78. Theorietag
Workshop about Algorithms and Complexity

Book of Abstracts

October 10–11 2019

Program

Thursday, October 10 2019

13:45–14:00	Welcome Reception
14:00–15:00	Bhaskar DasGupta: Why did the shape of your network change? (On detecting network anomalies via non-local curvatures)
15:00–15:10	Coffee Break
15:10–15:35	Andreas Göbel: Zeros and approximations of Holant polynomials on the complex plane
15:35–16:00	Martin Dietzfelbinger: Efficient Gauss Elimination for Near-Quadratic Matrices with One Short Random Block per Row, with Applications
17:00–19:20	City Tour "Berliner Hinterhöfe" ("Berlin backyards"; starts at Hackescher Markt; ≈25 minutes by public transport from the workshop venue)
19:30	Dinner at Clärchens Ballhaus (the city tour ends there)

Friday, October 11 2019

9:00–10:00	Holger Dell: Algorithms for Small Structures in Large Networks
10:00–10:15	Coffee Break
10:15–10:40	Benjamin Aram Berendsohn: Finding and counting permutations via CSPs
10:40–11:05	Yasir Mahmood: Parameterised Complexity of Abduction in Schaefer's Framework
11:05–11:30	Louise Molitor: Convergence and Hardness of Strategic Schelling Segregation
11:30–11:45	Coffee Break
11:45–12:10	Anna Melnichenko: Geometric Network Creation Games
12:10–12:35	Philipp Zschoche: Multistage Vertex Cover
12:35–13:00	Malte Renken: Shortest Paths in Terrain Visibility Graphs

Why did the shape of your network change? (On detecting network anomalies via non-local curvatures)

Bhaskar DasGupta, University of Illinois at Chicago

Anomaly detection problems (also called change-point detection problems) have been studied in data mining, statistics and computer science over the last several decades (mostly in non-network context) in applications such as medical condition monitoring, weather change detection and speech recognition. In recent days, however, anomaly detection problems have become increasing more relevant in the context of network science since useful insights for many complex systems in biology, finance and social science are often obtained by representing them via networks. Notions of local and non-local curvatures of higher-dimensional geometric shapes and topological spaces play a fundamental role in physics and mathematics in characterizing anomalous behaviours of these higher dimensional entities. However, using curvature measures to detect anomalies in networks is not yet very common. To this end, a main goal of this talk is to formulate and analyze curvature analysis methods to provide the foundations of systematic approaches to find critical components and detect anomalies in networks. For this purpose, we use two measures of network curvatures which depend on non-trivial global properties, such as distributions of geodesics and higher-order correlations among nodes, of the given network. Based on these measures, we precisely formulate several computational problems related to anomaly detection in static or dynamic networks, and provide non-trivial computational complexity results for these problems. It is our hope that this paper will stimulate and motivate further theoretical or empirical research concerning the exciting interplay between notions of curvatures from network and non-network domains, a much desired goal in our opinion.

(Joint result with M. V. Janardhanan and F. Yahyanejad)

Zeros and approximations of Holant polynomials on the complex plane

Andreas Göbel, Hasso Plattner Institute

We present fully polynomial approximation schemes for a broad class of Holant problems with complex edge weights, which we call Holant polynomials. We transform these problems into partition functions of abstract combinatorial structures known as polymers in statistical physics. Our method involves establishing zero-free regions for the partition functions of polymer models and using the high-energy terms of the cluster expansion to approx- imate them.

Results of our technique include new approximation and sampling algorithms for a diverse class of Holant polynomials in the low-energy regime and approximation algorithms for general Holant problems with small signature weights. Additionally, we give randomised approximation and sampling algorithms with faster running times for more restrictive classes.

Efficient Gauss Elimination for Near-Quadratic Matrices with One Short Random Block per Row, with Applications

Martin Dietzfelbinger, Technische Universität Ilmenau

In this work we identify a new class of sparse near-quadratic random Boolean matrices that have full row rank over $\mathbb{F}_2 = \{0, 1\}$ with high probability and can be transformed into echelon form in almost linear time by a simple version of Gauss elimination. The random matrix with dimensions $n(1 - \varepsilon) \times n$ is generated as follows: In each row, identify a block of length $L = \mathcal{O}((\log n)/\varepsilon)$ at a random position. The entries outside the block are 0, the entries inside the block are given by fair coin tosses. Sorting the rows according to the positions of the blocks transforms the matrix into a kind of band matrix, on which, as it turns out, Gauss elimination works very efficiently with high probability. For the proof, the effects of Gauss elimination are interpreted as a ("coin-flipping") variant of Robin Hood hashing, whose behaviour can be captured in terms of a simple Markov model from queuing theory. Bounds for expected construction time and high success probability follow from results in this area. They readily extend to larger finite fields in place of $\mathbb{F}_2$.

By employing hashing, this matrix family leads to a new implementation of a *retrieval* data structure, which represents an arbitrary function $f : S \to \{0, 1\}$ for some set S of $m = (1 - \varepsilon)n$ keys. It requires $m/(1 - \varepsilon)$ bits of space, construction takes $\mathcal{O}(m/\varepsilon^2)$ expected time on a word RAM, while queries take $\mathcal{O}(1/\varepsilon)$ time and access only one contiguous segment of $\mathcal{O}((\log m)/\varepsilon)$ bits in the representation ($\mathcal{O}(1/\varepsilon)$ consecutive words on a word RAM). The method is readily implemented and highly practical, and it is competitive with state-of-the-art methods. In a more theoretical variant, which works only for unrealistically large S, we can even achieve construction time $\mathcal{O}(m/\varepsilon)$ and query time $\mathcal{O}(1)$, accessing $\mathcal{O}(1)$ contiguous memory words for a query. By well-established methods the retrieval data structure leads to efficient constructions of (static) perfect hash functions and (static) Bloom filters with almost optimal space and very local storage access patterns for queries.

(Joint work with Stefan Walzer)

Algorithms for Small Structures in Large Networks

Holger Dell, ITU Copenhagen

This talk is about counting and sampling small subgraphs in a large input graph. You will obtain an overview of algorithmic and complexity-theoretic aspects of this topic, including evergreens such as the beautiful color-coding algorithm (Alon, Yuster, and Zwick 1995) and meet-in-the-middle (Vassilevska Williams and Williams 2009). We also discuss more recent algorithms based on abstract algebra (Koutis 2008, Brand, D, and Husfeldt 2018) and on graph homomorphisms (Curticapean, D, Marx 2017), and a more structural question about the relationship between the fine-grained complexities of sampling and detection (D, Lapinskas, and Meeks 2019).

Finding and counting permutations via CSPs

Benjamin Aram Berendsohn, Freie Universität Berlin

Permutation patterns and pattern avoidance have been intensively studied in combinatorics and computer science, going back at least to the seminal work of Knuth on stack-sorting (1968). Perhaps the most natural algorithmic question in this area is deciding whether a given permutation of length n contains a given pattern of length k.

In this work we give two new algorithms for this well-studied problem, one whose running time is $n^{k/4+o(k)}$, and a polynomial-space algorithm whose running time is the better of $O(1.6181^n)$ and $O(n^{k/2+1})$. These results improve the earlier best bounds of $n^{0.47k+o(k)}$ and $O(1.79^n)$ due to Ahal and Rabinovich (2000) resp. Bruner and Lackner (2012) and are the fastest algorithms for the problem when $k \in \Omega(\log n)$. We show that both our new algorithms and the previous exponential-time algorithms in the literature can be viewed through the unifying lens of constraint-satisfaction.

Our algorithms can also count, within the same running time, the number of occurrences of a pattern. We show that this result is close to optimal: solving the counting problem in time $f(k) \cdot n^{o(k/\log k)}$ would contradict the exponential-time hypothesis (ETH). For some special classes of patterns we obtain improved running times. We further prove that 3-increasing and 3-decreasing permutations can, in some sense, embed arbitrary permutations of almost linear length, which indicates that an algorithm with sub-exponential running time is unlikely, even for patterns from these restricted classes.

Parameterised Complexity of Abduction in Schaefer's Framework

Yasir Mahmood, Leibniz University Hannover

Abductive reasoning is a non-monotonic formalism stemming from the work of Peirce. It describes the process of deriving the most plausible explanations of known facts. Considering the positive version asking for sets of variables as explanations, we study, besides asking for existence of the set of explanations, two explanation size limited variants of this reasoning problem (less than or equal to, and equal to). In this paper, we present a thorough two-dimensional classification of these problems. The first dimension is regarding the parameterised complexity under a wealth of different parameterisations. The second dimension spans through all possible Boolean fragments of these problems in Schaefer's constraint satisfaction framework with co-clones (STOC 1978). Thereby, we almost complete the parameterised picture started by Fellows et al. (AAAI 2012), partially building on results of Nordh and Zanuttini (Artif. Intell. 2008). In this process, we outline a fine-grained analysis of the inherent parameterised intractability of these problems and pinpoint their FPT parts. As the standard algebraic approach is not applicable to our problems, we develop an alternative method that makes the algebraic tools partially available again.

Convergence and Hardness of Strategic Schelling Segregation

Louise Molitor, Hasso Plattner Institute

The phenomenon of residential segregation was captured by Schelling's famous segregation model where two types of agents are placed on a grid and an agent is content with her location if the fraction of her neighbors which have the same type as her is at least τ, for some $0 < \tau < 1$. Discontent agents simply swap their location with a randomly chosen other discontent agent or jump to a random empty cell.

We analyze a generalized game-theoretic model of Schelling segregation which allows more than two agent types and more general underlying graphs modeling the residential area. For this we show that both aspects heavily influence the dynamic properties and the tractability of finding an optimal placement. We map the boundary of when improving response dynamics (IRD), i.e., the natural approach for finding equilibrium states, are guaranteed to converge. For this we prove several sharp threshold results where guaranteed IRD convergence suddenly turns into the strongest possible non-convergence result: a violation of weak acyclicity. In particular, we show such threshold results also for Schelling's original model, which is in contrast to the standard assumption in many empirical papers. Furthermore, we show that in case of convergence, IRD find an equilibrium in $\mathcal{O}(m)$ steps, where m is the number of edges in the underlying graph and show that this bound is met in empirical simulations starting from random initial agent placements.

Geometric Network Creation Games

Anna Melnichenko, Hasso Plattner Institute

Network Creation Games are a well-known approach for explaining and analyzing the structure, quality and dynamics of real-world networks like the Internet and other infrastructure networks which evolved via the interaction of selfish agents without a central authority. In these games selfish agents which correspond to nodes in a network strategically buy incident edges to improve their centrality. However, past research on these games has only considered the creation of networks with unit-weight edges. In practice, e.g. when constructing a fiber-optic network, the choice of which nodes to connect and also the induced price for a link crucially depends on the distance between the involved nodes and such settings can be modeled via edge-weighted graphs. We incorporate arbitrary edge weights by generalizing the well-known model by Fabrikant et al. [PODC'03] to edge-weighted host graphs and focus on the geometric setting where the weights are induced by the distances in some metric space. In stark contrast to the state-of-the-art for the unit-weight version, where the Price of Anarchy is conjectured to be constant and where resolving this is a major open problem, we prove a tight non-constant bound on the Price of Anarchy for the metric version and a slightly weaker upper bound for the non-metric case. Moreover, we analyze the existence of equilibria, the computational hardness and the game dynamics for several natural metrics. The model we propose can be seen as the game-theoretic analogue of a variant of the classical Network Design Problem. Thus, low-cost equilibria of our game correspond to decentralized and stable approximations of the optimum network design.

Multistage Vertex Cover

Philipp Zschoche, Technische Universität Berlin

Covering all edges of a graph by a minimum number of vertices, this is the NP-hard Vertex Cover problem, is among the most fundamental algorithmic tasks. Following a recent trend in studying dynamic and temporal graphs, we initiate the study of Multistage Vertex Cover. Herein, having a series of graphs with same vertex set but over time changing edge sets (known as temporal graph consisting of various layers), the goal is to find for each layer of the temporal graph a small vertex cover and to guarantee that the two vertex cover sets between two subsequent layers differ not too much (specified by a given parameter). We show that, different from classic Vertex Cover and some other dynamic or temporal variants of it, Multistage Vertex Cover is computationally hard even in fairly restricted settings. On the positive side, however, we also spot several fixed-parameter tractability results based on some of the most natural parameterizations.

Shortest Paths in Terrain Visibility Graphs

Malte Renken, Technische Universität Berlin

Terrain visibility graphs are a well-known graph class in computational geometry. They are closely related to polygon visibility graphs, but a precise graph-theoretical characterization is still unknown. Over the last decade, terrain visibility graphs attracted considerable attention in the context of time series analysis (there called time series visibility graphs) with various practical applications in areas such as physics, geography and medical sciences. Computing shortest paths in visibility graphs is a common task, for example, in line-of-sight communication. For time series analysis, graph characteristics involving shortest paths lengths (such as centrality measures) have proven useful. In this talk, we present a fast output-sensitive shortest path algorithm on a class of graphs that includes all induced subgraphs of terrain visibility graphs. Our algorithm runs in $O(d \log \Delta)$ time, where d is the length (that is, the number of edges) of the shortest path and Δ is the maximum vertex degree. Alternatively, with an $\mathrm{O}(n^2)$-time preprocessing our algorithm runs in $O(d)$ time.