Software Development for a Full-stack Quantum Computer

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1 INTRODUCTION

Quantum computing (QC) is getting huge attention due to its strong potential for significant computational advantages over classical digital computers, *e.g.*, the parallel efficiency that can be naturally driven by the superposition property of quantum bits (qubits) [2]. Being well-represented with the IBM Quantum in the United States [1], fully programmable circuit-based quantum computers are already available via cloud-based services. The European Union is putting massive effort in developing quantum computers through the European Quantum Initiative program that has been launched since 2018 [3]. Recognizing the promise of QC for revolutionization of high performance computing, the Republic of Korea (ROK) have also participated in the race to develop a full-stack gate-based quantum computer under the support of the Ministry of Science and ICT. This work briefly discuss the national flagship QC project of ROK with a particular focus on the software development that is being carried by the Korea Institute of Science and Technology Information (KISTI).

2 DEVELOPMENT OF A 50-QUBIT QUANTUM COMPUTER: SOFTWARE FRAMEWORK

Having been launched in June 2022, the QC project in ROK aims to develop a full-stack circuit-based 50-qubit quantum computer where qubits are encoded to electron charges in Josephson junction (JJ) arrays [6], and is carried by a research consortium consisting of the four institutes (Figure 1(a)): the Korea Research Institute of Standards and Science (KRISS), Sungkyunkwan University (SKKU), Ulsan National Institute of Science & Technology (UNIST), and KISTI. Here, superconductor-based JJ arrays are fabricated by SKKU and UNIST. KRISS integrates physical qubits into a computing system and designs qubit controls. KISTI develops software components needed to serve computing hardware and conducts theoretical researches with classical simulations of quantum circuits.

Figure 1(b) illustrates software components and a workflow of the service framework that we are developing. The Q-Circuit Studio in the **Web Portal** box is a web-based python programming interface via which users select their preferred backend resources (a circuit simulator installed in a supercomputer or a QC hardware (Q-Emulator or Q-Device in the **Resource** box)). The Programming Service in the **Service Framework** box is presented to each user through a container, being associated with the Account Service (authentication), the Data Service (job-data management), and the Resource Service (resource management) component. The Q-Emulator is based on the PENNYLANE SDK [5], and is under code-modernization to enable large-scale circuit simulations with MPI processes. As an application R&D, the practicality of variational quantum algorithms is being investigated for tight-binding simulations of semiconductor structures [4].

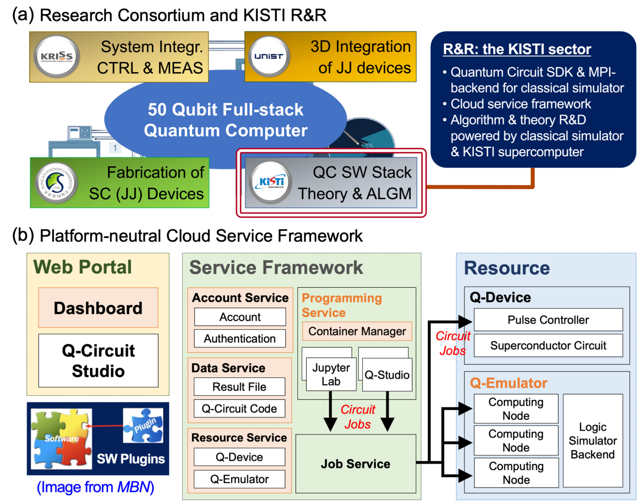

Figure 1: (a) The research consortium working on implementation of a full-stack quantum computer. KISTI develops the software framework for a cloud-based service of computing resources, and also studies the practicality of variational quantum algorithms for electronic structure simulations of realistically sized semiconductor devices. (b) An illustration showing software components and a workflow of the service framework that is currently being developed.

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