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Title: Programmable quantum processors: equivalence and learning

Abstrakt: In the first part of the work, the equivalence of quantum deterministic and probabilistic processors was investigated. A programmable quantum processor is a device able to transform input data states in a desired way. Deterministic equivalence as well as three types of probabilistic equivalences - strong, weak, and structural - were defined. Necessary and sufficient conditions for deterministic and structural equivalence of unitarily related processors were discovered. Equivalence of deterministic SWAP processor for two-dimensional data and two-dimensional program space was completely solved. It was found that spans of operators of structurally equivalent processors are identical. Relations between types of individual equivalences were also examined. In the second part, robustness of probabilistic storing and retrieval device (PSAR), originally optimized for implementing a phase gate, to noise was examined - specifically to depolarization and phase damping. In the case of a depolarizing channel mixed with a unitary channel, the device implements noisy channel with the probability that decreases with an increasing number of times the given channel is applied. In the case of the phase damping channel, the device implements noisy channel with the same probability as the original PSAR device optimized for phase gate. Concrete implementations - through the Vidal-Masanes-Cirac scheme and virtual qudit - were examined. Vidal-Masanes-Cirac gives the same result for both noisy channels which is better than the result from PSAR. Implementation through virtual qudit for depolarization yields worse probability of successful measurement than Vidal-Masanes-Cirac. However, it is still better than the probability for PSAR. Probability of successful measurement obtained for phase damping implemented through virtual qudit is the same as for Vidal-Masanes-Cirac and PSAR.

V prvej časti práce bola skúmaná ekvivalencia kvantových deterministických a pravdepodobnostných procesorov. Programovateľný kvantový procesor je zariadenie, ktoré je schopné zmeniť vstupný dátový stav želaným spôsobom. Bola definovaná deterministická a tri typy pravdepodobnostnej (silná, slabá a štruktúrna) ekvivalencie. Boli objavené nevyhnutné a postačujúce podmienky pre deterministickú a štruktúrnu ekvivalenciu unitárne zviazaných procesorov. Ekvivalencia deterministického SWAP procesora pre dvojdimenzionálny dátový a dvojdimenzionálny programový priestor bola kompletne vyriešená. Bolo zistené, že spany operátorov štruktúrne ekvivalentných procesorov sú identické. Vzťahy medzi rôznymi typmi ekvivalencií boli takisto preskúmané. V druhej časti bola preskúmaná odolnosť pravdepodobnostného úložného a získavacieho zariadenia (PÚAZ), ktoré bolo pôvodne optimalizované pre implementáciu fázového hradla, voči šumu. Konkrétne voči depolarizácii a fázovému tlmeniu. V prípade depolarizačného kanála zmiešaného s unitárnym kanálom, zariadenie implementuje zašumený kanál s klesajúcou pravdepodobnosťou vzhľadom k rastúcemu počtu použití daného kanálu. V prípade fázového tlmenia, zariadenie implementuje zašumený kanál s rovnakou pravdepodobnosťou ako originálne PÚAZ optimalizované pre fázového hradlo. Konkrétne implementácie - cez Vidalovu-Masanesovu-Cirac-ovu schému a virtuálny qudit - boli tiež preskúmané. Vidal-Masanes-Cirac dáva rovnaké výsledky pre oba zašumené kanály, ktoré sú zároveň lepšie ako výsledky z PÚAZ. Implementácia depolarizačného kanála pomocou virtuálneho quditu prináša zhoršenú pravdepodobnosť úspešného merania v porovnaní s Vidalom-Masanesom-Ciracom. Avšak, je stále lepšia ako v prípade PÚAZ. Pravdepodobnosť úspešného merania pre fázové tlmenie implementované pomocou virtuálneho quditu je rovnaká ako pre Vidalovu-Masanesovu-Ciracovu schému a PÚAZ.

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