Thesis Topic: Fine-Grained Parameterized Approximation Algorithms and Complexity

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Thesis Description

Short summary: The goal of this thesis is to explore new approaches for dealing with NP-hard optimization problems on graphs, such as various versions of domination and coloring. Such problems are widely believed to require exponential time to solve exactly; they are also very often still hard even if one asks for an approximately optimal solution. The main plan of attack that will be studied combines two of the ideas that have so far been the most successful in attacking NP-hard problems, namely parameterized complexity (FPT algorithms) and approximation algorithms. More precisely, the goal is to develop new algorithmic techniques that lead to running times which are super-polynomial yet practical, and solution quality that is almost optimal. Along the way, the work done for this thesis will advance the fine-grained investigation of parameterized approximation questions, with the goal of determining as precisely as possible the time complexity of approximately solving various intractable optimization problems.

Scientific Context: The question of dealing with the phenomenon of NP-hardness is of central importance to the field of theoretical computer science, because NP-hard problems abound in all fields of science and engineering. Unfortunately, such problem are widely believed to be intractable (under standard assumptions such as P≠NP). The foundation upon which the topic of this thesis rests is made up of three fields of theoretical computer science which have been developed in order to deal with the phenomenon of NP-hardness: **parameterized complexity**, **approximation algorithms**, and **fine-grained complexity**. In a few words, parameterized complexity studies algorithms which have running times which are exponential in the worst case, but where the exponential function can be confined in a parameter that measures the *structure* rather than the size of the input, hence this field aims to use measures of input structure to tame NP-hardness [3]; approximation algorithms are algorithms which are guaranteed to execute efficiently but are allowed to return a solution that may be within some error margin of the true optimal [10]; while fine-grained complexity aims to pinpoint the exact time complexity function that corresponds to the best running time for solving each problem [6].

The motivation for this thesis is that for many major problems it is now known that these approaches fail, or at least that the algorithms they can offer are best possible in each respective context. This poses the question of what can be achieved via an analysis that combines ideas from all three domains, and this is a topic that has recently attracted much attention [5].

Research Plan: The research work of this thesis will advance by tackling concrete optimization problems on graphs for which complexity lower bounds are known in both the parameterized and approximation setting. We will focus on situations where the "parameter" that measures the input structure is a structural graph measure, such as treewidth [2]. This line of research builds on a series of recent works which attack graph problems with applications in various fields, such as communication networks [1], AI [4], and algorithmic game theory [9]. The goal is to start from individual problems and gradually build into a toolbox of standard techniques that will be useful for developing parameterized approximation algorithms in general [7]. We will also incorporate into our thinking fine-grained questions, and work on computational complexity lower bounds that rely on more advanced assumptions, such as the ETH and SETH [8].

Position Description and Research Environment

The successful candidate will work on a thesis supervised by Michael Lampis, as a member of LAMSADE, Université Paris-Dauphine. LAMSADE, a CNRS lab attached to Dauphine, is a world-class research center

in theoretical computer science, with a vibrant and international research environment. Université Paris-Dauphine is one of the leading universities in Paris, located in the 16th district, a few minutes away from the Arc de Triomphe.

She/he will be offered a competitive 3-year fellowship, through which she/he will be hired as a full-time temporary employee of the university. This entitles her/him to all basic benefits given to French public employees (such as health insurance). Net salary is expected to be around 1700 Euros/month. A light teaching load (such as, for example tutoring programming labs) is possible, with a salary complement.

Candidate Profile

The ideal candidate for this thesis topic will have:

- A Master's (or equivalent) degree in Computer Science or a related field, such as applied mathematics
- Strong skills in at least one of the following topics: discrete algorithms, computational complexity, graph theory.
- Good communication skills in spoken and written English.
- **Above all** a strong interest in dealing with fun but challenging algorithmic problems on graphs.

An ability to speak French is a plus, but is **not** required.
Interested candidates are invited to send informal inquiries to Michael Lampis `michail.lampis@dauphine.fr` before submitting a full application.

References

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