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1st Workshop on Quantum Software Architecture (QSA)

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I. Workshop Theme

Quantum computing is becoming real: Several vendors offer quantum computers in the cloud or on premise, companies invest to become familiar with this technology and its potentials, several software companies build corresponding software tools, and many consulting companies offer services to build solutions. However, software to be run on a quantum computer is quite different from software for classical computers. Thus, the current state of the art is that solutions are hand-crafted in an ad-hoc manner.

Consequently, a solid foundation for building quantum software is missing. For example, today's successful applications are hybrid applications consisting of both, classical and quantum parts, that are iterating to reduce the quantum resources needed. Thus, a first architectural style is appearing. From this point of view, several major questions arise: Which other architectural styles seem to become successful (today and in future when quantum computers mature)? Which existing styles can successfully be applied? Also first patterns for building quantum software are appearing: How can these be evolved into a pattern language? Which existing pattern languages can contribute and be combined with a pattern language for quantum software?

Since today's quantum computers are used to solve individual problems and one at a time, architectural problems about non-functional properties are arising. For example, how can scalability be achieved? And what about high availability? Security and privacy are further issues.

Many today's and future applications will benefit from quantum technologies because a lot of intractable problems (in the sense of complexity classes) may realize up to exponential speedups on quantum computers. How can today's applications be re-factored into hybrid quantum software?

Thus, the workshop's topics of interest include – but are not limited to – the following themes: (i) architecture styles for hybrid quantum software, (ii) quantum and classical computation integration, (iii) functional and non-functional requirements for quantum software architectures, (iv) best practices in quantum software engineering, and (v) testing and quality measuring of solutions (KPIs).

II. Workshop Goals

The goal of the 1st Workshop on Quantum Software Architecture was to bring together researchers and practitioners from different areas of quantum computing and (classical) software architecture to strengthen the quantum software community and discuss architectural styles and best practices of quantum software, including interoperability, scalability, portability, and required integration techniques for hybrid quantum software.

The workshop also focused on other aspects of the quantum software development lifecycle, among others, to investigate ways to properly test quantum software, to discuss migration paths from proof-of-concept software to productive systems, to automate the deployment of hybrid quantum software, and to elaborate KPIs for measuring the quality of solutions.

Therefore, the workshop offered a platform for the presentation of novel scientific ideas as well as practical experiences and enabled the exchange with experts from different areas of software architecture as well as quantum computing.

III. Workshop Contributions

Based on a single-blind, peer-review process with at least three reviewers per paper, four papers were selected to become part of this proceedings. The first article extends a quantum computing pattern language with further data encoding patterns. The intuition behind is to understand the (potentially severe) consequences of particular data encoding as the data loading routine itself may have a complexity that in some cases diminishes a potential quantum speedup. The paper is followed by a contribution on modeling for quantum error mitigation. This systematic approach enables the representation of cause-effect relations as well as the evaluation of methods or combinations thereof with respect to a selection of relevant criteria.

The third article is focused on presenting a hybrid quantum-classical neural network for the classification of finance and MNIST data. Compared to a pure classical neural network the author reports advantages regarding some performance measures, but also problems regarding overfitting on the datasets. The final paper is a contribution on a composable programming scheme for hybrid quantum-classical algorithms and hybrid workflows for quantum simulations. The idea is to construct and use an expressive set of data structures and methods that enable the development of complex hybrid applications.

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