Approximation hierarchies for graph parameters

This PhD position is funded by the Marie Curie program of European Union through the innovative training network (ITN) POEMA on polynomial optimization.

More info and positions at https://easychair.org/cfp/POEMA-19-22.
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Scientific context. Many graph problems in discrete optimization lead to hard instances of polynomial optimization problems and their non-commutative analogues arise naturally in the study of non-local games in quantum information, when allowing matrices (of arbitrary size) instead of scalar variables. Typical such hard discrete optimization problems include finding minimum graph colorings, maximum cliques and the Shannon capacity of a graph. A related combinatorial problem that can be captured using polynomial optimization is bounding the size of the matrices arising in factorizations problems, such as nonnegative and completely positive factorizations (the commutative case) and (completely) positive semidefinite factorizations (the non-commutative case). The aim of this project is to investigate the power of real algebraic and moment based hierarchies for designing tractable approximations to these combinatorial problems. Examples of questions that may be addressed include:
• Find separations between classical and quantum graph parameters and identify new classes of graphs allowing efficient computation.
• Investigate whether a recent algebraic reformulation for the Shannon capacity can be exploited to derive new tractable approximations.
• Matrix factorization ranks are used to model quantum entanglement and whether convex polytopes allow compact higher dimensional representations; explore techniques to make the computation of the bounds obtained via these hierarchies more efficient.

Working Context. The PhD candidate will be hosted by the research group *Networks and Optimization* at CWI (Centrum Wiskunde & Informatica). CWI is the Dutch national research institute for mathematics and computer science, located in Amsterdam. The group is internationally recognized for its expertise in algorithmic, algebraic and geometric methods for discrete and continuous optimization. The group, and CWI at large, hosts international students, postdocs and senior researchers in a nice and stimulating working environment. Next to possible collaborations with other CWI groups, the candidate will also benefit from exposure to applications in quantum information within QuSoft, the Dutch research center for quantum software in Amsterdam. In addition the candidate will be able to collaborate with POEMA partners (Etienne de Klerk) at the University of Tilburg and to follow courses e.g. via the national MasterMath and LNMB programs.

Planned secondments. The PhD candidate will have a research stay at at the University of Konstanz (Markus Schweighofer) and with IBM Research, Dublin, Ireland (Martin Mevissen).

Required Skills. Motivated candidates should hold at the date of recruitment a Master's degree, in Mathematics (preferably), Computer Science or Engineering. The applicant should have a solid mathematical background, with expertise and taste in several topics including optimization, discrete mathematics, real algebraic geometry and functional analysis. Good programming skills are also a plus. The candidate should have good communication skills and be fluent in English. Interested candidates are kindly asked to send an e-mail with "POEMA candidate" in the title, and the application to M.Laurent@cwi.nl and to also submit their documents at https://easychair.org/cfp/POEMA-19-22.