Publications of Ankit Chauhan

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Journal articles

[1] Chauhan, A., Friedrich, T., Rothenberger, R., Greed is Good for Deterministic Scale-Free Networks. In: *Algorithmica* 82, pp. 3338–3389, 2020.

Large real-world networks typically follow a power-law degree distribution. To study such networks, numerous random graph models have been proposed. However, real-world networks are not drawn at random. Therefore, Brach, Cygan, Lacki, and Sankowski [SODA 2016] introduced two natural deterministic conditions: (1) a power-law upper bound on the degree distribution (PLB-U) and (2) power-law neighborhoods, that is, the degree distribution of neighbors of each vertex is also upper bounded by a power law (PLB-N). They showed that many real-world networks satisfy both deterministic properties and exploit them to design faster algorithms for a number of classical graph problems. We complement the work of Brach et al. by showing that some well-studied random graph models exhibit both the mentioned PLB properties and additionally also a power-law lower bound on the degree distribution (PLB-L). All three properties hold with high probability for Chung-Lu Random Graphs and Geometric Inhomogeneous Random Graphs and almost surely for Hyperbolic Random Graphs. As a consequence, all results of Brach et al. also hold with high probability or almost surely for those random graph classes. In the second part of this work we study three classical NP-hard combinatorial optimization problems on PLB networks. It is known that on general graphs with maximum degree Δ, a greedy algorithm, which chooses nodes in the order of their degree, only achieves a $\Omega(\ln \Delta)$-approximation for Minimum Vertex Cover and Minimum Dominating Set, and a $\Omega(\Delta)$-approximation for Maximum Independent Set. We prove that the PLB-U property suffices for the greedy approach to achieve a constant-factor approximation for all three problems. We also show that all three combinatorial optimization problems are APX-complete even if all PLB-properties holds hence, PTAS cannot be expected unless P=NP.

Conference papers

[2] Sukmana, M. I., Torkura, K. A., Graupner, H., Chauhan, A., Cheng, F., Meinel, C., Supporting Internet-Based Location for Location-Based Access Control in Enterprise Cloud Storage Solution. In: *International Conference on Advanced Information Networking and Applications*. Springer, pp. 1240–1253, 2019.

[3] Chauhan, A., Lenzner, P., Molitor, L., Schelling Segregation with Strategic Agents. In: *Symposium on Algorithmic Game Theory (SAGT)*, 2018.

Schelling's segregation model is a landmark model in sociology. It shows the counter-intuitive phenomenon that residential segregation between individuals of different groups can emerge even when all involved individuals are tolerant. Although the model is widely studied, no pure game-theoretic version where rational agents strategically choose their location exists. We close this gap by introducing and analyzing generalized game-theoretic models of Schelling segregation, where the agents can also have individual location preferences. For our models we investigate the convergence behavior and the efficiency of their equilibria. In particular, we prove guaranteed convergence to an equilibrium in the version which is closest to Schelling's original model. Moreover, we provide tight bounds on the Price of Anarchy.

[4] Chauhan, A., Friedrich, T., Quinzan, F., Approximating Optimization Problems using EAs on Scale-Free Networks. In: *Genetic and Evolutionary Computation Conference (GECCO)*, pp. 235–242, 2017.

It has been experimentally observed that real-world networks follow certain topologicalproperties, such as small-world, power-law etc. To study these networks, many random graph models, such as Preferential Attachment, have been proposed. In this paper, we consider the deterministic properties which capture power-law degree distribution and degeneracy. Networks with these properties are known as scale-free networks in the literature. Many interesting problems remain NP-hard on scale-free networks. We study the relationship between scale-free properties and the approximation-ratio of some commonly used evolutionary algorithms. For the Vertex Cover, we observe experimentally that the $(1 + 1)$ EA always gives the better result than a greedy local search, even when it runs for only $O(n \log(n))$ steps. We give the construction of a scale-free network in which a multi-objective algorithm and a greedy algorithm obtain optimal solutions, while the $(1+1)$ EA obtains the worst possible solution with constant probability. We prove that for the Dominating Set, Vertex Cover, Connected Dominating Set and Independent Set, the $(1 + 1)$ EA obtains constant-factor approximation in expected run time $O(n \log(n))$ and $O(n^4)$ respectively. Whereas, GSEMO gives even better approximation than $(1+1)$ EA in expected run time $O(n^3)$ for Dominating Set, Vertex Cover and Connected Dominating Set on such networks.

[5] Chauhan, A., Lenzner, P., Melnichenko, A., Molitor, L., Selfish Network Creation with Non-Uniform Edge Cost. In: *Symposium on Algorithmic Game Theory (SAGT)*, pp. 160–172, 2017.

Network creation games investigate complex networks from a game-theoretic point of view. Based on the original model by Fabrikant et al. [PODC'03] many variants have been introduced. However, almost all versions have the drawback that edges are treated uniformly, i.e. every edge has the same cost and that this common parameter heavily influences the outcomes and the analysis of these games. We propose and analyze simple and natural parameter-free network creation games with non-uniform edge cost. Our models are inspired by social networks where the cost of forming a link is proportional to the popularity of the targeted node. Besides results on the complexity of computing a best response and on various properties of the sequential versions, we show that the most general version of our model has con- stant Price of Anarchy. To the best of our knowledge, this is the first proof of a constant Price of Anarchy for any network creation game.

[6] Chauhan, A., Friedrich, T., Rothenberger, R., Greed is Good for Deterministic Scale-Free Networks. In: *Foundations of Software Technology and Theoretical Computer Science (FSTTCS)*, pp. 33:1–33:15, 2016.

Large real-world networks typically follow a power-law degree distribution. To study such networks, numerous random graph models have been proposed. However, real-world networks are not drawn at random. Therefore, Brach, Cygan, Lacki, and Sankowski [SODA 2016] introduced two natural deterministic conditions: (1) a power-law upper bound on the degree distribution (PLB-U) and (2) power-law neighborhoods, that is, the degree distribution of neighbors of each vertex is also upper bounded by a power law (PLB-N). They showed that many real-world networks satisfy both deterministic properties and exploit them to design faster algorithms for a number of classical graph problems. We complement the work of Brach et al. by showing that some well-studied random graph models exhibit both the mentioned PLB properties and additionally also a power-law lower bound on the degree distribution (PLB-L). All three properties hold with high probability for Chung-Lu Random Graphs and Geometric Inhomogeneous Random Graphs and almost surely for Hyperbolic Random Graphs. As a consequence, all results of Brach et al. also hold with high probability or almost surely for those random graph classes. In the second part of this work we study three classical NP-hard combinatorial optimization problems on PLB networks. It is known that on general graphs with maximum degree Δ, a greedy algorithm, which chooses nodes in the order of their degree, only achieves a $\Omega(\ln \Delta)$-approximation for Minimum Vertex Cover and Minimum Dominating Set, and a $\Omega(\Delta)$-approximation for Maximum Independent Set. We prove that the PLB-U property suffices for the greedy approach to achieve a constant-factor approximation for all three problems. We also show that all three combinatorial optimization problems are APX-complete even if all PLB-properties holds hence, PTAS cannot be expected unless P=NP.

[7] Chauhan, A., Lenzner, P., Melnichenko, A., Münn, M., On Selfish Creation of Robust Networks. In: *Symposium on Algorithmic Game Theory (SAGT)*, pp. 141–152, 2016.

Robustness is one of the key properties of nowadays networks. However, robustness cannot be simply enforced by design or regulation since many important networks, most prominently the Internet, are not created and controlled by a central authority. Instead, Internet-like networks emerge from strategic decisions of many selfish agents. Interestingly, although lacking a coordinating authority, such naturally grown networks are surprisingly robust while at the same time having desirable properties like a small diameter. To investigate this phenomenon we present the first simple model for selfish network creation which explicitly incorporates agents striving for a central position in the network while at the same time protecting themselves against random edge-failure. We show that networks in our model are diverse and we prove the versatility of our model by adapting various properties and techniques from the non-robust versions which we then use for establishing bounds on the Price of Anarchy. Moreover, we analyze the computational hardness of finding best possible strategies and investigate the game dynamics of our model.

[8] Chauhan, A., Rao, B. V. R., Parameterized Analogues of Probabilistic Computation. In: *Conference on Algorithms and Discrete Applied Mathematics (CALDAM)*, pp. 181–192, 2015.

We study structural aspects of randomized parameterized computation. We introduce a new class W[P]-PFPT as a natural parameterized analogue of PP. Our definition uses the machine based characterization of the parameterized complexity class W[P] obtained by Chen et.al [TCS 2005]. We translate most of the structural properties and characterizations of the class PP to the new class W[P]-PFPT. We study a parameterization of the polynomial identity testing problem based on the degree of the polynomial computed by the arithmetic circuit. We obtain a parameterized analogue of the well known Schwartz-Zippel lemma [Schwartz, JACM 80 and Zippel, EUROSAM 79]. Additionally, we introduce a parameterized variant of permanent, and prove its #W[1] completeness.