EFFICIENCY OF APPLICATION OF VARIATION QUANTUM ALGORITHMS

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Abstract. *The main feature of all algorithms of the type of variational quantum algorithms is the calculation of the cost function that must be minimized. In optimization and logistics and efficient solution problems, the cost function is simply the quantity to be minimized and must include constraints. In quantum chemistry, the cost function is often the energy of the molecule under study. Many machine learning problems require the optimization of a loss function that measures the quality of the prediction. In the variational quantum algorithm, the cost function is mapped to a quantum circuit with adjustable parameters. Designing a quantum circuit for a given cost function is challenging, but several existing circuit architectures are being improved. This paper explores "Problem-Dependent" architectures and focuses on improving problem-specific architectures based on quantum algorithms.*
Keywords: *quantum, variational quantum algorithms, artificial intelligence, machine learning, noisy intermediate-scale quantum.*

Introduction. Nowadays, simulating complex quantum systems or solving large-scale linear algebra problems is very difficult for very high-performance classical computers. Quantum computers and algorithms make it possible to obtain a solution with high accuracy.Variational quantum algorithms, which use a classical optimizer to train a parameterized quantum circuit, are emerging as an improved technology to address these limitations. Variational quantum algorithms have been proposed for nearly all applications of quantum computers, and they are becoming increasingly effective in finding the best solution to achieve quantum dominance. However, challenges remain, including the trainability, accuracy, and efficiency of variational quantum algorithms. This research paper reviews the field of variational quantum algorithms, highlighting the exciting prospects of using them to achieve quantum supremacy. Testing quantum algorithms and identifying new problems with artificial intelligence, which quantum computers take advantage of, is becoming increasingly sophisticated today.

Nowadays, variational quantum algorithms are used to perform complex mathematical calculations and improve the speed, efficiency and accuracy of artificial intelligence. This field allows quantum computing to be used in a variety of processes, including the use of artificial intelligence to construct a mathematical model for any process. Quantum computing holds promise for a number of applications that have fueled decades of research to create the necessary physical devices. For example, quantum algorithms can factor numbers, simulate quantum systems, or solve systems of linear equations with exponential speed compared to classical methods [1].

The advent and development of quantum cloud computing

Initially, in 2016, access to the first cloud-based quantum computer was made possible, but this too was plagued by noise and qubit limitations that hindered the full implementation of the aforementioned quantum algorithms. This has led to the creation of noisy medium-scale quantum computers, and many new ideas about how many fields can be advanced with the new devices.

Today's state-of-the-art devices range in size from 100 to 200 qubits, making it possible to achieve "quantum supremacy". It is distinguished by the fact that it outperforms the best classical supercomputer for performing complex mathematical tasks that require a lot of time to solve [2].

Nevertheless, the real operating principle of quantum computers - speeding up applications, which is often called the quantum advantage - serves as an important motivation for processes that have not yet been implemented [3]. In addition, the emergence of fault-tolerant quantum computers is accelerating the development of society. Thus, it was possible to simulate complex physical, biological and chemical processes based on quantum algorithms [4]. This suggests that any strategy is required to account for the finite number of qubits, the finite connectivity of qubits, and the consistent and unpredictable errors that limit the depth of the quantum chain [5].

Discussion

A challenge for variational quantum algorithms is that the cost function may have "non-increasing plateaus" that cannot be easily solved.

There are two approaches to overcoming non-incremental plateaus. First, the schemes used must be carefully designed. For example, "hardware efficient" circuits are optimized for various quantum devices. Second, the initial parameters used should not be chosen randomly. based on these two parameters, in 2021, Alejandro et al. showed significant improvements by studying the successful parameter structure from a set of related problems [6]. Proper selection of initial parameters is particularly useful for optimization problems that need to be solved iteratively, such as real-time traffic flow optimization. Arthur Pesah then analyzed quantum convolutional neural networks (QCNNs) and was able to determine that they do not exhibit exponential plateaus [7].

Vartiaosion quantum algorithms have also been used in machine learning with some effective results and we can categorize their uses into the following [8]. Use cases include:

classifiers trained to predict each input channel performance of quantum data compression autoencoders;

the study of probability distributions that generate a given set of data based on generative models;

able to work with two neural networks through generative adversarial networks, where a generator and a discriminator can work together;

the discriminator is trained to recognize the image and the generator produces fake images to test the discriminator to see if they are real;

able to work effectively in quantum neural networks where each node in the neural network is replaced by a qubit;

accelerating the need for rapid data processing in data science using artificial intelligence algorithms;

There are three challenges that must be met in order to work effectively in these above cases: invariant i.e. barren plateaus, local minimization, and the integration of quantum and classical computers.

Nevertheless, the actual operating principle of quantum computers - speeding up applications, often referred to as quantum supremacy - serves as an important impetus for processes that have yet to be realized. In addition, the emergence of fault-tolerant quantum computers is accelerating the development of society. Thus, the main technological question arises, that is, how to properly use today's SCM devices to achieve quantum supremacy. In doing so, any strategy must take into account the limited number of qubits, the limited connectivity of qubits, and coherent and non-coherent errors that limit the depth of the quantum chain.

Development of the scheme of dependence of quantum algorithms on domains

Another major problem is that quantum devices must be tightly coupled to a classical device, so they don't waste time sending messages over and over again. IBM's quantum roadmap anticipates this demand and envisions quantum devices seamlessly interwoven with classical CPUs and GPUs. Digital Catapult is working with leading UK quantum companies including BT, ORCA Computing and Riverlane to build a quantum data center of the future that will help solve this problem [9].

Nvida recently announced Quantum Optimized Device Architecture (QODA), an "open programming model aimed at making hybrid quantum-classical programming more accessible," and a series of collaborations with quantum hardware providers.

Variational quantum algorithms have emerged as a leading strategy for achieving quantum dominance in SCM devices. Addressing all the constraints imposed by NISQ computers with a single strategy requires an optimization or learning-based approach, specifically using variational quantum algorithms. VKAs are, of course, the quantum analogue of highly successful machine learning methods such as neural networks [10]. In addition, VKAs use a classical optimization toolbox because they use parameterized quantum circuits to run on a quantum computer and then pass parameter optimization to a classical optimizer process. This approach has the added advantage of keeping the depth of the quantum circuit shallow and thus mitigating noise, unlike quantum algorithms designed for fault-tolerant circuits.

Variational quantum algorithms have been considered for many applications, as shown in Figure 1, and research covers all applications for quantum computers. Although they may be the key to near-term quantum supremacy, VKAs still face significant challenges, including their training, accuracy, and efficiency.

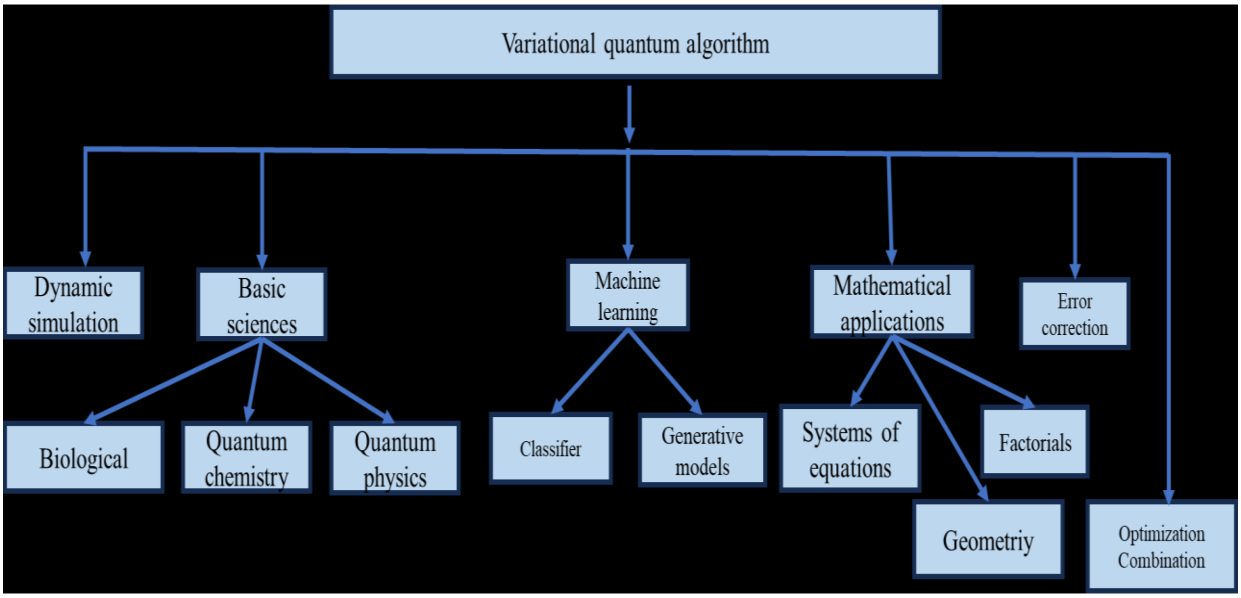

Fig 1. Scheme of application of variational quantum algorithms in fields.

However, it is possible to work under the assumption of perfect training and global optimality in the cost landscape may require whether such noise is robust. This is REF's approach, which shows that VKAs for quantum compilation exhibit a special type of noise robustness known as optimal parameter robustness. The optimal parameter robustness corresponds to the global minimum of the noisy cost function corresponding to the global minimum of the noise-free cost function.

Results

Based on the above considerations, there is a demand to develop a unique hybrid quantum algorithm for many fields. Based on this approach, we select the necessary approaches and the necessary parameters to develop the Hybrid-classic model. Hybrid quantum-classical models are a natural extension of variational quantum algorithms, one of which is parameterized using classical (eg, neural network) and quantum algorithms, and such models may facilitate many applications in the near future (Fig. 2). Based on the above, at the same time, a hybrid scheme was formed for quantum computers to find the optimal solution for physical connections, mathematical calculations, creation of 3D shapes using neural networks.

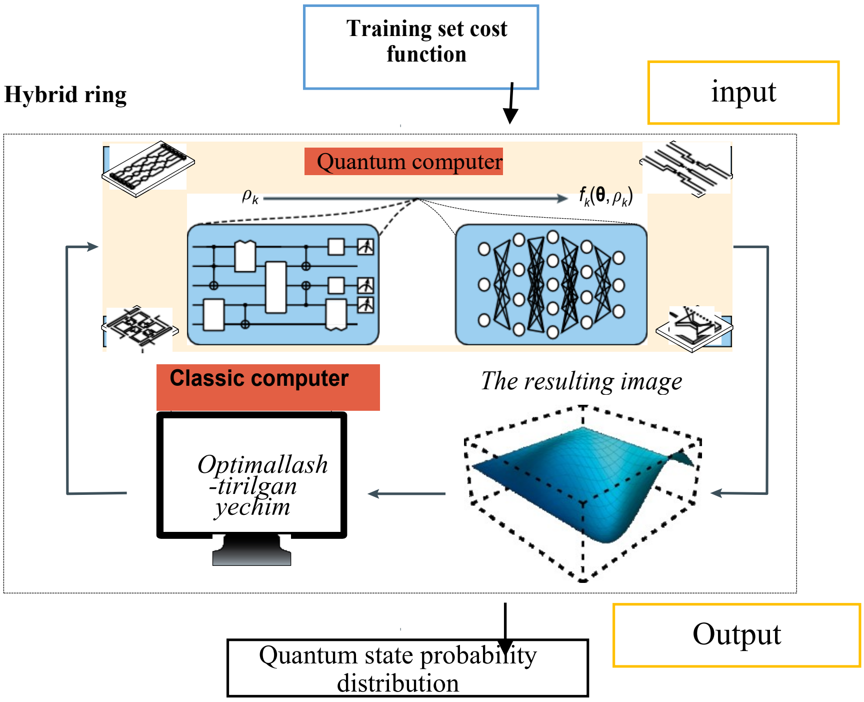

Fig.2. Hybrid Scheme of Variational Quantum Algorithm

Conclusion

In conclusion, it can be said that analytical and heuristic scale analysis of variational quantum algorithms is becoming more and more important in the pursuit of quantum supremacy. Advances in physics, chemistry, and mathematics are expected to be achieved through better methods of scaling variational quantum algorithms. These likely include gradient scaling and other scaling aspects, such as the density of local minima and the shape of the cost landscape. These fundamental results contribute to the search for quantum supremacy. Thus, the article considers various approaches to combining all the mentioned factors, quantum algorithms are used to perform efficient calculations in various fields, especially the optimization of transport and logistics problems, taking into account the initial input data.

At present, we do not know whether a quantum computer will be used commercially than a classical computer. Today, we find it very true that quantum devices can perform useful calculations more cheaply than classical computers. We base this on the promising proof of concepts we have seen and the future improvements in quantum devices and algorithms. Variational quantum algorithms, quantum annealing and photonic computers are the most promising technologies for the near future.

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