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Review of Habilitation Thesis of Dr. Andreas Emil Feldmann

The Habilitation Thesis of Dr Feldmann consists of a number of important contributions to the area of parameterized approximation algorithms. Parameterized complexity theory and approximation are mature areas of research, and hence to make further progress a thorough understanding of both areas is required. Dr Feldmann clearly has such knowledge and research skills, as evidenced by the very high quality of his thesis.

The thesis consists of three chapters (sections) and uses material from a number of conference and journal papers published in very prestigious venues, such as SIAM Journal on Computing, FOCS and ICALP. These papers are added as appendices. As explained in the thesis, some parts are copied over from these papers. This naturally explains the high percentage matches found by Turnitin. I checked the Turnitin document and did not spot any other irregularities.

Section 1. The first section of the thesis consists of an easy-to-understand introduction into both approximation and parameterized algorithms and serves as motivation for the remainder of the thesis. In short: computing optimal solutions for most discrete optimization problems is not feasible and both types of algorithms are highly sensible ways of dealing with the computational hardness. Approximation algorithms offer solutions that might not be optimal but "close" to optimal. Parameterized algorithms identify some part of the input that may be considered to be small (depending on the problem context) and then exploit this assumption to find optimal solutions. Combining these two algorithmic techniques gives us some very powerful tools. In addition, it is also useful to know to what extent these techniques can be applied. Both aspects are clearly illustrated in the thesis.

The problems to which the new techniques are applied lie in the area of network design and clustering. Each area is discussed in their own section: Section 2 is on network design and Section 3 is on clustering.

Section 2. A graph (network) consists of a set of nodes also called vertices some of which are pairwise connected by links (edges). In the design of networks we often want to connect a specified set of vertices, called terminals, by using a small number of edges of the graph only (or in the edge-weighted version, by using a set of edges of small weight). This leads to the classical Steiner Tree problem, one of the most studied problems in graph theory due to its many practical applications.

Results in Section 2 include two parameterized alpha-approximation algorithms, namely a parameterized approximation scheme and a polynomial-sized approximate kernelization scheme for Steiner Tree, where the parameter is the number of non-terminal vertices. The situation is then compared to the variant where the edges in a graph represent directed links (going out of some vertex, going into some other vertex). It is proved that results for the undirected variant only partially carry over to the directed variant. Other results are results where the parameter is the number of terminals and where the graphs are restricted to some special graph class, namely planar bidirected graphs. Planar graphs (those graphs that can be drawn into the plane without edge crossings) form a central graph class in network design. The results in this section have nontrivial proofs, are highly novel and form significant contributions to the area.

Section 3. In this section, a number of clustering problems are studied that model transportation networks. In general form, we are given a metric on some vertex set and we want to group vertices that are “close” to each other. Three basic clustering problems are considered: k-Median, k-Center, and Facility Location. The parameters that are chosen are relevant for transportation networks, in particular the so-called doubling and highway dimension.

The results in this section include, amongst others, a near-linear time approximation scheme with parameter doubling dimension and a polynomial-time approximation scheme with parameter highway dimension for k-Median and Facility Location. The section also contains a large number of hardness results (subject to well-known complexity assumptions) for the three problems. In particular k-Center is harder to approximate than the other two problems and this is confirmed by the new hardness results. As mentioned, these hardness results are all very useful to know, as they indicate the extent to which we can use the algorithmic techniques. Just like the results in Section 2, the results in Section 3 are also of high quality. They are novel, significant and have non-trivial proofs.

Summary. This is an impressive Habilitation Thesis in every aspect. It is a very well written and complete piece of work that provides solutions to a number of central problems and key questions. As such, it makes a very substantial contribution to the area of Discrete Optimization.

Yours sincerely,

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