into another. Both problems are PSPACE-complete in general, but in our setting the former is polynomial time solvable and the latter is NP-complete.

Algorithms for Explorable Uncertainty: Parallel Queries and Untrusted Predictions

Thomas Erlebach

(University of Leicester, UK)

13:30 – 14:30

In computing with explorable uncertainty, an algorithm is initially given an input where some values are uncertain (e.g., given as intervals), and queries can be made to reveal the exact input values. The goal is usually to minimize the number of queries made until enough information has been obtained to compute a provably correct solution. We consider problems such as sorting, computing the minima of multiple sets, selection, and the minimum spanning tree problem. For these problems, we present new results for the case where a limited number of queries can be made in parallel, and for the case where untrusted predictions (e.g. obtained using machine learning) of the exact values are available.

(Based on joint work with Michael Hoffmann, Murilo Santos de Lima, Nicole Megow and Jens Schlöter.)

A Timecop's Chase Around the Table

Petra Wolf

(Universität Trier, Germany)

14:50 – 15:15

We consider the cops and robber game variant consisting of one cop and one robber on time variable graphs (TVG). The considered TVGs are edge periodic graphs, i.e., for each edge, a binary string s_e determines in which time step the edge is present, namely the edge e is present in time step t if and only if the string s_e contains a 1 at position $t \mod |s_e|$. This periodicity allows for a compact representation of the infinite TVG. We proof that even for very simple underlying graphs, i.e., directed and undirected cycles the problem whether a cop-winning strategy exists is NP-hard and W1-hard parameterized by the number of vertices. Our second main result are matching lower bounds for the ration between the length of the underlying cycle and the least common multiple (LCM) of the lengths of binary strings describing edge-periodicies over which the graph is robber-winning. Our third main result improves the previously known EXPTIME upper bound for Periodic Cops & Robbers on general edge periodic graphs to PSPACE-membership.

Based on joined work with Nils Morawietz (Philipps-Universität Marburg).

A Fine-Grained View on the Hospital Residents Problem with Lower and Upper Quotas

Niclas Böhmer

(Technische Universität Berlin, Germany)

15:15 – 15:40

In the Hospital Residents problem with lower and upper quotas, a generalization of the famous Stable Marriage problem, we are given a set of residents, each with preferences over hospitals, and a set of hospitals, each with an upper and lower quota and preferences over residents, and the goal is to find a stable matching of residents to hospitals where the number of residents matched to a hospital is either between its lower and upper quota or zero. We analyze the influence of several natural parameters, such as the number of hospitals and the number of residents, on the computational complexity of this problem. Moreover, we present a polynomial-time algorithm that finds a stable matching if it exists on instances with maximum lower quota two.

(Based on joint work with Klaus Heeger.)

Related manuscript: https://arxiv.org/abs/2009.14171

Maximizing coverage while ensuring fairness: a tale of conflicting objectives

Bhaskar DasGupta

(University of Illinois at Chicago, USA)

15:40 – 16:05

Ensuring fairness in computational problems has emerged as a key topic during recent years, buoyed by considerations for equitable resource distributions and social justice. It is possible to incorporate fairness in computational problems from several perspectives, such as using optimization, game-theoretic or machine learning frameworks. In this talk we address the problem of incorporation of fairness from a combinatorial optimization perspective. We formulate a combinatorial optimization framework, suitable for analysis by researchers in approximation algorithms and related areas, that incorporates fairness in maximum coverage problems as an interplay between two conflicting objectives. Fairness is imposed in coverage by using coloring constraints that minimizes the discrepancies between number of elements of different colors covered by selected sets; this is in contrast to the usual discrepancy minimization problems studied extensively in the literature where (usually two) colors are not given a priori but need to be selected to minimize the maximum color discrepancy of each individual set. Our main results are a set of randomized and deterministic approximation algorithms that attempts to simultaneously approximate both fairness and coverage in this framework.

(joint work with Abolfazl Asudeh, Tanya Berger-Wolf and Anastasios Sidiropoulos)

Double Coverage with Machine-Learned Advice

Alexander Lindermayr

(Universität Bremen, Germany)

16:20 – 16:45

We study the fundamental online k-server problem in a learning-augmented setting. While in the traditional online model, an algorithm has no information about the request sequence, we assume that there is given some advice (e.g. machine-learned predictions) on an algorithm's decision. There is, however, no guarantee on the quality of the prediction and it might be far from being correct.

Our main result is a learning-augmented variation of the well-known Double Coverage algorithm for k-server on the line (Chrobak et al., SIDMA 1991) in which we integrate predictions as well as our trust into their quality. We give an error-dependent competitive ratio, which is a function of a user-defined trustiness parameter, and which interpolates smoothly between an optimal consistency, the performance in case that all predictions are correct, and the best-possible robustness regardless of the prediction quality. When given good predictions, we improve upon known lower bounds for online algorithms without advice. We further show that our algorithm achieves for any k an almost optimal consistency-robustness tradeoff, within a class of deterministic algorithms respecting local and memoryless properties. Our algorithm outperforms a previously proposed (more general) learning-augmented algorithm. It is remarkable that the previous algorithm heavily exploits memory, whereas our algorithm is memoryless. Finally, we demonstrate in experiments the practicability and the superior performance of our algorithm on real-world data.

(Based on joint work with Nicole Megow and Bertrand Simon.)

Related manuscript: https://arxiv.org/abs/2103.01640

Quantum Graphs and (Modular) Counting

J. A. Gregor Lagodzinski

(Hasso-Plattner-Institut, Universität Potsdam, Germany)

16:45 – 17:10

Roughly six years ago, Faben and Jerrum raised the question: what is the complexity of counting the number of homomorphisms to a fixed image graph modulo a prime? Graph homomorphisms are well understood from a complexity point of view but remain of high interest with connections to multiple fields, e.g. the study of graph limits and networks with major contributions by recent Abel price laureate László Lovász. Faben and Jerrum conjectured for the modulus 2 that the complexity behaviour follows roughly the same characterization as the affiliated non-modular problem, for which Dyer and Greenhill gave a dichotomy. This conjecture is still unproven and for a couple of years there was no progress; until last year.

One possible generalization of a graph is the symbolic linear combination of graphs for which László Lovász introduced the term "quantum graph". This point of view proved to be fruitful for many studies of counting problems as combined with an algebra of graphs it grants access to the powerful machine that is linear algebra. Following this approach we derived a universal reduction technique for (subproblems of) counting graph homomorphisms. By this we established a chain of reductions from the general problem of counting homomorphisms to a quantum graph modulo a prime to the problem of counting a restricted family of homomorphisms to a bipartite graph modulo a prime. Due to a thorough structural study we were able to show the Faben and Jerrum conjecture for a rich class of graphs for all prime moduli.

In this talk, we will focus on the technique and insights provided by the point of view of quantum graphs with the goal to provide a clear picture on the reduction arguments. Additionally, we will briefly talk about the problems caused by the modulus, i.e. the question "why is the conjecture still not proven?".

Related manuscript: https://arxiv.org/abs/2011.04827

Equitable Scheduling on a Single Machine

Hendrik Molter

(Ben-Gurion University of the Negev, Israel)

17:10 – 17:35

We introduce a natural but seemingly yet unstudied generalization of the problem of scheduling jobs on a single machine so as to minimize the number of tardy jobs. Our generalization lies in simultaneously considering several instances of the problem at once. In particular, we have n clients over a period of m days, where each client has a single job with its own processing time and deadline per day. Our goal is to provide a schedule for each of the m days, so that each client is guaranteed to have their job meet its deadline in at least $k \leq m$ days. This corresponds to an equitable schedule where each client is guaranteed a minimal level of service throughout the period of m days. We provide a thorough analysis of the computational complexity of three main variants of this problem, identifying both efficient algorithms and worst-case intractability results.

Based on joint work with Klaus Heeger, Danny Hermelin, George B. Mertzios, Rolf Niedermeier, and Dvir Shabtay.