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Quantum computing, norms and polynomials

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Abstract

In this thesis, *Quantum computing, norms, and polynomials*, we investigate the interplay between quantum mechanics, complexity theory, and functional analysis, three central areas of physics, computer science, and mathematics, respectively. The unifying theme throughout the thesis is the dynamic exchange between quantum computing and functional analysis: we explore new applications of functional inequalities in quantum computing, and, in the process, establish novel results in functional analysis itself.

In the first part, we study quantum query algorithms through their correspondence with completely bounded polynomials, as established in earlier work. We begin by revisiting this correspondence, extending it, and presenting it in a new form. Building on this foundation, we draw an analogy between quantum query algorithms and the Grothendieck inequality. Finally, we conclude this part by employing completely bounded polynomials to solve a special case of one of the main open problems in quantum query complexity, the Aaronson–Ambainis conjecture.

In the second part, we turn to quantum learning theory, which seeks to determine how much information must be extracted from a quantum system to fully characterize it. We begin by applying existing versions of the Bohnenblust–Hille inequalities and deriving new ones to obtain results in the learning of low-degree quantum objects. We conclude by presenting some of the first results in the emerging area of Hamiltonian testing and learning.

We also include a third part, as a bonus, where we gather three new proofs, that we find elegant and concise, of known results related to the analysis of Boolean functions.