Qubits, completeness, and contextuality: A new approach to foundations of quantum information

Jan-Åke Larsson
Department of Electrical Engineering, Linköping University
581 83 Linköping, SWEDEN

Abstract

The usual explanation of the quantum computing speedup is parallel calculation, inserting a superposition of all possible input values into the computation. The picture painted is that the machine performs a calculation for every input, perhaps in multiple parallell worlds, and then combines the outcomes of each individual calculation by interference to obtain the desired answer. This explanation has become standard, but does not give any guidance on how to identify new mathematical problems that could be solved, and how to design algorithms to solve them. New developments seem to need another explanatory model.

An alternative is tracing the calculation in phase space, a standard tool in classical mechanics but more challenging to use in the quantum realm. The reason is that the Liouville distribution, the probability distribution over classical phase space, becomes the Wigner function in quantum mechanics, a quasi-probability distribution that is not always positive. A negative Wigner function has been linked to presence of quantum contextuality, a behavior only seen in quantum systems.

This presentation will introduce a description of the phase space of a restriction of quantum mechanics, that generates a positive distribution but still reproduces the contextual behavior of quantum systems. The description is Einstein-complete, but distinct from Bohmian mechanics. We will briefly see how this can be used to give a better explanation of the quantum speedup, but also use this new description as a tool for reasoning about more generic interpretational issues within the foundations of quantum mechanics.

Biography

Jan-Åke Larsson is Professor and Head of department at the Department of Electrical Engineering at Linköping University. He has published about 80 papers, most of which on the foundations of quantum mechanics, especially on violations of local realism and noncontextual realism, an example is that he contributed to the statistical analysis on the measurement data and the loophole analysis of the 2015 loophole-free Bell inequality violation in the Vienna group. More recently he has turned his interest to the speedup of quantum computation, and its possible causes.