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A Dynamic Programming Based Graph Traversal Approach for Efficient Implementation of Nearest Neighbor Architecture in 2D

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Sneha Lahiri ; Megha Kesh ; Rupsa Mandal ; Anirban Bhattacharjee ; Sovan Bhattacharya ; Dola Sinha **All Authors**

Abstract:
In the fascinating realm of quantum circuit design, tackling the intricacies of swap gate insertion presents a host of challenges. Among these, the prominent issue of the... **View more**

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Abstract:
In the fascinating realm of quantum circuit design, tackling the intricacies of swap gate insertion presents a host of challenges. Among these, the prominent issue of the nearest neighbor condition emerges as a pivotal hurdle. This constraint not only shapes the layout and connectivity of the quantum circuit but also amplifies the complexity of orchestrating efficient quantum computations. While navigating the Quantum Realm, unraveling the overhead conundrum in swap Gate insertion, motivated us to propose an efficient 2D transformation scheme for NN quantum circuit realization with a primary objective of forming efficient NN structures while minimizing SWAP usage. The design phase involves the introduction of a new parameter to calculate qubit interactions in the circuit. We then employ a dynamic graph-based algorithm to determine the qubit interaction order. Finally, the resultant order is placed on the suitable grid to calculate the number of SWAP gates required. Our approach is extensively tested with various benchmarks, and it outperforms some state-of-the-art design works. In addition to this work, we also have shown how this NN designs can be transformed into Clifford +T based NN compliant architecture to get fault-tolerant property.

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Sneha Lahiri
Dr. B.C. Roy Engineering College, INDIA

Megha Kesh
Dr. B.C. Roy Engineering College, INDIA

Rupsa Mandal
Dr. B.C. Roy Engineering College, INDIA

Anirban Bhattacharjee
The LNM Institute of Information Technology, Jaipur, INDIA

Sovan Bhattacharya
Dr. B.C. Roy Engineering College, INDIA
National Institute of Technology, Durgapur, INDIA

Dola Sinha
Dr. B.C. Roy Engineering College, INDIA
Indian Institute of Technology, Dhanbad, INDIA

Chandan Bandyopadhyay
Dr. B.C. Roy Engineering College, INDIA
University of Bremen, GERMANY

Laxmidhar Biswal
International Institute of Information Technology, Bhubaneswar, INDIA

Robert Wille
Technical University of Munich, GERMANY

Rolf Drechsler
University of Bremen, GERMANY

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I. Introduction

Over the past few decades, quantum computing has emerged as a captivating frontier in the realm of computational technologies, promising to revolutionize the way we solve complex problems that lie beyond the capabilities of classical computers. One of the key challenges in harnessing the power of quantum computing lies in efficiently designing quantum circuits that adhere to the constraints of physical quantum systems. The exploration of nearest-neighbor (NN) interactions, where qubits are limited to communicate with their adjacent neighbors in quantum circuits, has unfolded across two distinct architectures: one-dimensional (1D) [25], two-dimensional (2D) [24] and three-dimensional (3D) layouts [20]. In the realm of 1D or linear nearest neighbor (LNN)