

# A Modern Survey of Quantum Programming Languages and Frameworks

## Review

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### A. Paper summary

This paper try to propose a modern survey of Quantum Computing (QC) which:

1. Summarizing various aspects of quantum computing.
2. Emphasizing the advances in quantum computing programming language and compilation.
3. Focusing on the work in the last decade.

### Content list:

#### Introduction

- Tremendous advances in QC
- Compiler and Programming language contribution
- Nowadays Quantum Programming Languages: haven't found the proper equivalent to a program statement of more traditional programming languages.
- QPLs with abstractions and semantics near or at the level of the application domain are necessary.
- Current proposed languages require further refinement before they can fully support QC algorithmic:
  1. Extremely low-level and do not leverage quantum application domain knowledge.
  2. Higher but can not offer abstractions and data types that best support correct and productive QC programming

#### Background

- High-performance application-specific accelerators, capable of making some currently-intractable problems tractable.
- Qubits, superposition, measurement, entanglement, no-cloning.
- Quantum state evolvment in time with unitary operators (program)

- Compiler find an efficient circuit that is equivalent to input matrix by decomposing it into a sequence of simpler/smaller matrices. Obstacles:
  1. The size and the structure of the matrix largely determines the number of factors.
  2. Decoherence: hard to deeper circuit and longer run time.
  3. Must-made approximation

### **Quantum Technologies**

- Decoherence problem
- Quantum Error Correction (QEC) can not totally solve the decoherence problem and resource intensive.

### **Quantum Compilation Phases**

- Typical quantum compilation flow

### **Circuit Synthesis (for unitary operators)**

- Householder: from a unitary matrix to its triangular form by  $2(n-1)$  square roots
- Deutsch: almost all  $n$ -bit gates,  $n > 2$ , can represent any computing task
- Barenco: universal unitary operations
- .....

### **Quantum Programming Languages**

- OpenQASM: users declare classical and quantum registers, and apply gates to different qubits to perform the task.
- Scaffold: raise the level of abstraction to assembly level
- Q#: extension for C#
- ProjectQ: extension for Python
- Still is a substantial semantic gap between the quantum domain and the state-of-the-art in quantum language.

### **Quantum Compiler Frameworks**

- Nowadays research has largely concentrated to extending classical imperative languages to enable the manipulation of quantum gates.

## **B. List of main strengths of the paper**

- Given out an overview of almost all aspects of Quantum Computing
- Described many vital research advances in the last decade
- Detailed concrete idea of these works

**C. List of major weaknesses of the paper**

- Without a clear outline for most sections, especially in section 5 and section 7
- Just stacking the brief summary of the mentioned works without discussing their key idea, influence, reserved problems and relationship between each other
- Did not show the evolvement of Quantum Computing and difference between long-past works and modern important works
- Did not give out the general definition of problems, basical knowledge and solution ideas in every section, which confused me when I read stacked detail of the mentioned works

**D. Overall merit**

Choices:

- A. Good paper, I will champion it
- B. OK paper, but I will not champion it
- C. Weak paper, though I will not fight strongly against it
- D. Reject

My choice: C

**E. Reviewer expertise**

Choices:

- X. I am an expert in this area
- Y. I am knowledgeable in this area, but not an expert
- Z. I am not an expert; my evaluation is that of an informed outsider

My choice: Z

**F. How much time did you spend on reviewing the paper?**

Choices:

- 1. Limited: I browsed through the paper quickly
- 2. Medium: I read through the paper but did not check the details
- 3. High: I read the paper thoroughly and carefully checked the technical details

My choice: 2

**G. Short summary of your review explaining your overall merit score.**

A survey paper should at least give out the problems of the domain it summarized, but in this paper I can not figure out what problem so much research try to address. In addition, this paper did not show me the involvement of great ideas and crucial works in Quantum Computing, stacking of paper-summary can not give me a clear overview of modern Quantum Computing advances and future working directions.

**H. Novelty**

Choices:

1. Published before or openly commercialized
2. Incremental improvement
3. New contribution
4. Surprisingly new contribution

My choice: 1

**I. Potential for impact**

Choices:

1. No impact: Will not influence other efforts
2. Limited impact: Unlikely to influence other efforts
3. Moderate impact: Will influence other efforts
4. High impact: Will have a major influence on other efforts
5. Foundational: Will open new areas of inquiry

My choice: 2

**J. Writing quality**

Choices:

1. Unacceptable
2. Need improvement
3. Adequate
4. Well-written
5. Outstanding

My choice: 2

**K. Best paper candidate**

Do you feel that the paper is on par with or better than the recent LCPC Best Papers?

Choices:

- A. Yes.
- B. No.

My choice: B

**L. Questions for authors' response**

Specific questions that could affect your accept/reject decision. Remember that the authors have limited space and must respond to all reviewers.

- What do you think as the great idea within these modern quantum computing works ?
- Is there an evolving outline of these research ?

- What are the basic concerns of modern quantum computing ?

**M. Comments to authors**

I think basic problem definition and great ideas are more important than stacking modern research works summary for a survey paper of modern quantum computing.

**N. Comments to PC****O. Declare concurrent work**

Are you working on the exact same problem as this submission and have a similar solution?

Choices:

1. No
2. Yes, work is ongoing
3. Yes, paper submitted to LCPC 2020
4. Yes, paper submitted to another venue
5. Not sure

My choice: 1

**P. Recommended reviewers for 2nd round**