Alexandria Quantum Computing Group (AleQCG): Research, Education and Community Outreach in Egypt and Africa

Ahmed Younes

Professor of Quantum Computing
Alexandria University and Alamein International University

Representative of the Arab States in IYQ2025 SC

Quantum Science and Technology across Africa

Exploring the Future of QST in Africa

June 23-27, 2025

Who are we?

- **Alexandria Quantum Computing Group (AleQCG)** has been at the forefront of quantum computing research in Egypt since 2016.
- AleQCG has started by the PhD and Master Students.
- AleQCG is currently a vibrant community of passionate individuals dedicated to advancing quantum computing knowledge, research, and applications.

Our Mission

- **Research:** We aim to drive real-world impact by promoting quantum research and its practical applications.
- **Education:** We provide workshops, seminars, and hands-on sessions to demystify quantum concepts and algorithms.
- **Innovation:** Explore cutting-edge developments in quantum software, and applications.
- **Collaboration:** Connect with like-minded peers, industry experts, and academia to foster collaboration and knowledge exchange.
- **Community Services:** Engage with the broader community through outreach programs, public lectures, and educational initiatives to raise awareness and understanding of quantum technologies.

https://scialex.org/~aleqcg/

ALEΦCG

Alexandria Quantum Computing Group (AleQCG)

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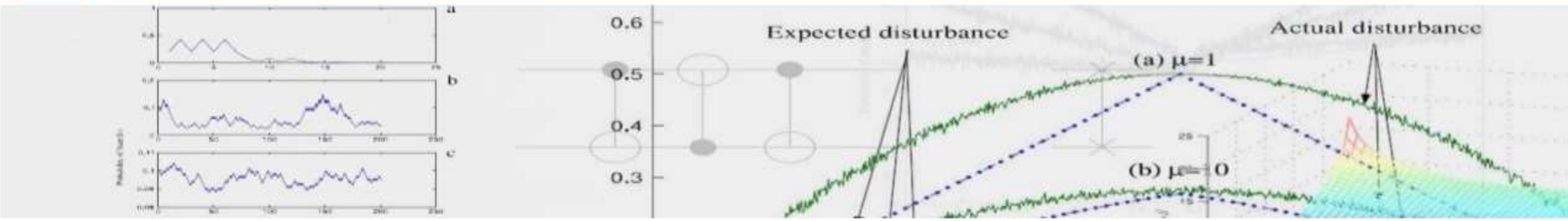
search...



Overview

AleQCG is located in Department of Mathematics and Computer Science, Faculty of Science Alexandria University and has collaboration with researchers from:

- School of Computer Science, University of Birmingham, United Kingdom.
- Computer and Information Science Department, Universiti Teknologi PETRONAS, Malaysia.
- Mathematics Department, Zewail City of Science and Technology, Egypt.
- Department of Physics, Faculty of Science, Al-Azhar University, Egypt.
- College of Computing and Information Technology, Arab Academy for Science, Technology & Maritime Transport, Egypt.
- Egypt-Japan University of Science and Technology, Egypt.
- Department of Mathematics and Computer Science, Damanhour University, Egypt.
- Department of Information Technology, Institute of Graduate Studies and Research, Alexandria University, Egypt.
- Department of Mathematics, Faculty of Education, Alexandria University.

Faculty

Prof. Ahmed Younes
Professor

Dr. Ashraf Elsayed
Associate Professor

Dr. Islam Elkabani
Assistant Professor

Dr. Shaimaa A. Elmorsy
Assistant Professor

Dr. Rasha Montaser
Assistant Professor

Dr. Mohamed Osman
Assistant Professor

Dr. Manal Samir Khawaik
Assistant Professor

Dr. Ahmed Moustafa
Assistant Professor

Dr. Doaa A. Shoieb
Assistant Professor

PhD Students

Sahar Saleh
PhD student

Taghreed Ebed
Teaching Assistant

Mohamed Shaban
PhD Student(USA)

Menna El-Masry
Teaching Assistant

Mirna Hosny
Teaching Assistant

Norhan Nasr
Teaching Assistant

Mariam Medhat
PhD Student (USA)

Sara Anwer
Teaching Assistant

Master Students

Basma Elias
Demonstrator

Doha Abd El-Fattah
Demonstrator

Esraa Ahmed
MSc Researcher

Monica Magdy
MSc Researcher

Makkah Mohamed
MSc Researcher

Ahmed Saad El Fiky
Researcher

Professtional Master Students

Mohamed Montaser
Researcher

Moataz Fayek
Researcher

Mohamed Youssef
Researcher

Ahmed M. Ellamie
Researcher

Islam Elgendy
Researcher

Mousa Ahmed Mustafa
Researcher

Muhammad Akram Shalabi
Researcher

Ola Walid Shalaby
Researcher

Omar Akram Shalabi
Researcher

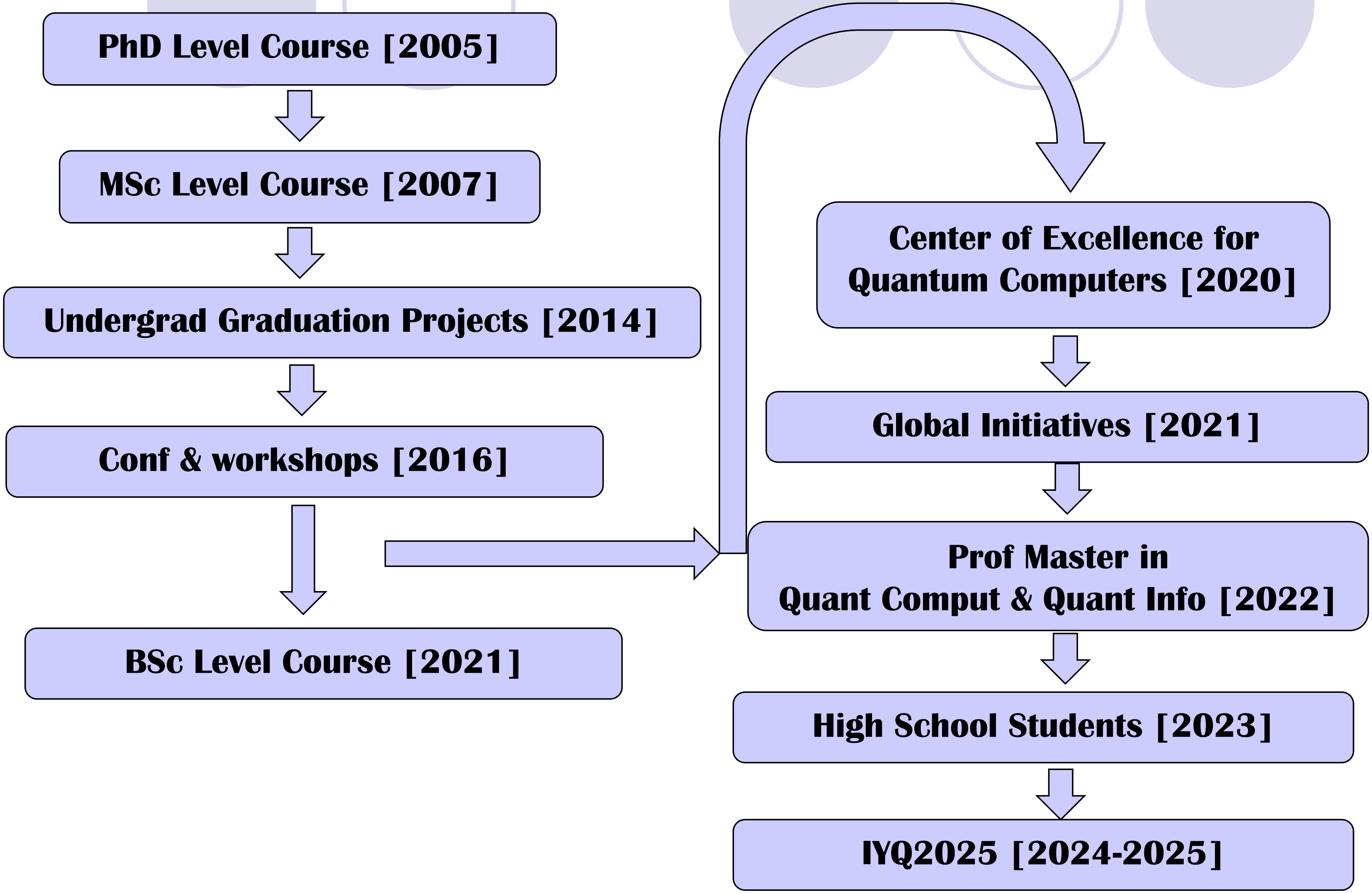
Omar Wael
Researcher

Omar Sengab
Researcher

Members of AleQCG Affiliations

- Alexandria University
- Damanhour University
- Arab Academy for Science, Technology, and Maritime Transport
- Suez Canal University
- Cairo University
- Alamein International University
- Alexandria Higher Institute of Engineering and Technology

Establishment of AleQCG



Research in AleQCG

- Quantum Search Algorithms.
- Amplitude Amplification Techniques.
- Quantum Machine Learning.
- Synthesis and Optimization of Reversible/ Quantum Circuits.
- Quantum Data Encoding.
- Quantum Image Processing.
- Quantum Cryptography.
- Quantum Logic.
- Quantum Measurements.
- Quantum dot Cellular Automata.
- Quantum Internet.
- Merging between Quantum Computing and DNA Computing.

AleQCG Focus

1. **Quantum Algorithms:** AleQCG designs novel quantum algorithms to address complex computational problems, leveraging the unique properties of quantum systems.
2. **Quantum Circuit Synthesis and Optimization:** The group conducts pioneering research in optimizing quantum and reversible circuits, ensuring efficient utilization of quantum resources.
3. **Quantum Machine Learning:** AleQCG explores the intersection of quantum computing and machine learning, aiming to unlock new capabilities through quantum-enhanced models.
4. **Quantum Cryptography:** Investigating secure communication protocols based on quantum principles, AleQCG contributes to the field of quantum-safe cryptography.

Education and Community Outreach

One day conference of Quantum Computer and Quantum Information

Faculty os Science, Alexandria University
July 26, 2016, Egypt

ALEΦCG

ALEXANDRIA UNIVERSITY

AlexU-QCSS19

Alexandria Quantum Computing Summer School, 14-20 July 2019

ALEΦCG

Alexandria One Day Conference on Quantum Computing and Quantum Information

July 2019. (AlexU-QCQIC19)

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ALEXANDRIA UNIVERSITY

CENTER OF EXCELLENCE FOR QUANTUM COMPUTERS

AlexU-QCWS21

Alexandria Quantum Computing Winter School, 1-5 February 2021

ALEΦCG

Workshop of Quantum Computer and Quantum Information, 3 February 2021

ALEXANDRIA

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جامعة الإسكندرية
ALEXANDRIA
UNIVERSITY

AlexU-QCSS19

Alexandria Quantum Computing Summer School, 14-20 July 2019

Alexandria One Day Conference on Quantum Computing and Quantum Information

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AlexU-QCWS21

Alexandria Quantum Computing Winter School, 1-5 February 2021

Workshop of Quantum Computer and Quantum Information, 3 February 2021

Invited Talks

Title:Quantum Game Theory: The Quest for Optimal Quantum Technology

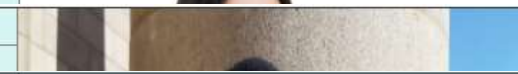
Speaker:Faisal Shah Khan

Title:An Introduction to Quantum Machine Learning.

Speaker:Amira Abbas

Title:Quantum computing in Africa.

Speaker:Farai Mazhandu



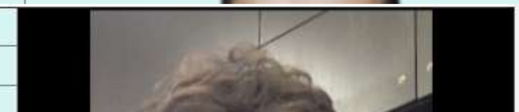
Title:Non-Classical Computing Problems: Toward Novel Type of Quantum Computing Problems

Speaker:Dr. Mohamed Zidan

Title:A Gentle Introduction to the Quantum Approximate Optimization Algorithm

Speaker:Zoltán Zimborás

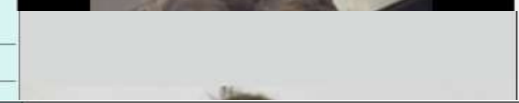
Time:1:00 PM to 1:45 PM



Title:The Application of Quantum Annelaing to Solving VRP and its Variants.

Speaker:Bio Pawel Gora

Time:3:00 PM to 3:45 PM



Title:Quantum Machine Learning with PennyLane

Speaker:Thomas Bromley

Title:“Superconducting Qubit Architecture”

Speaker:Nick bronn

Time:5:00 PM to 5:45 PM

After earning his Ph.D. in Condensed Matter Physics from the University of Illinois, supported in part by a National Science Foundation Graduate Research Fellowship, Nick joined IBM Quantum as a post-doctoral researcher in 2013.
Continuing as a Research Staff Member since 2015, he has been responsible for developing and integrating quantum hardware and deploying quantum systems over the cloud, and now focuses on enabling Qiskit on different hardware platforms, hardware-focused quantum applications, and education of the quantum community at large.

Alexandria Quantum Computing Hypatia Series

[#hypatia_aqc]

Hypatia
(born c. 350–370; died 415 AD)

https://en.wikipedia.org/wiki/Hypatia

Alexandria Quantum Computing Hypatia Series

#hypatia_aqc

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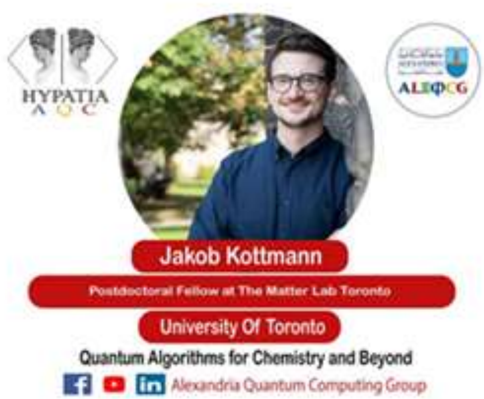

Center of Excellence for Quantum Computers, Faculty of Science, Alexandria University, 2020

جامعة الإسكندرية

ALEXANDRIA UNIVERSITY

كلية العلوم

مركز التميز في الحاسبات الكمية

CENTER OF EXCELLENCE FOR QUANTUM COMPUTERS

In Cooperation with

- Quantum Computing and Information Group, Theoretical Physics Department, Wigner Research Centre for Physics, Budapest, Hungary.
- Quantum AI Foundation, The Warsaw Quantum Computing Group, Faculty of Mathematics, Computer Science, and Mechanics, University of Warsaw, Banacha 2, 02-097 Warszawa, Poland.
- ITI – Information Technology Institute, Alexandria, Egypt.


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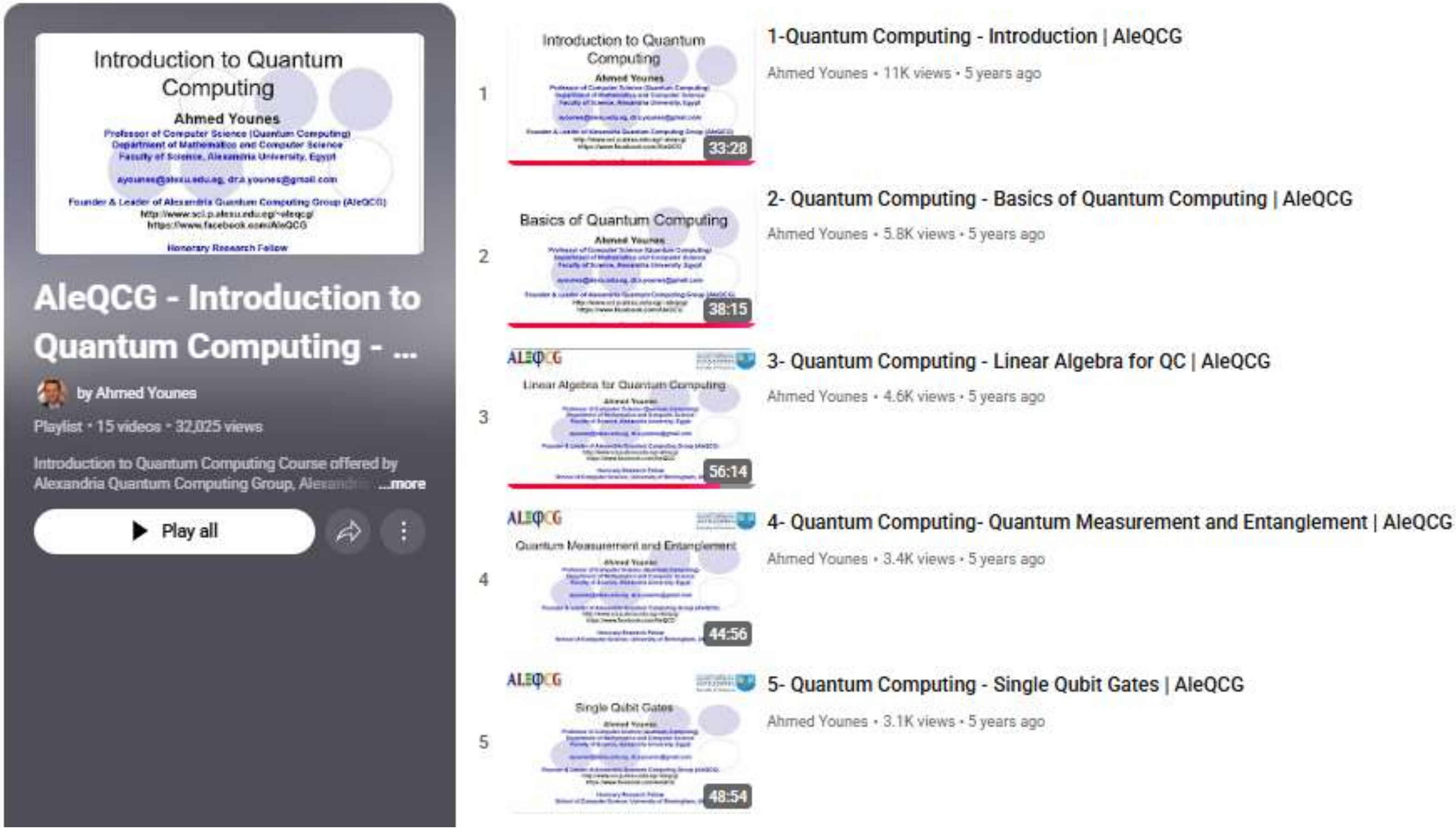
QUATUMN COMPUTERS



https://www.youtube.com/playlist?list=PLkpYqKNqc_Cud5sLg896FsnbkoQiHlkpZ

QWORLD

QCOUSINS

Egypt

Joint Institute for Nuclear Research

SCIENCE BRINGS NATIONS TOGETHER

TENNESSEE TECH

1915

أكاديمية البحث العلمي والتكنولوجيا

Academy of Scientific Research & Technology

GUC

German University in Cairo

GUC Microptics Lab.

Enabling innovative photonic systems

ScienceUp

QUANTUM AI

FOUNDATION

معهد تكنولوجيا المعلومات

Information Technology Institute (ITI)

وزارة الإتصالات وتكنولوجيا المعلومات

PRINCE OF SONGKLA UNIVERSITY

WORLD QUANTUM DAY

APRIL 14

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Wigner Research Centre for Physics

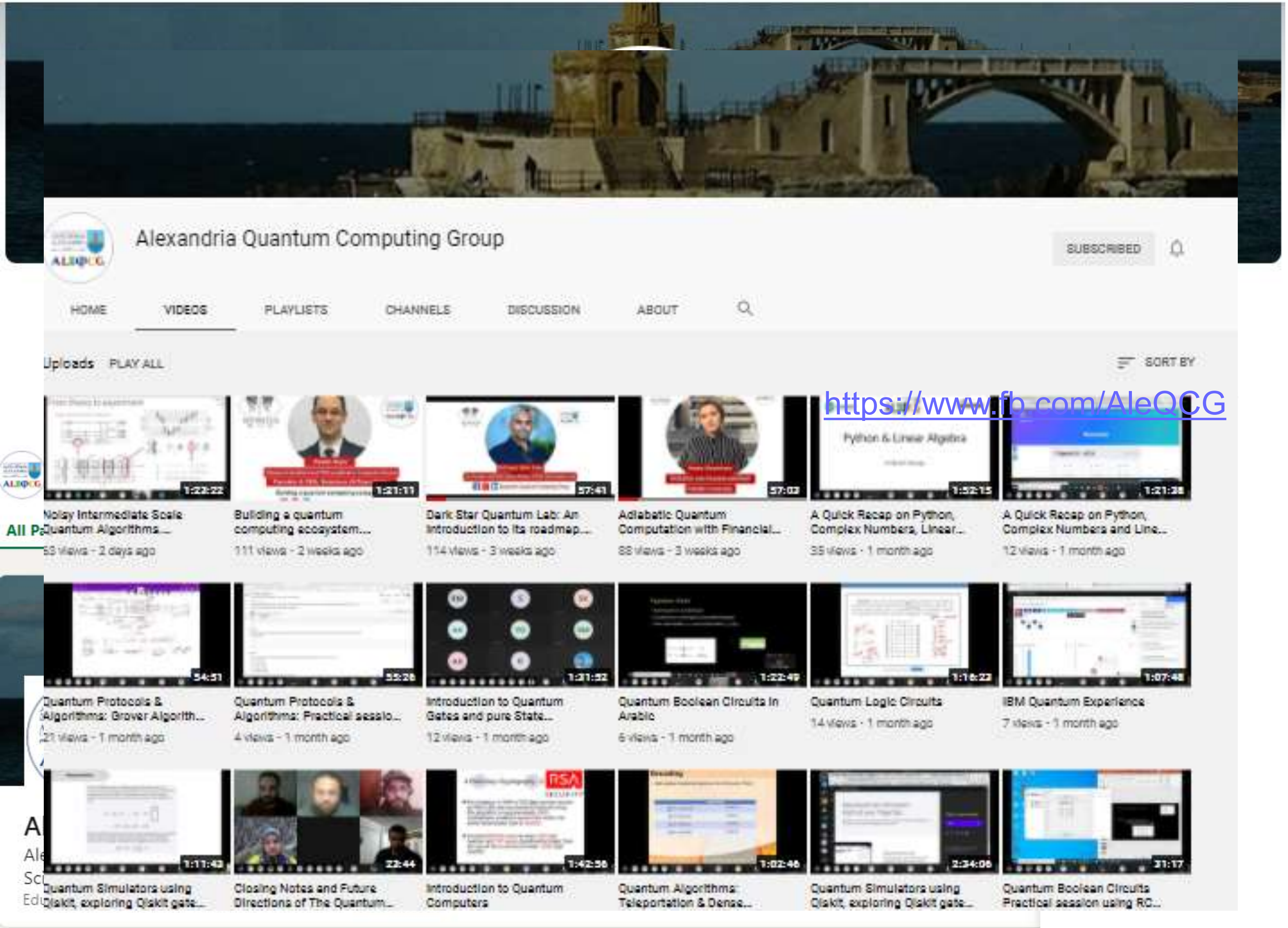
All Colors of Physics

Warsaw Quantum Computing Group

Technical University of Munich

ONE QUANTUM AFRICA

Washington DC Quantum Computing Meetup Group



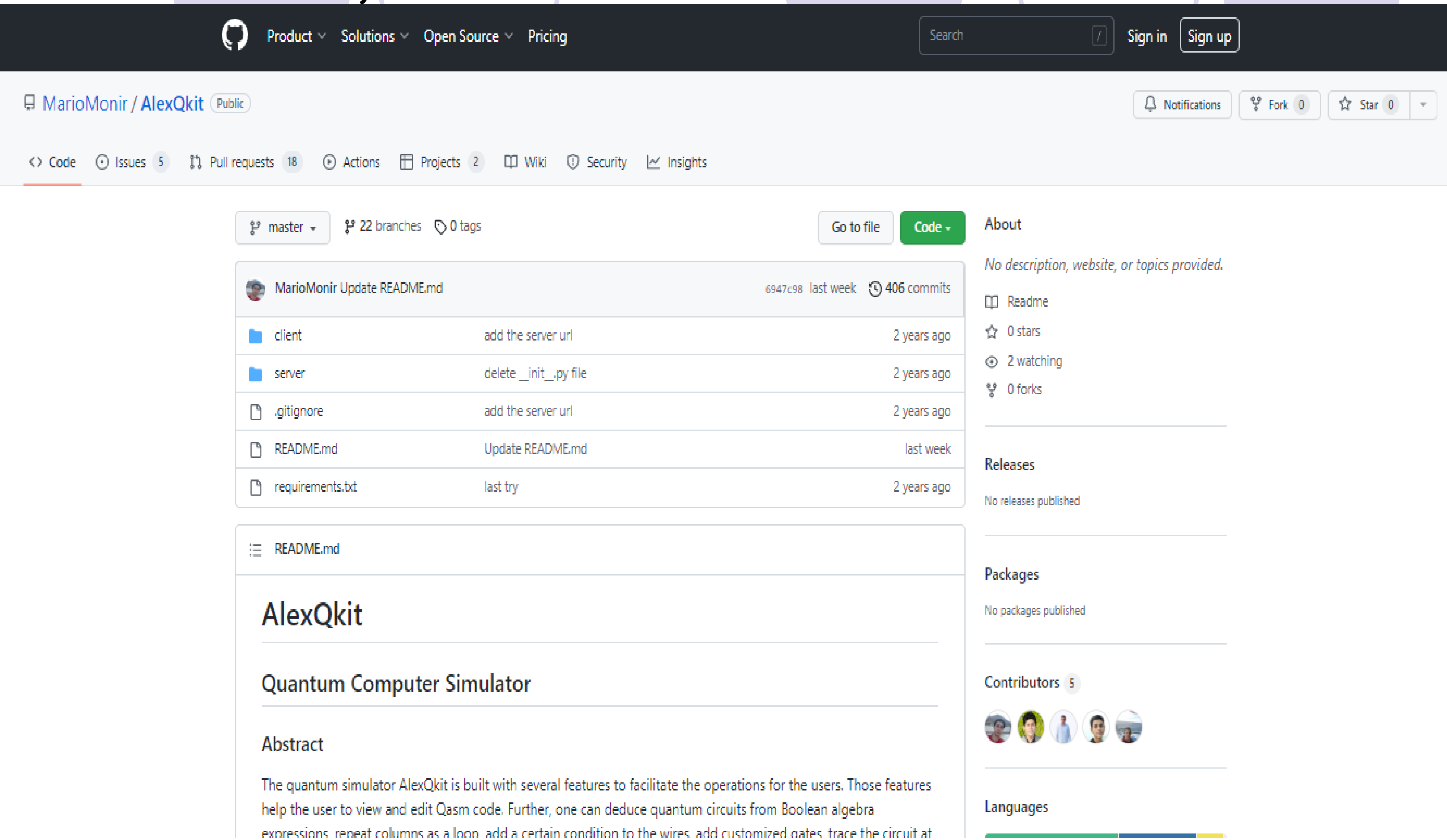
https://www.fb.com/AleQCG

Software and Simulators

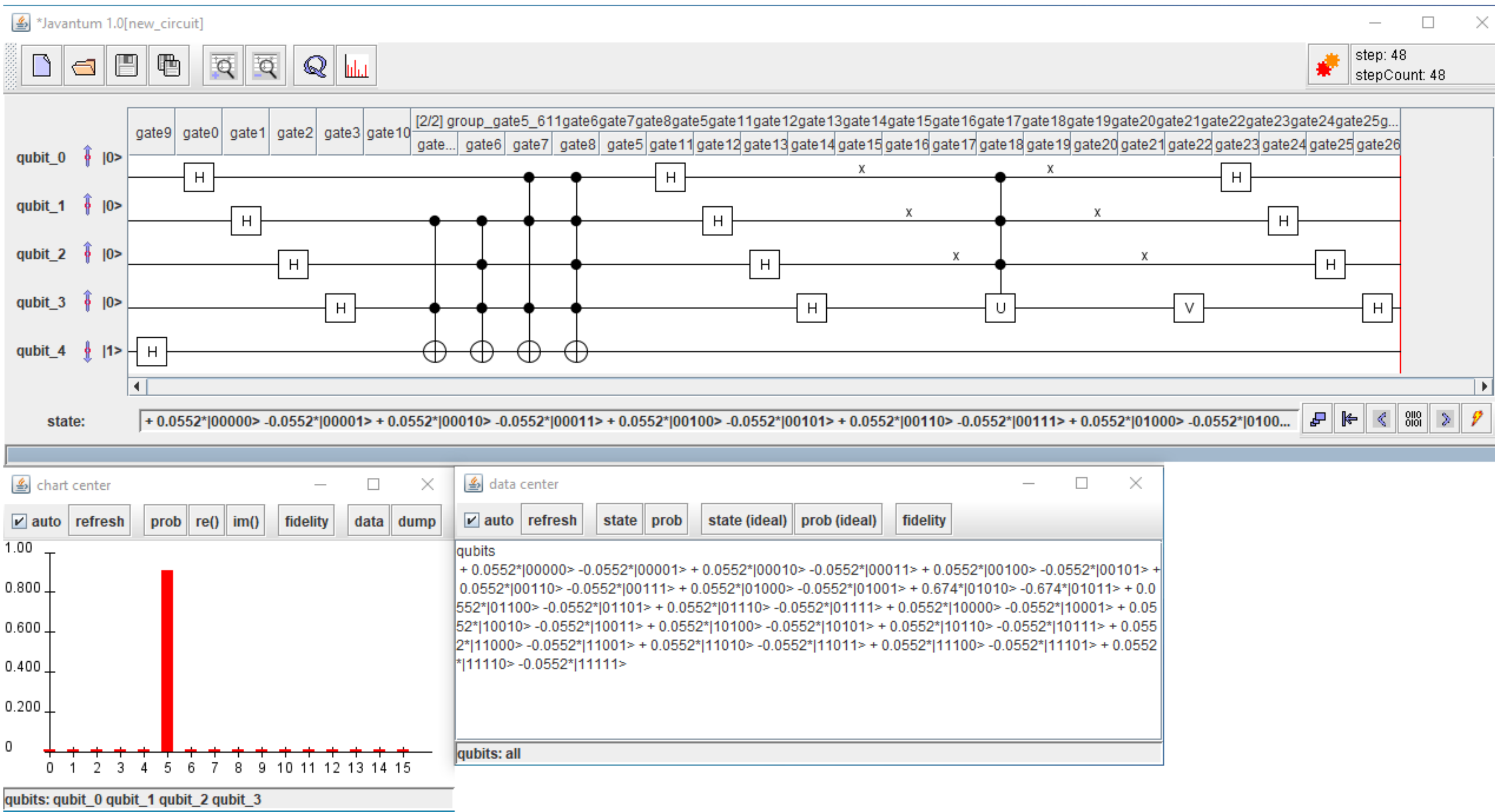
AlexQkit is an interactive quantum simulator that is used to visualize and simulate quantum computing. The quantum circuits can be exported to run on IBMQ devices.. AlexQkit has been developed as a graduation project under the supervision of Prof. Ahmed Younes and Eng. Kareem H. El-Safty in 2020 from Department of Mathematics and Computer Science, Faculty of Science, Alexandria University by Mario Monir, Freddie Samy, Mohamed Hassan, and Mohamed Hamdy.

Javantum is an interactive quantum simulator that is used to visualize and simulate quantum computing on classical computers. It is purely developed using Java 8 based on the interactive quantum computer simulator jaQuzzi 0.1 . Javantum has been developed as a graduation project from Department of Mathematics and Computer Science, Faculty of Science, Alexandria University in 2016 by Fatimah Ahmed, Yehya Beram, Muhammad Al-Alem, Muhammad Kamal, Muhammad Mahmoud, Muhammad Salah and Nayera Ali under the supervision of Dr. Ahmed Younes.

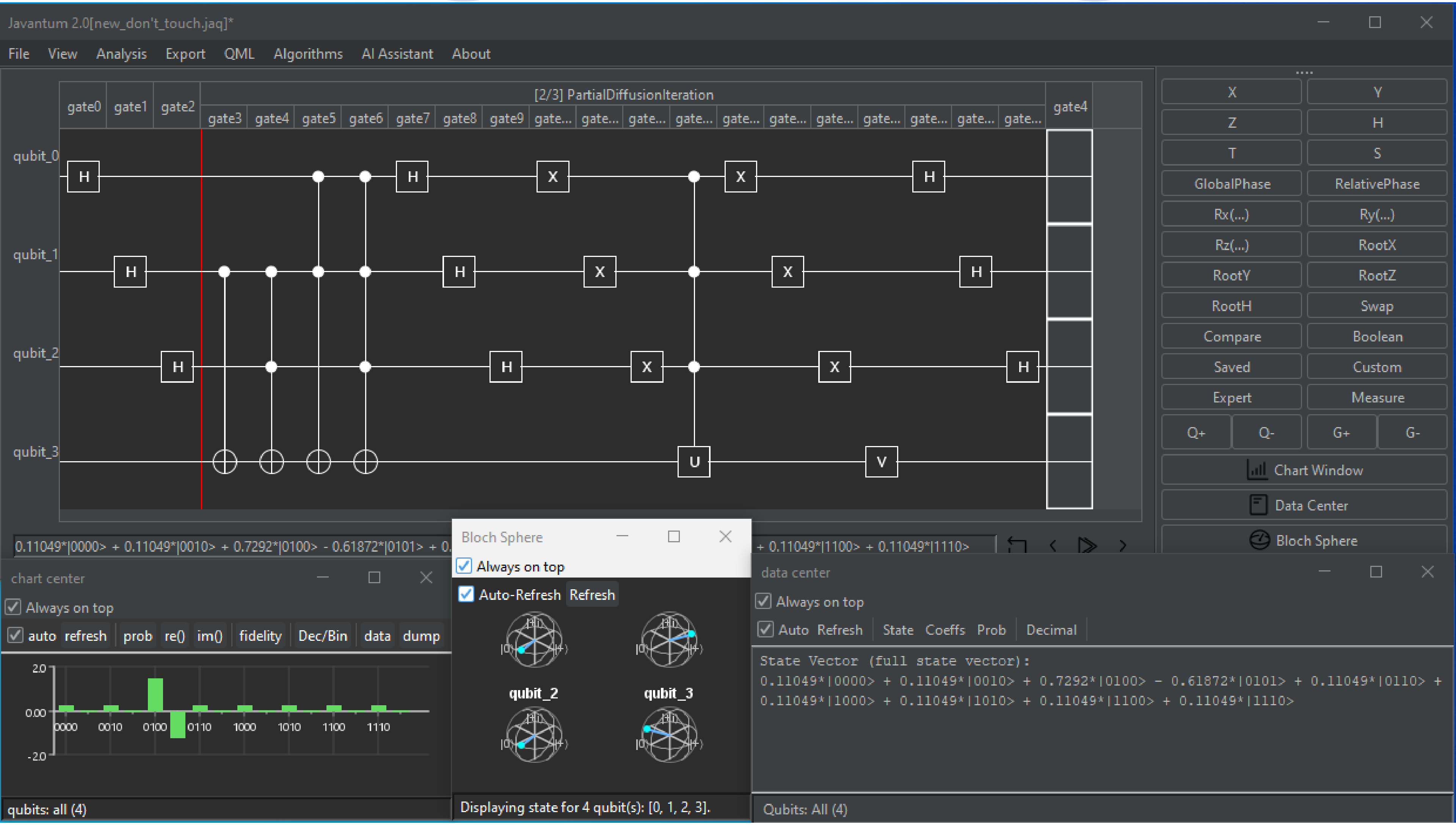
AlexQkit, 2020



Javantum1.0, 2016



Javantum 2.0, 2025 (Beta version)



QWORLD

QCOUSINS

QWorld (Association) is a non-profit global organization that brings quantum computing researchers & enthusiasts together.

Our main goal is to popularize quantum technologies and software.

Also, through education and skill development opportunities, QWorld is training the next generation of quantum scientists.

qworld.net

2021

qworld.net

QWORLD

EVENTS PROJECTS QCOUSINS QEDUCATION QRESEARCH ABOUT US QWORLD

OUR DEPARTMENTS

qworld.net/qegypt/

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QEgypt is founded in April 2021 by the main pillars of the Alexandria Quantum Computing Group (at Faculty of Science, Alexandria University) that abides by the law of the Ministry of Higher Education in Egypt. The main advantage of those pillars is that Alexandria Quantum Computing Group has members from different academic backgrounds and universities. QEgypt is established on embracing innovative ideas and the strong belief of communicating the revolution of Quantum Computing to the community.

The main goal is to create a more engaging and fruitful environment for creating new quantum educational material and a strong research base that can help researchers and universities in academia and also pave the way for new industrial adopters of quantum technologies. Our diverse team below is eager to widen its circle of connections and open to collaborations in different research areas within the field of quantum information science.

We invite you to our social media channels!

Facebook | LinkedIn

QWORLD

QBronze

The introductory level workshop series on the basics of quantum computing and quantum programming.

QWORLD

QNickel

The elementary level workshop series on quantum computing and programming focusing on oracular quantum algorithms.

QWORLD

QSilver

The intermediate level workshop series on quantum computing and programming.

qworld.net/qprep16/

QWORLD

EVENTS PROJECTS QCOUSINS QEDUCATION QRESEARCH ABOUT US QWORLD

qworld.net/qbronze147/

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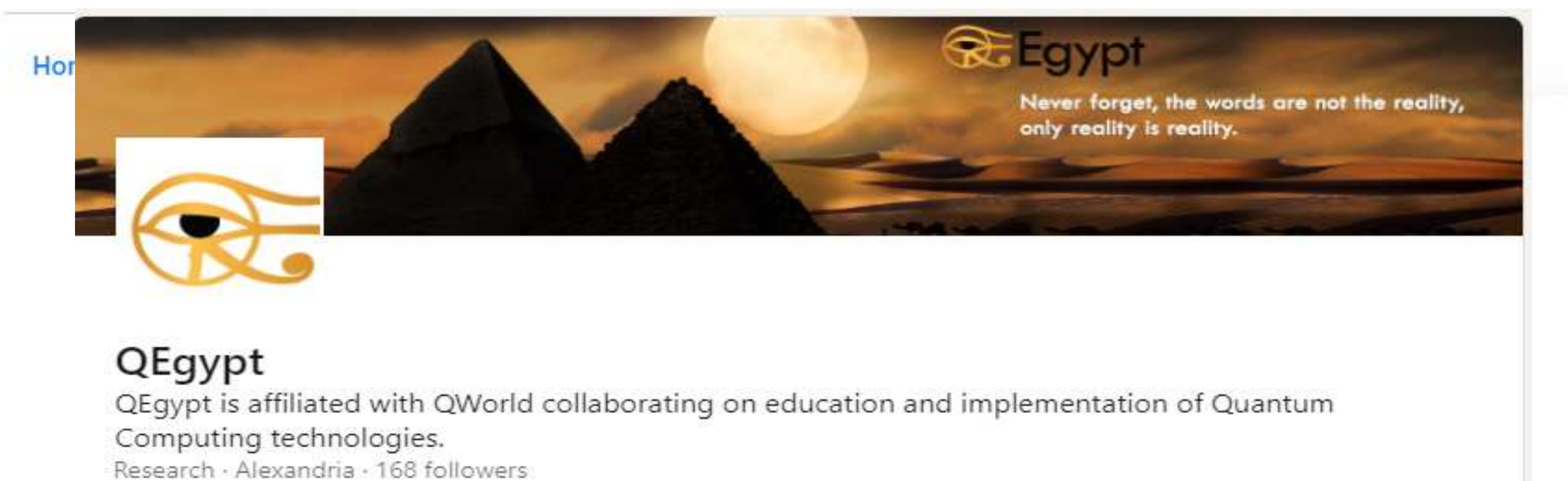
QBronze147 | Quantum Computing and Programming Workshop, Online, December 2-6, 2024

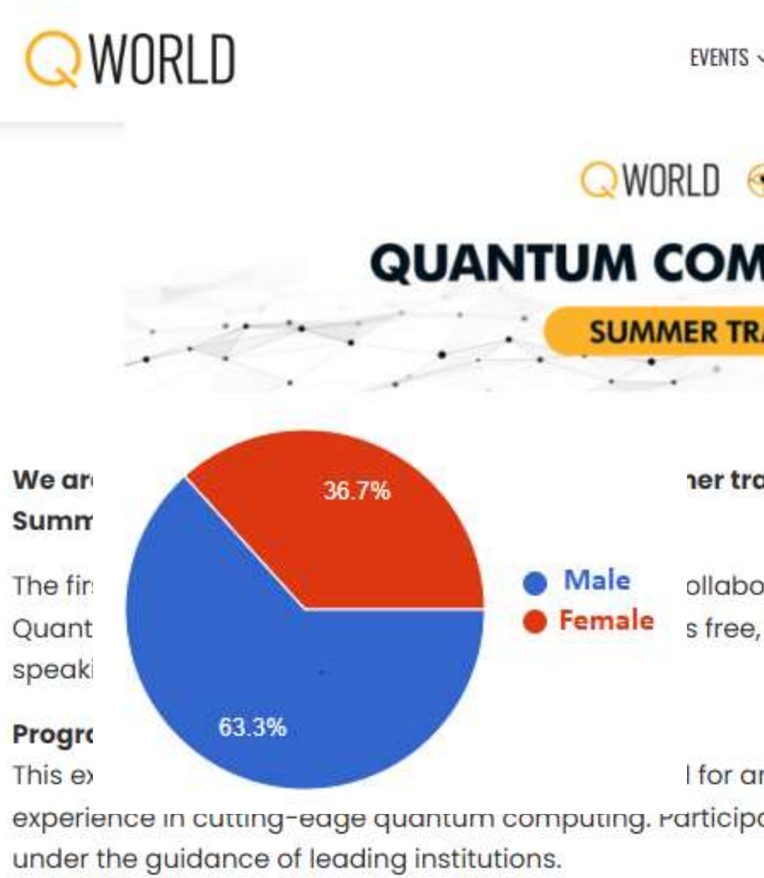
For the first time, leading experts from nine African QCousins – QSouthAfrica, QLibya, QNigeria, QCameroon, QAlgeria, QEgypt, QMorocco, QZimbabwe and QGhana – come together in a groundbreaking workshop. This pioneering event fosters cross-border collaboration, knowledge sharing, and collective growth, paving the way for a stronger, more resilient Africa.

We are pleased to announce the first quantum programming workshop organized jointly by QAfrica and QWorld! Join us for the introductory workshop and learn the basics of quantum computing and how to write simple quantum programs.

We invite highschool students, university students and graduates, researchers, professors, and industry experts. We will use introductory tutorials called Bronze-Qiskit by QWorld. We will use Discord to communicate with each other and conduct the workshop. Jupyter notebooks, lectures, and mentoring will be in English. We will also provide mentoring in a few other languages.

https://www.fb.com/QuEgypt



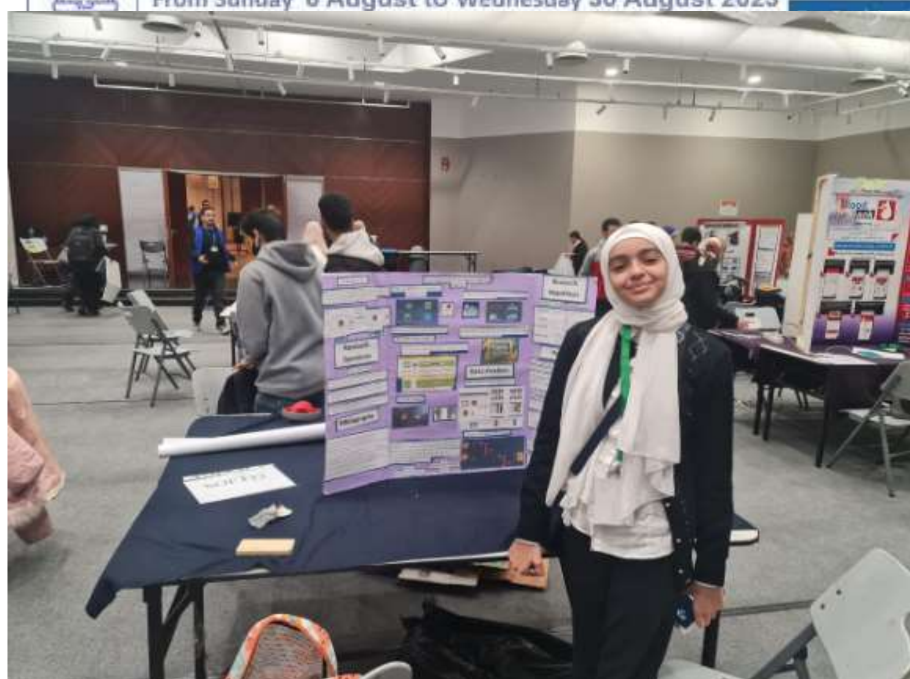


500+ Students
60+ Egyptian Universities

https://qworld.net/qcourse110-1/

https://quantum.bibalex.org/

Quantum Computer Programming for High School Students

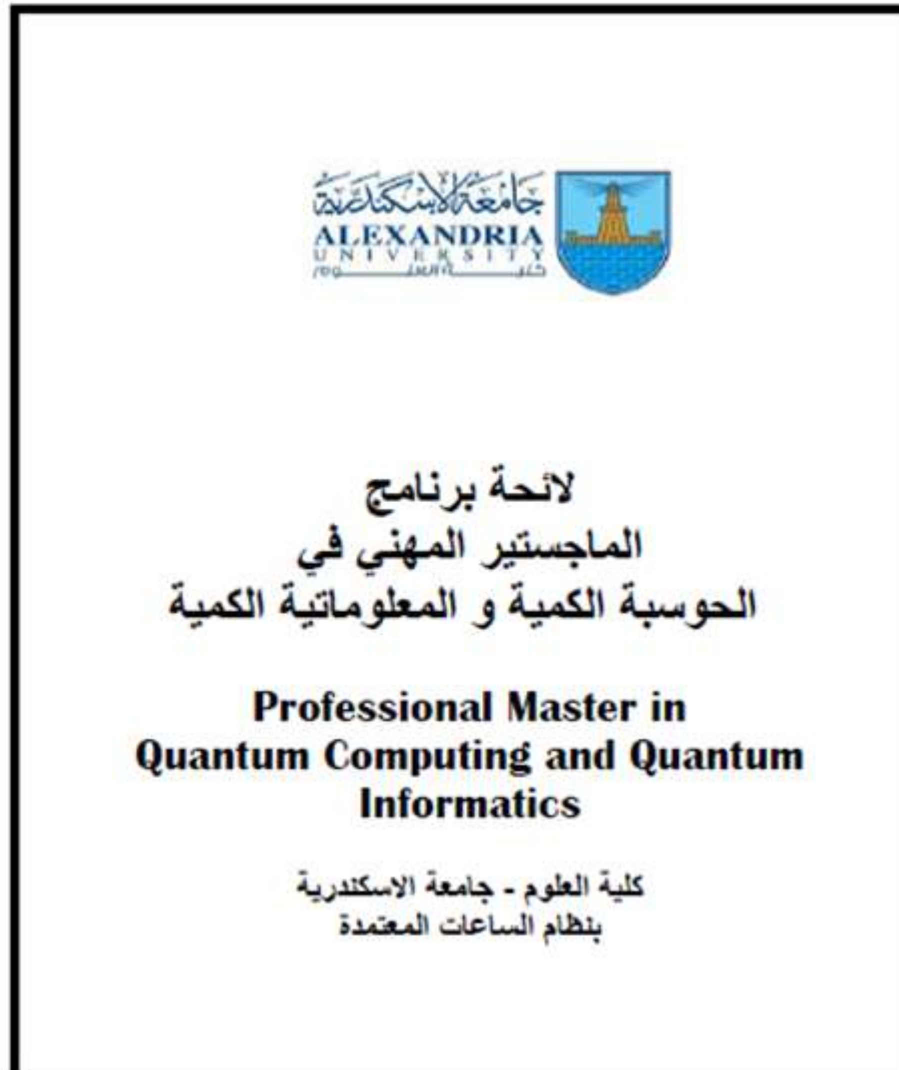


Professional Master in Quantum Computing and Quantum Informatics 2022

36 Credits

- Mandatory Courses: 15 Cr.
- Elective Courses: 15 Cr.
- Project: 6 Cr

- Cover All required background
  - Mathematics
  - Computer Science
  - Physics
  - Engineering


جامعة الإسكندرية
ALEXANDRIA UNIVERSITY

لائحة برنامج
الماجستير المهني في
الحوسبة الكمية و المعلوماتية الكمية

Professional Master in Quantum Computing and Quantum Informatics

كلية العلوم - جامعة الاسكندرية
بنظام الساعات المعتمدة

Core Courses

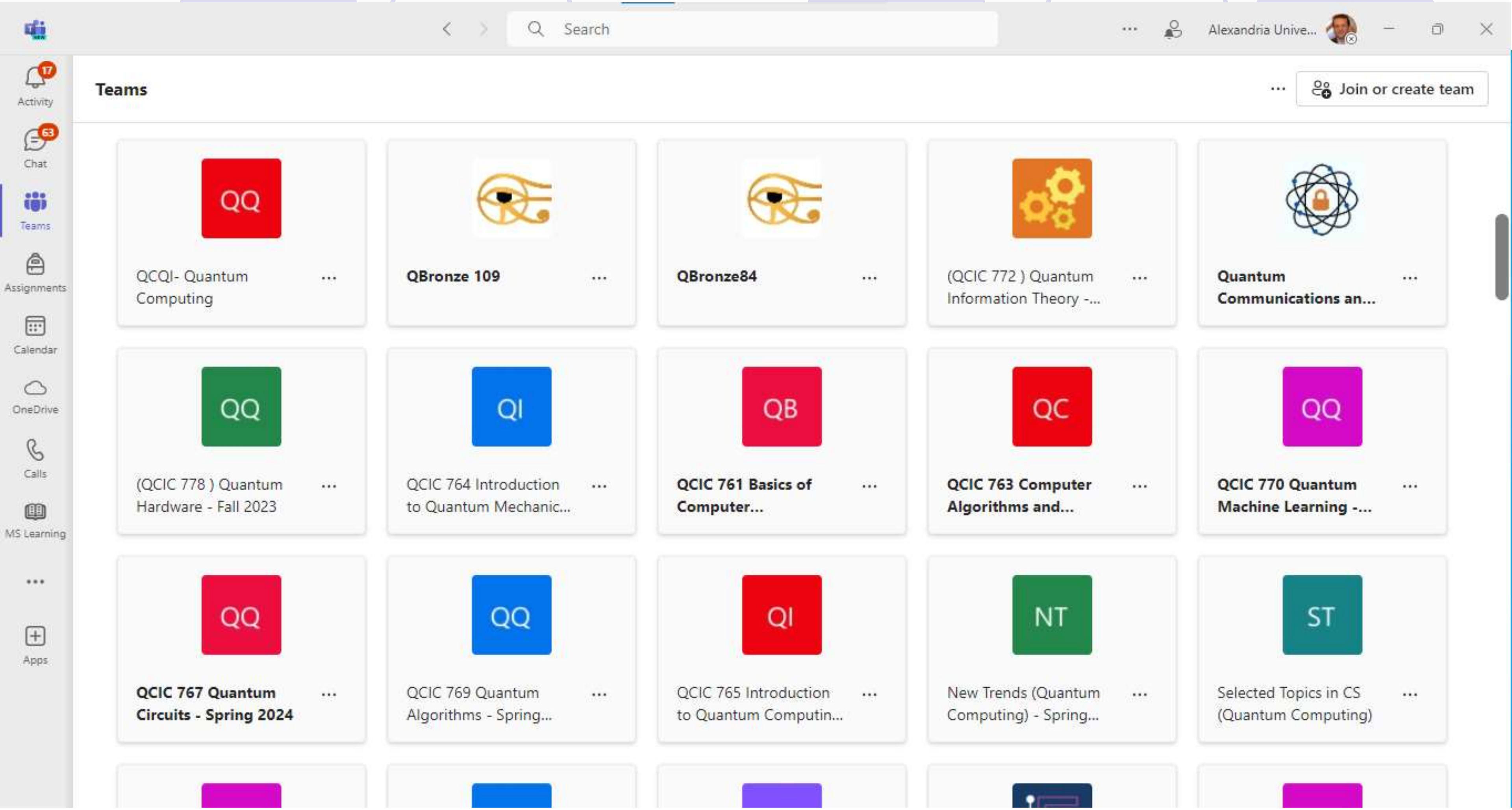
15 Cr + 6 Cr Research Project

Course Title	Lec.	Lab.	Cr.
Basics of Computer Programming	2	2	3
Introduction to Probability and Statistics	2	2	3
Computer Algorithms and Models of Computations	2	2	3
Introduction to Quantum Mechanics	2	2	3
Introduction to Quantum Computing	2	2	3
Project	6	-	6

Elective Courses

15 Cr

Course Title	Lec.	Lab.	Cr.
Quantum Circuits	2	2	3
Reversible Computing	2	2	3
Quantum Algorithms	2	2	3
Quantum Machine Learning	2	2	3
Quantum Communications and Cryptography	2	2	3
Quantum Information Theory	2	2	3
Quantum Error-Correction	2	2	3
Quantum Image Processing	2	2	3
Quantum Dot Cellular Automata	2	2	3
Adiabatic Quantum Computing	2	2	3
Nanoelectronics for Quantum Computing	2	2	3
Quantum Hardware	2	2	3
Photonic Quantum Computing	2	2	3



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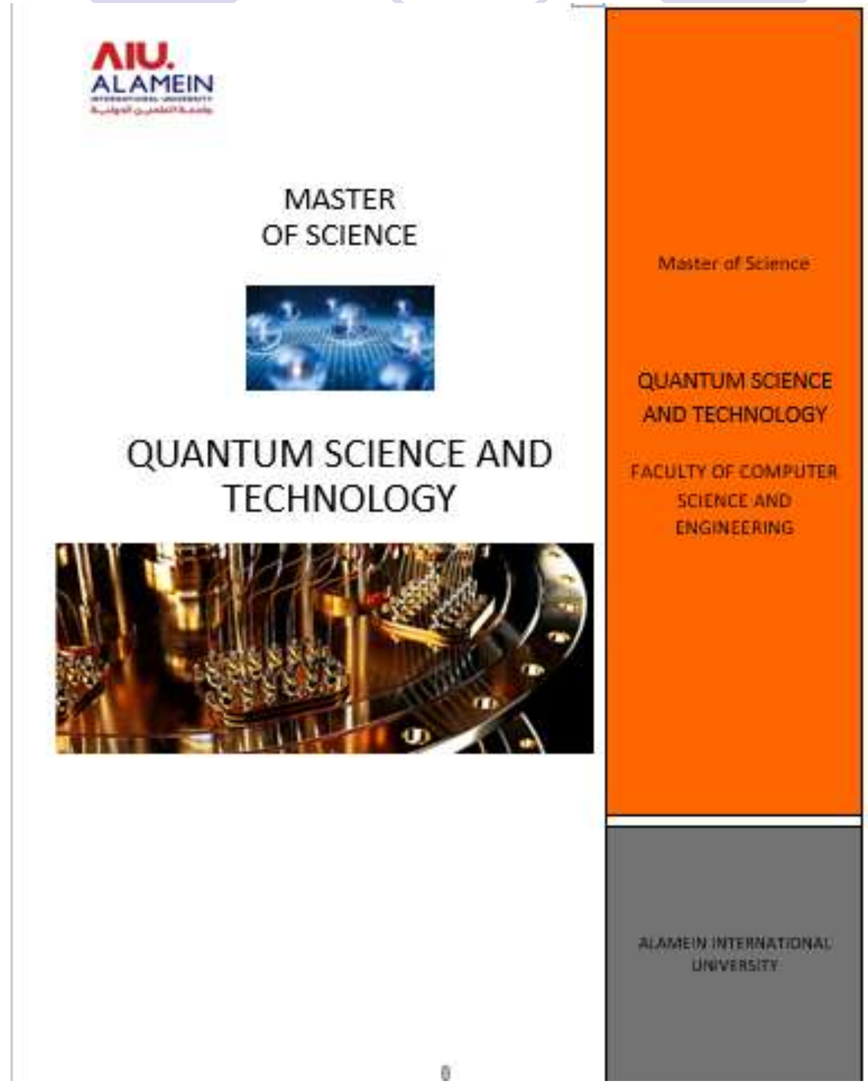
QCQI- Quantum Computing
QBronze 109
QBronze84
(QCIC 772) Quantum Information Theory -...
Quantum Communications an...
QQ
(QCIC 778) Quantum Hardware - Fall 2023
QI
QCIC 764 Introduction to Quantum Mechanic...
QB
QCIC 761 Basics of Computer...
QC
QCIC 763 Computer Algorithms and...
QQ
QCIC 770 Quantum Machine Learning -...
QQ
QCIC 767 Quantum Circuits - Spring 2024
QQ
QCIC 769 Quantum Algorithms - Spring...
QI
QCIC 765 Introduction to Quantum Computin...
NT
New Trends (Quantum Computing) - Spring...
ST
Selected Topics in CS (Quantum Computing)

MSC IN QUANTUM SCIENCE AND TECHNOLOGY

AIU.
ALAMEIN
INTERNATIONAL UNIVERSITY
جامعة العلمين الدولية



Africa Quantum Consortium (AQC)

https://africaquantum.org/

About the Africa Quantum Consortium (AQC)

Vision

To **unite Africa's quantum leaders** in a **collaborative forum**, driving **innovation** and **shaping the future** of quantum technologies on the continent.

Mission

To **accelerate** quantum technology **adoption** in Africa through **collaboration, local expertise, and global partnerships**.

2022

worldquantumday.org

worldquantumday.org/about/

WORLD QUANTUM DAY APRIL 14

Events | World Quantum Day | News | About | Contact

Chao-Yang Lu
CHINA

Not secure | sci.p.alexu.edu.eg/~aleqcg/wqd2022/wqd2022-Egypt.htm

ALEQCG

Several quantu

Friday

14 APR

09:00 - 17:00 (EE

World Qua

https://worldquantum

General public, stude

By:

Dr Salem F. Hegazy;

Where:

Alexandria, Cairo, Is

Online event

On the occasion of W

Tom
GER

Not secure | sci.p.alexu.edu.eg/~aleqcg/wqd2024/wqd2024-Egypt.htm

ALEQCG

Sunday

14 APR

01:00 PM - 03:00 PM

WORLD QUANTUM APRIL 14

World Quan

Register now:
https://forms.office.com/

General public, students

ALEQCG Alexandria Quantum Computing Group (AleQCG) | WORLD Egypt | International Year of Quantum Science and Technology | AIU ALAMEIN INTERNATIONAL UNIVERSITY جامعة العلمين الدولية

MONDAY, 14 APR 2025

07:00 PM - 09:30 PM (Cairo time)

World Quantum Day in Egypt 2025

WORLD QUANTUM DAY APRIL 14 • EVERY DAY IN 2025

Quantum City Prize

World and Continental Quantum City Prize

Key Information

The Quantum City Prize rewards initiatives bringing Quantum Science and Technology to the public space of a city. For example, placing posters in the public transport network of the city, or organising an activity in a square of the city, etc.

The idea is that the public should not have to register in an event, or have to travel to a venue, to access the corresponding contents, but will find it serendipitously in the city.

Prizes are divided into 3 categories:

- cities with less than 100 000 inhabitants.
- cities with a population larger than 100 000 inhabitants, and smaller than 1 000 000 inhabitants.
- cities with more than 1 000 000 inhabitants.

INTERNATIONAL YEAR OF
Quantum Science
and Technology

https://worldquantumday.org/quantum-city-prize

AleQCG Research Focus

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4. **Quantum Cryptography:** Investigating secure communication protocols based on quantum principles, AleQCG contributes to the field of quantum-safe cryptography.

Quantum Algorithms

Quantum Algorithms   Filter by publication year range:2014 to 2023

SciVal

Top countries/regions

Entity: Quantum Algorithms · Within: All subject areas (THE) · Region: Africa · Year range: 2014 to 2023 ·
Data source: Scopus, up to 06 Nov 2024

Countries & territories	Scholarly Output ↓	Views Count	Field-Weighted Citation Impact	Citation Count
Egypt	223	6,687	1.90	4,026
South Africa	100	3,290	1.74	3,692
Algeria	85	1,511	1.18	794
Morocco	49	1,281	0.58	287
Tunisia	35	739	1.31	423
Nigeria	23	654	0.74	289
Ghana	10	456	2.35	283
Senegal	10	120	0.30	19
Cameroon	7	91	0.25	27
Ethiopia	7	185	1.58	49

Quantum Algorithms

Quantum Algorithms   Filter by publication year range:2014 to 2023

SciVal

Top Institutions

Entity: Quantum Algorithms · Within: All subject areas (THE) · Region: Africa · Year range: 2014 to 2023 · Data source: Scopus, up to 06 Nov 2024

Institution	Scholarly Output ↓	Views Count	Field-Weighted Citation Impact	Citation Count
Alexandria University	44	863	0.98	384
University of the Witwatersrand	36	1,690	0.85	416
University of KwaZulu-Natal	33	1,097	3.30	3,062
Al-Azhar University	30	885	1.81	579
Menoufia University	27	834	3.41	973
Mohammed V University in Rabat	22	790	0.67	139
Sohag University	21	582	2.15	496
Ain Shams University	20	672	0.88	267
University of Science and Technology Houari Boumediene	20	373	0.93	224
Cairo University	19	765	1.66	369

Quantum Computer; Grover Algorithm; Computational Complexity T.3993

Quantum Computer; Grover Algorithm; Computational Complexity T.3993
Filter by publication year range:2014 to 2023

SciVal

Top countries/regions

Entity: Quantum Computer; Grover Algorithm; Computational Complexity T.3993 · Within: All subject areas (THE) · Region: Africa · Year range: 2014 to 2023 · Data source: Scopus, up to 06 Nov 2024

Countries & territories	Scholarly Output ↓	Views Count	Field-Weighted Citation Impact	Citation Count
Egypt	17	309	1.25	218
Nigeria	8	79	0.36	30
South Africa	5	97	0.81	56
Morocco	3	24	0.00	1
Tunisia	3	23	0.07	7
Algeria	2	19	1.10	5
Libya	2	25	0.49	4
Cameroon	1	3	0.00	0
Ethiopia	1	15	2.25	2

Quantum Computer; Grover Algorithm; Computational Complexity T.3993

Quantum Computer; Grover Algorithm; Computational Complexity T.3993
Filter by publication year range:2014 to 2023

SciVal

Top Institutions

Entity: Quantum Computer; Grover Algorithm; Computational Complexity T.3993 · Within: All subject areas (THE) · Region: Africa · Year range: 2014 to 2023 · Data source: Scopus, up to 06 Nov 2024

Institution	Scholarly Output ↓	Views Count	Field-Weighted Citation Impact	Citation Count
Alexandria University	6	79	0.17	25
Zewail City of Science and Technology	5	96	1.64	87
Al-Azhar University	4	93	0.44	57
Kano University of Science and Technology	4	48	0.28	4
Sohag University	4	84	0.26	15
Ain Shams University	3	56	1.07	27
Mansoura University	3	73	4.67	103
Mohammed V University in Rabat	3	24	0.00	1
Abubakar Tafawa Balewa University, Bauchi	2	11	0.87	26
The British University in Egypt	2	35	1.28	15

Logic Gate; Quantum Computer; Theory of Computation T.7121

Logic Gate; Quantum Computer; Theory of Computation T.7121
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Countries & territories	Scholarly Output ↓	Views Count	Field-Weighted Citation Impact	Citation Count
Egypt	14	313	0.74	78
Algeria	7	150	0.67	22
Tunisia	4	68	0.21	16
Morocco	2	18	0.00	0
Nigeria	2	100	0.98	31
Ethiopia	1	18	0.55	7

Logic Gate; Quantum Computer; Theory of Computation T.7121

Logic Gate; Quantum Computer; Theory of Computation T.7121
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Top Institutions

Entity: Logic Gate; Quantum Computer; Theory of Computation T.7121 · Within: All subject areas (THE) · Region: Africa · Year range: 2014 to 2023 · Data source: Scopus, up to 06 Nov 2024

Institution	Scholarly Output ↓	Views Count	Field-Weighted Citation Impact	Citation Count
Alexandria University	12	292	0.54	75
University of Sidi-Bel-Abbès	4	95	0.34	6
Frères Mentouri Constantine 1 University	3	55	1.10	16
University of Monastir	3	58	0.11	11
University of Sousse	3	66	0.28	16
Abdelmalek Essaâdi University	2	18	0.00	0
Academy of Scientific Research and Technology	2	23	0.26	4
Al-Azhar University	2	107	1.33	31
Damanhour University	2	34	0.46	6
Ibn Tofail University	2	18	0.00	0

Quantum Cryptography; Secret Sharing; Authentication T.4450

Quantum Cryptography; Secret Sharing; Authentication T.4450
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Entity: Quantum Cryptography; Secret Sharing; Authentication T.4450 · Within: All subject areas (THE) · Region: Africa · Year range: 2014 to 2023 · Data source: Scopus, up to 06 Nov 2024

Countries & territories	Scholarly Output ↓	Views Count	Field-Weighted Citation Impact	Citation Count
Egypt	30	527	1.19	527
Morocco	6	98	1.27	82
South Africa	4	78	1.70	202
Algeria	2	11	0.30	9
Botswana	1	6	0.61	4
Ethiopia	1	8	2.81	1
Tunisia	1	7	1.31	8

Quantum Computer; Image Processing; Steganography T.35465

Quantum Computer; Image Processing; Steganography T.35465
Filter by publication year range:2014 to 2023

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Entity: Quantum Computer; Image Processing; Steganography T.35465 · Within: All subject areas (THE) · Region: Africa · Year range: 2014 to 2023 · Data source: Scopus, up to 06 Nov 2024

Countries & territories	Scholarly Output ↓	Views Count	Field-Weighted Citation Impact	Citation Count
Egypt	31	652	1.84	866
Tunisia	3	47	0.19	6
Algeria	2	36	0.47	11
Morocco	2	54	0.36	10
Ghana	1	9	0.00	1
South Africa	1	31	0.54	20

Neural Network; Quantum Computer; Artificial Intelligence T.27147

Neural Network; Quantum Computer; Artificial Intelligence T.27147
Filter by publication year range:2014 to 2023

Top countries/regions

Entity: Neural Network; Quantum Computer; Artificial Intelligence T.27147 · Within: All subject areas (THE) · Region: Africa · Year range: 2014 to 2023 · Data source: Scopus, up to 06 Nov 2024

Countries & territories	Scholarly Output ↓	Views Count	Field-Weighted Citation Impact	Citation Count
Egypt	10	207	2.63	282
Cameroon	2	53	0.45	23
Morocco	1	20	0.25	3
South Africa	1	20	0.26	4

Quantum Computer; Machine Learning; Mathematical Optimization T.1516

Quantum Computer; Machine Learning; Mathematical Optimization T.1516
Filter by publication year range:2014 to 2023

SciVal

Top countries/regions

Entity: Quantum Computer; Machine Learning; Mathematical Optimization T.1516 · Within: All subject areas (THE) · Region: Africa · Year range: 2014 to 2023 · Data source: Scopus, up to 06 Nov 2024

Countries & territories	Scholarly Output ↓	Views Count	Field-Weighted Citation Impact	Citation Count
South Africa	40	1,040	3.55	3,312
Egypt	12	337	2.26	236
Algeria	11	150	0.65	30
Morocco	9	173	1.23	80
Ghana	4	55	1.95	68
Nigeria	3	40	0.06	1
Ethiopia	2	33	0.00	0
Angola	1	1	0.00	0
Botswana	1	7	3.95	11

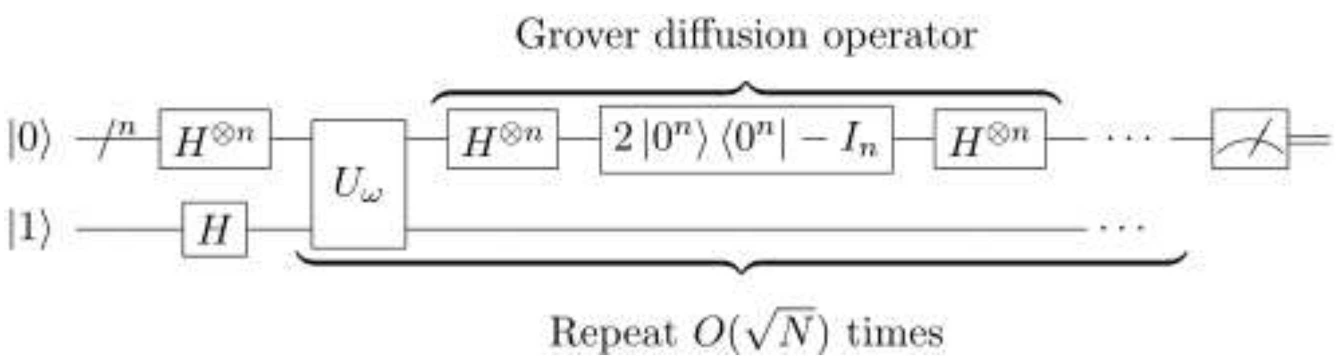
Quantum Search Algorithms and Amplitude Amplification Techniques

Unstructured Search Problem

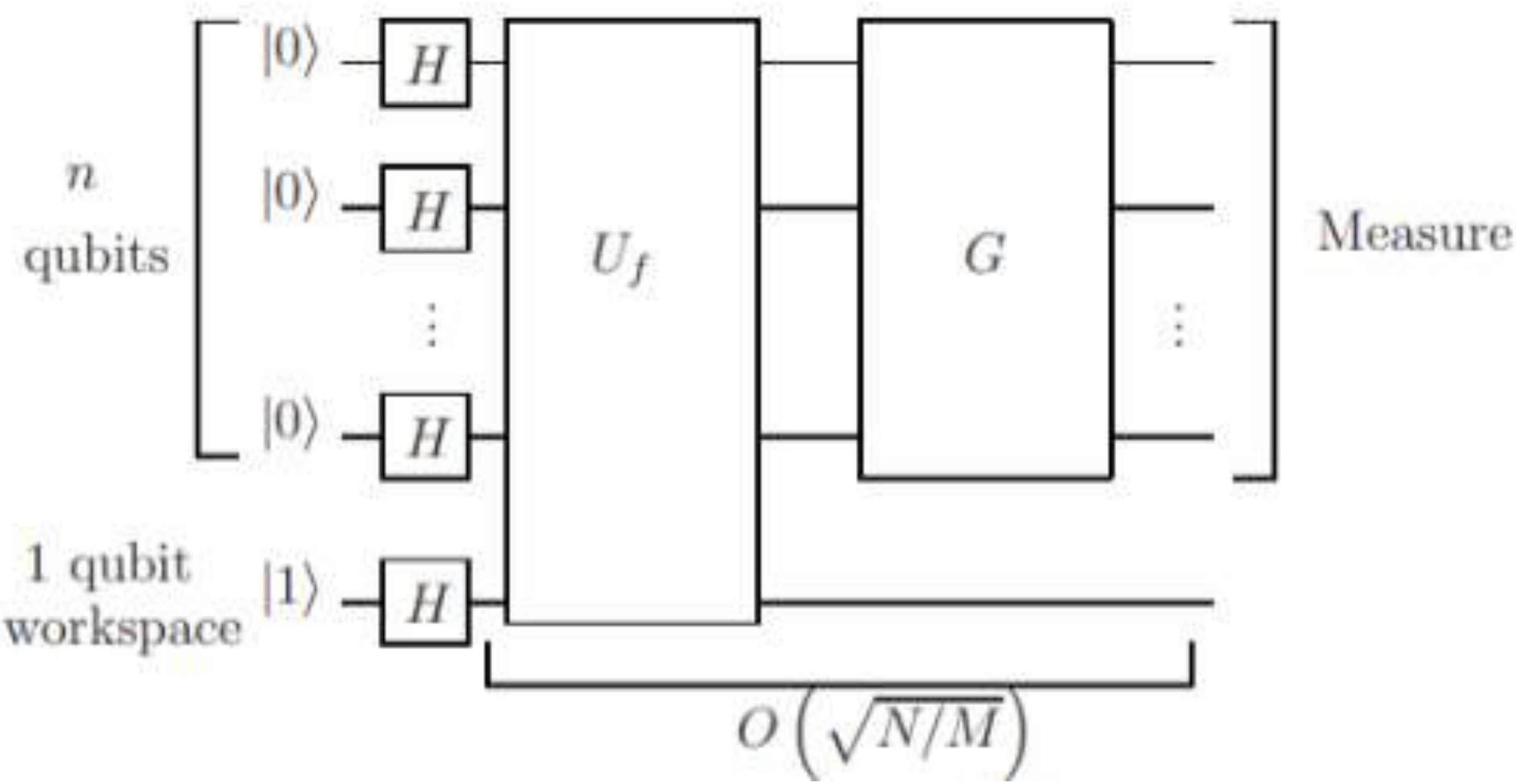
- Consider an unstructured list L of N items.
- For simplicity and without loss of generality we will assume that $N = 2^n$ for some positive integer n.
- Suppose the items in the list are labelled with the integers {0, 1, ..., $N-1$}, and consider a function (oracle) f which maps an item $i \in L$ to either 0 or 1 according to some properties this item should satisfy, i.e. $f : L \to \{0, 1\}$.
- The problem is to find any $i \in L$ such that $f(i) = 1$ assuming that such i exists in the list.

Grover's Quantum Search Algorithm

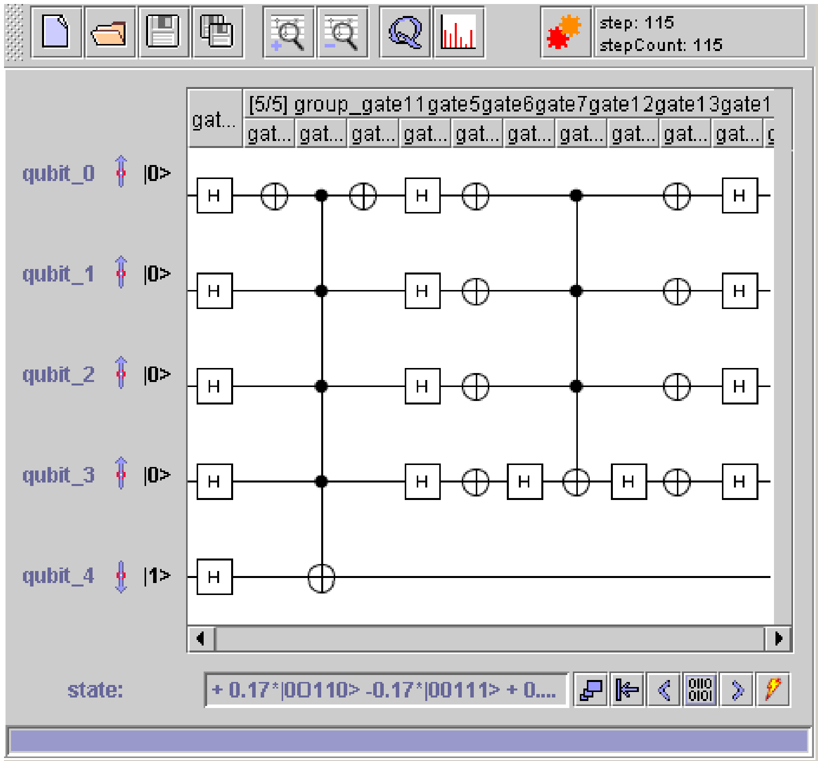
- Given a List L of N=2^n items
  - Step 1 – Prepare a superposition on N items on O(log N)
  - Step 2 – Iterate the Amplitude Amplification for $O(\sqrt{N})$
  - Step 3- Measure the quantum register
- Classical Computers require O(N) iteration.

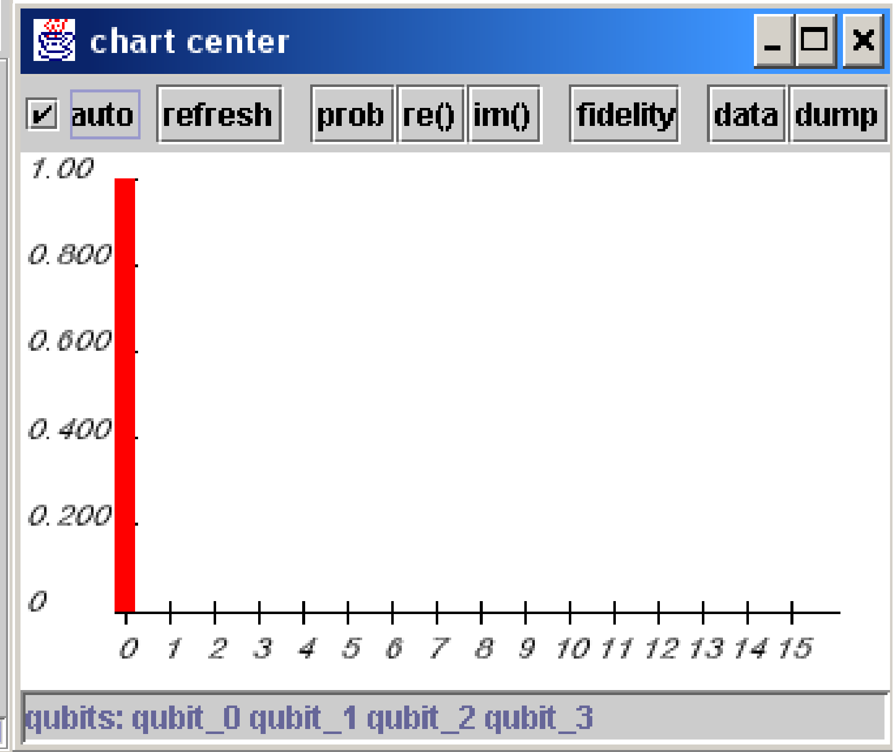


Quantum Circuit for Grover's algorithm

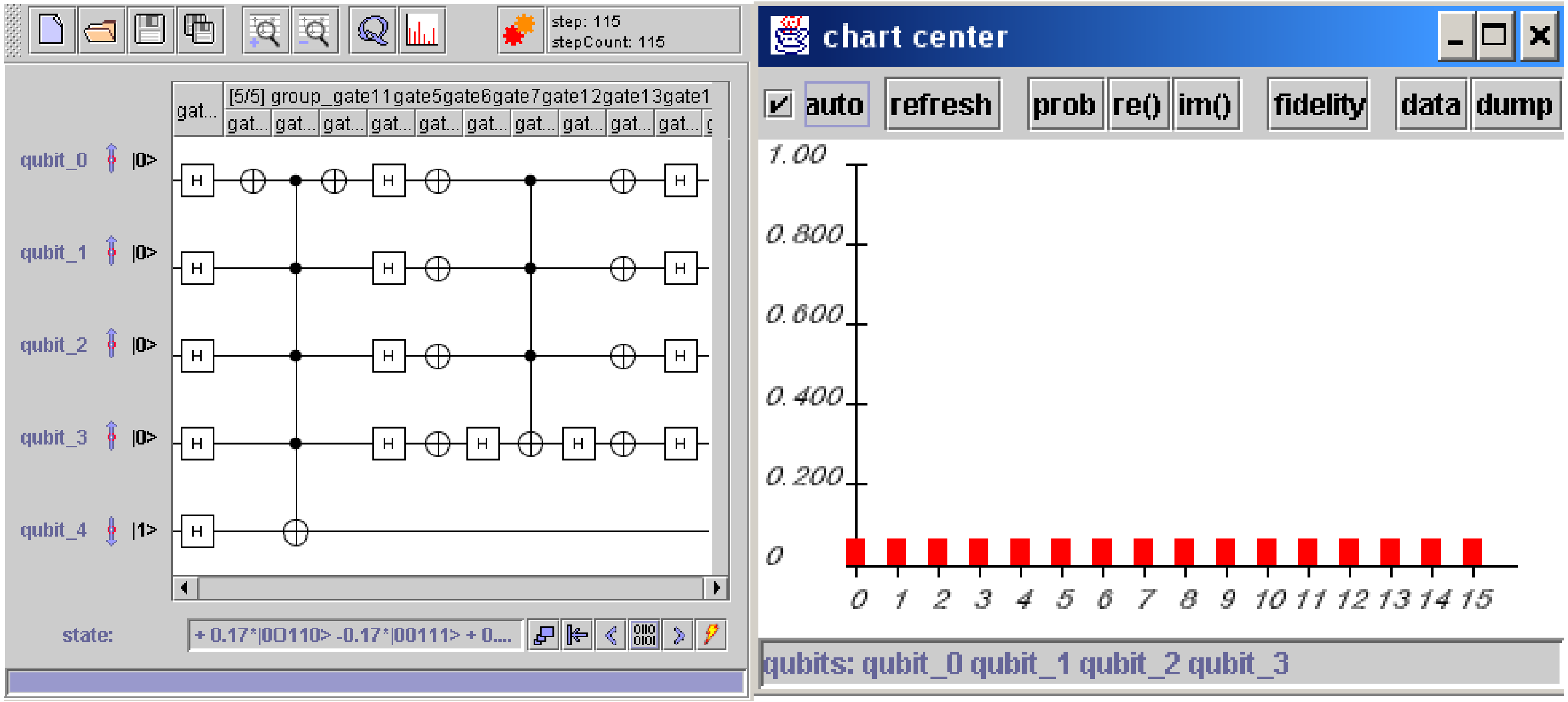


Example: Search for ?.



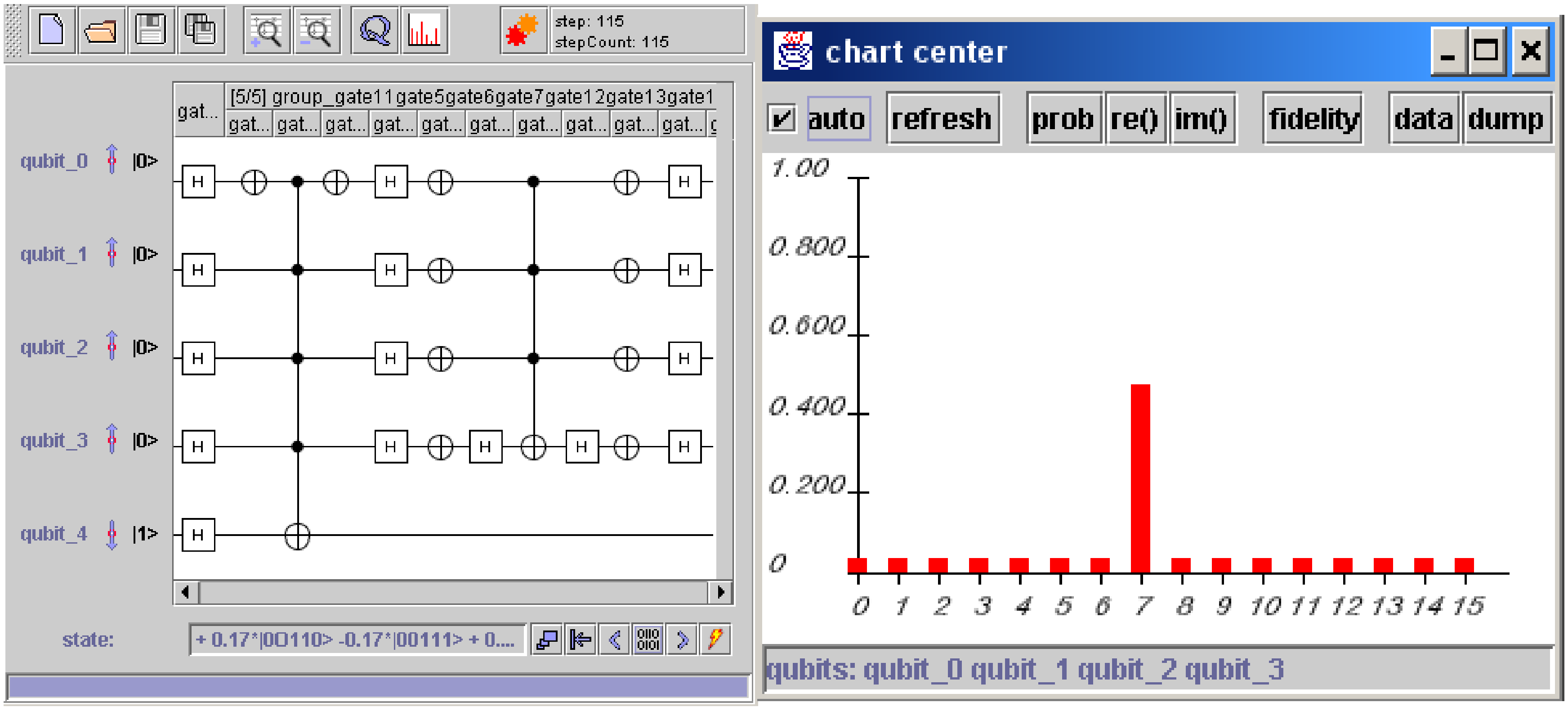


Example: Search for ?.



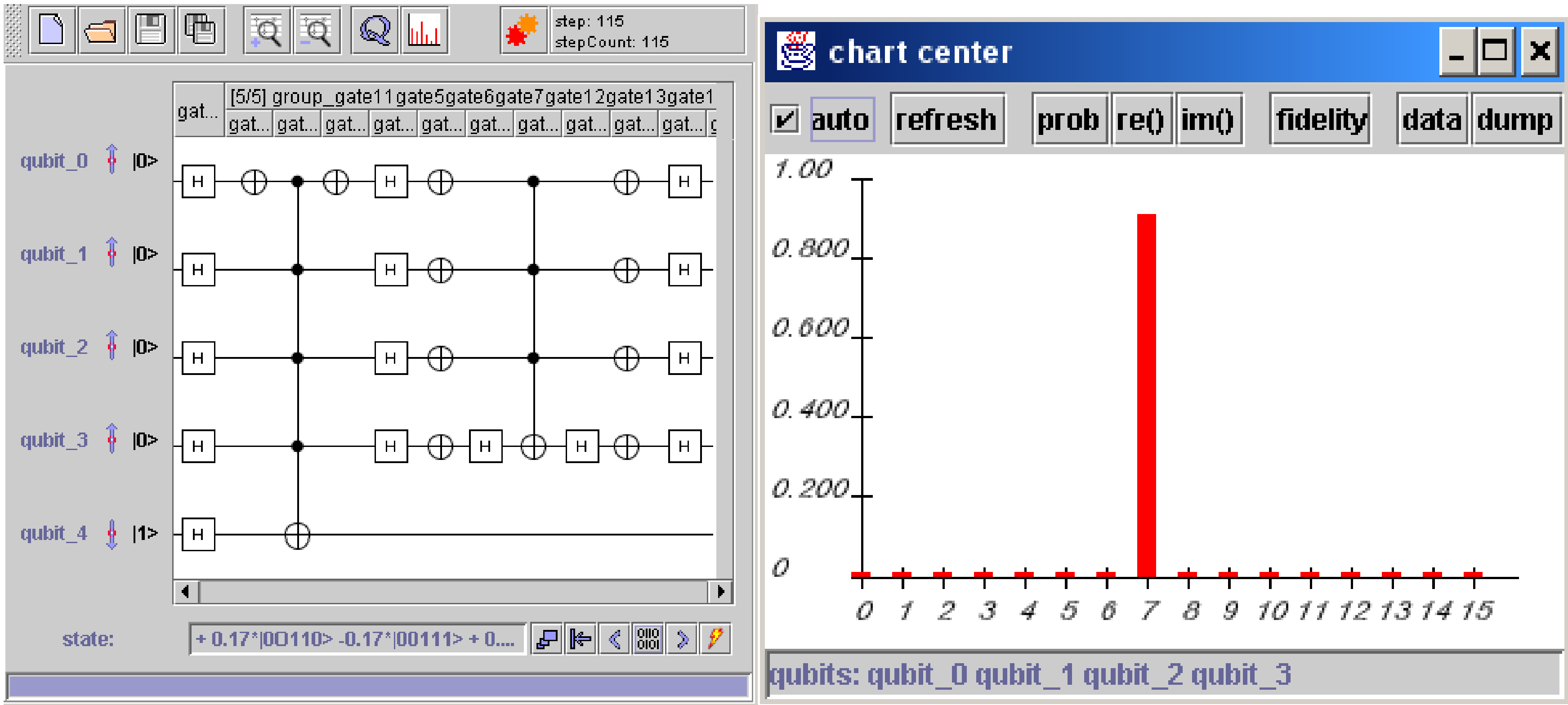
initialization

Example: Search for 7.



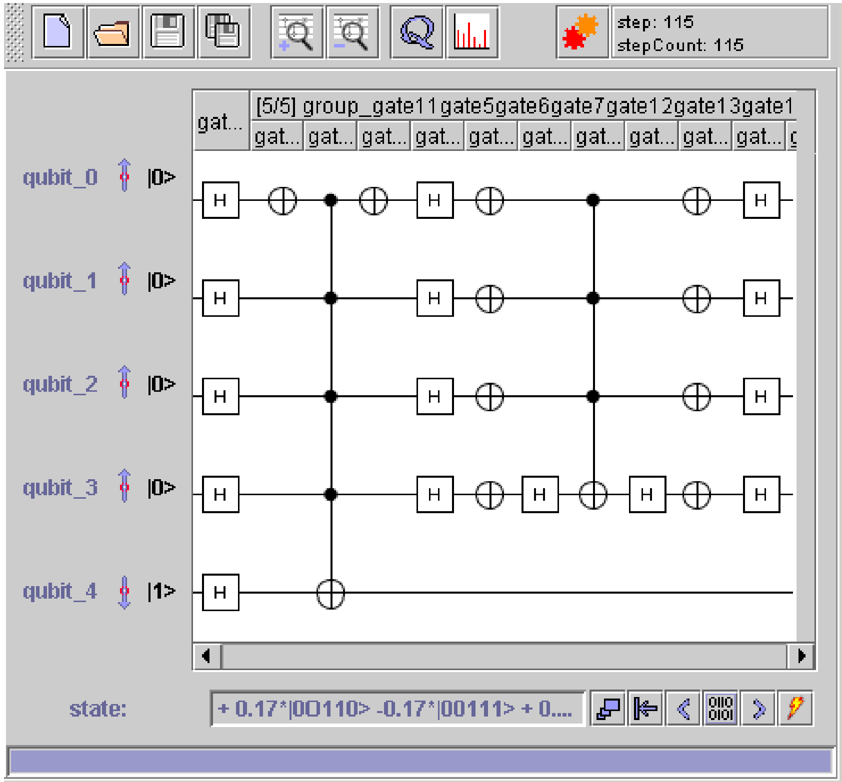
1st Iteration

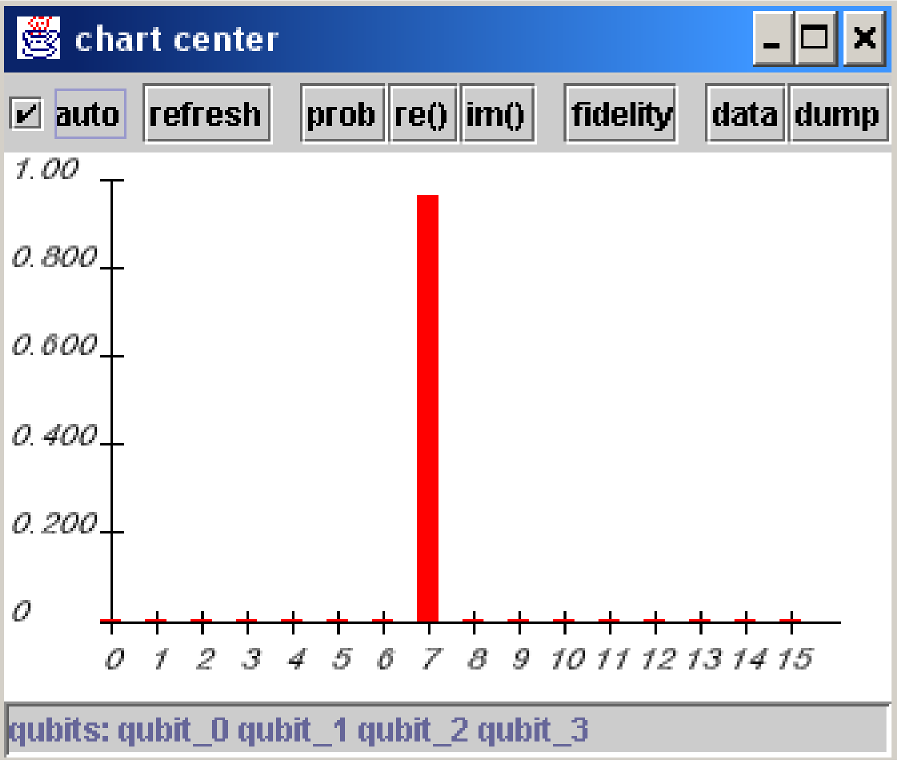
Example: Search for 7.



2nd Iteration

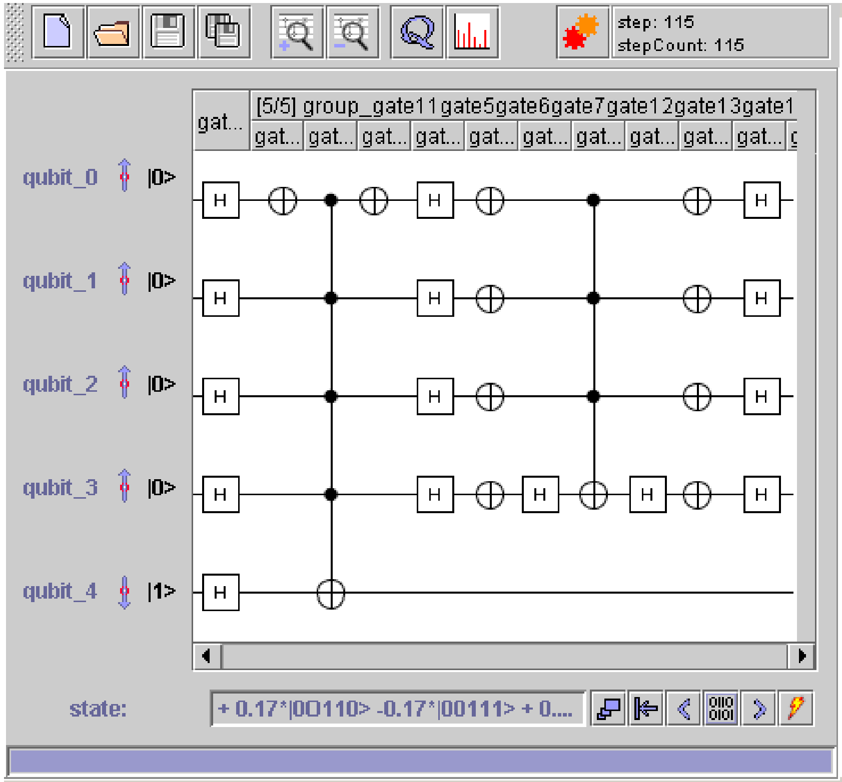
Example: Search for 7.

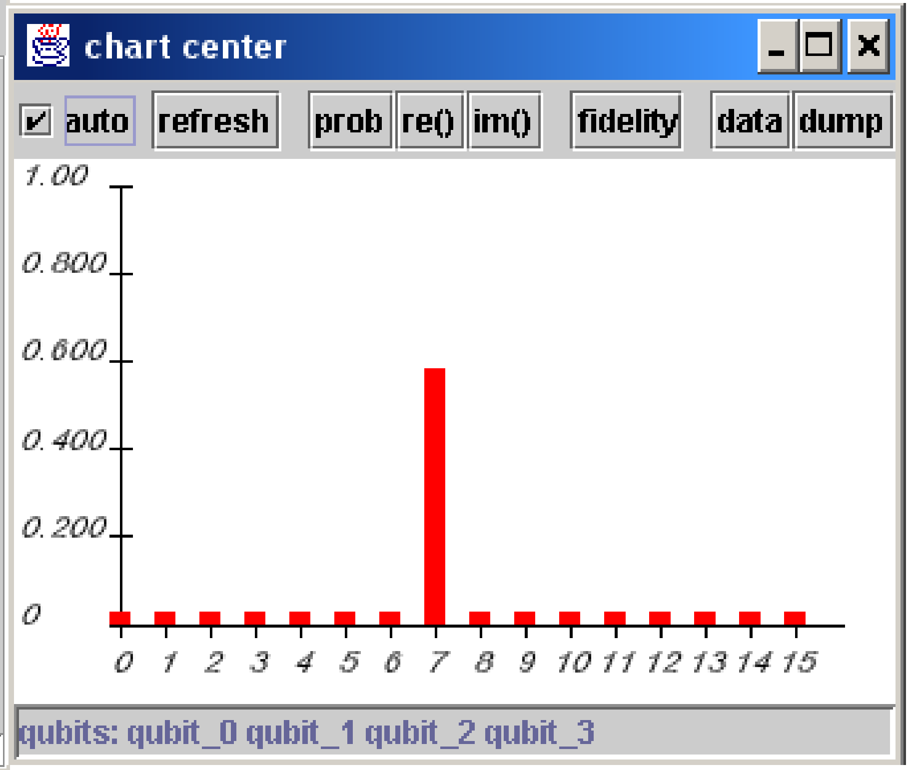




3rd Iteration

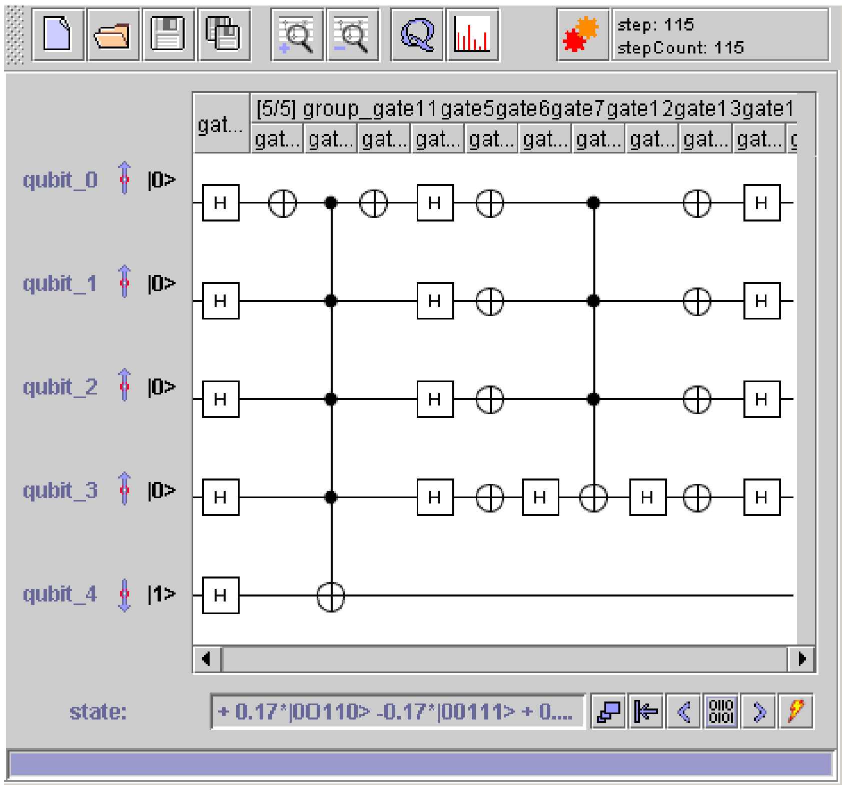
Example: Search for 7.

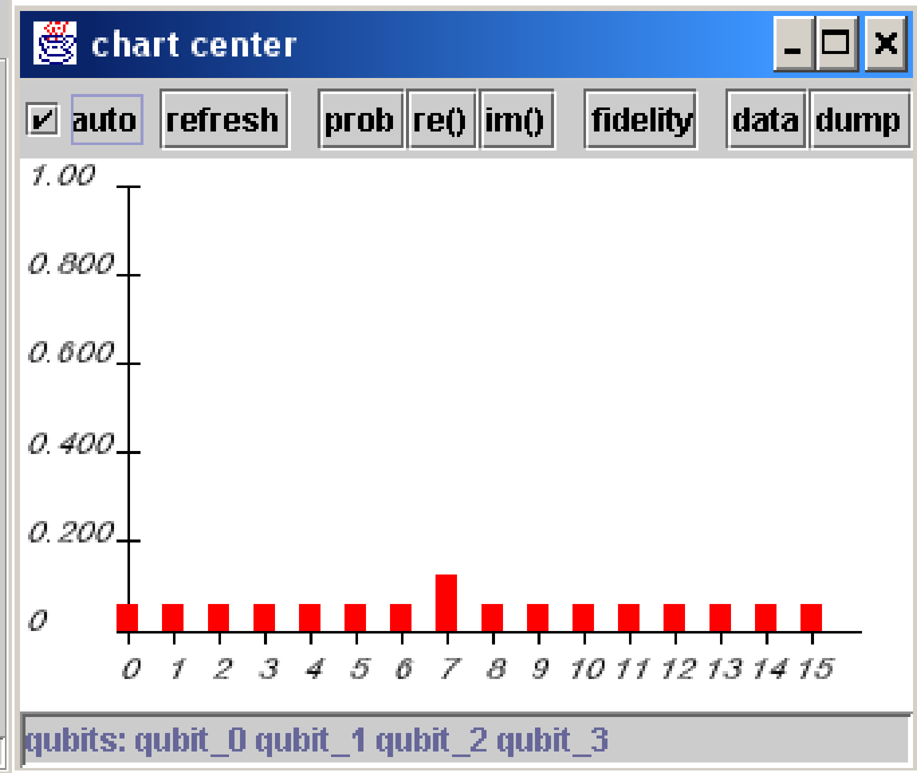




4th Iteration

Example: Search for 7.





5th Iteration

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Enhanced quantum searching via entanglement and partial diffusion

A. Younes[a,*], J. Rowe[b], J. Miller[c]

[a] Department of Mathematics and Computer Science, Faculty of Science, Alexandria University, Alexandria, Egypt
[b] School of Computer Science, University of Birmingham, Birmingham, Edgbaston, B15 2TT, United Kingdom
[c] Department of Electronics, University of York, York, Heslington, YO10 5DD, United Kingdom

Received 19 May 2007; accepted 19 December 2007
Available online 31 December 2007

Communicated by S. Kai

Highlights

- Employs a Partial Diffusion Operator and entanglement to enhance search efficiency in unstructured lists.
- Operates in O(√N/M) time complexity, demonstrating improved reliability and performance, particularly when multiple (unknown) matches are present.
- An oracle function to map items in the list, creating entanglement between solution and non-solution subspaces.
- More robust against de-amplification effects, maintaining a higher probability of finding solutions.

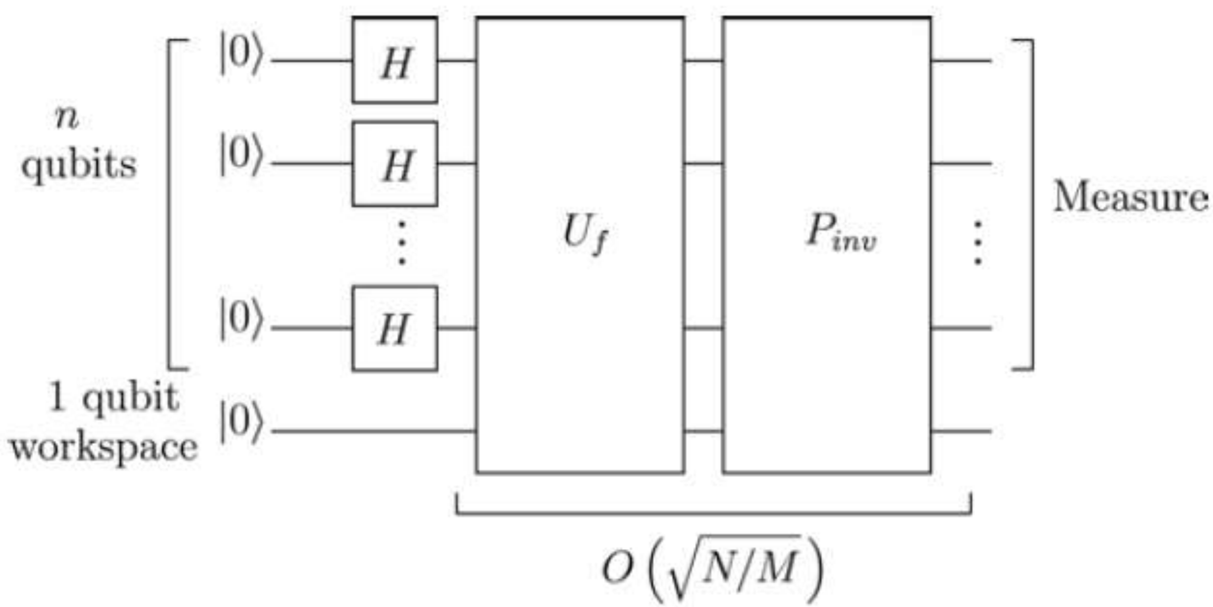
Partial Diffusion and Entanglement

$$P_{inv} = \left(H^{\otimes n} \otimes I_1\right)\left(2\left|0\right\rangle\left\langle 0\right| - I_{n+1}\right)\left(H^{\otimes n} \otimes I_1\right),$$

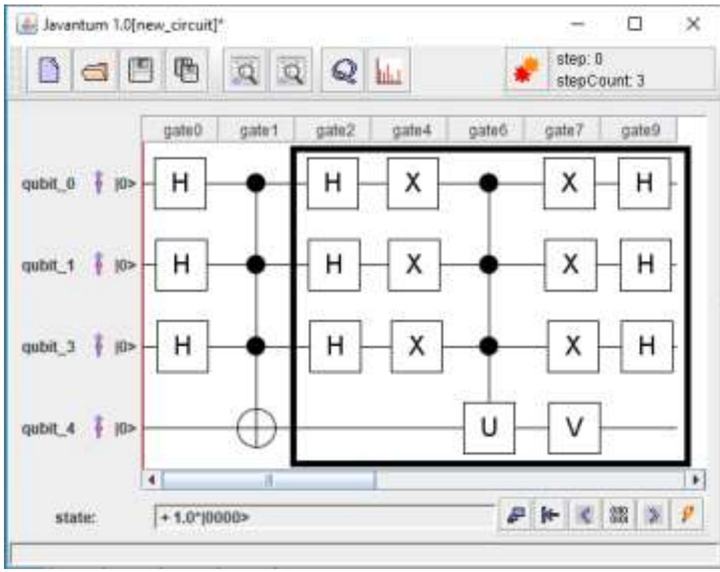
$$|\psi\rangle = \sum_{j=0}^{N-1} \alpha_j \left(|j\rangle \otimes |0\rangle\right) + \sum_{j=0}^{N-1} \beta_j \left(|j\rangle \otimes |1\rangle\right).$$

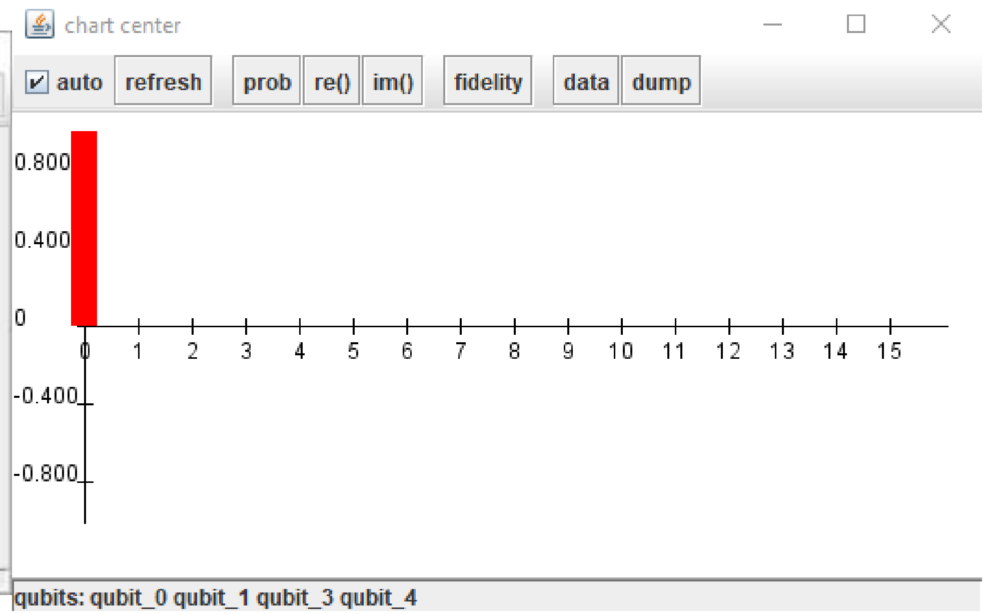
Applying P_{inv} on $|\psi\rangle$ gives, $\sum_{j=0}^{N-1} \left(2\langle\alpha\rangle - \alpha_j\right)\left(|j\rangle \otimes |0\rangle\right) - \sum_{j=0}^{N-1} \beta_j \left(|j\rangle \otimes |1\rangle\right),$

where $\langle\alpha\rangle = \frac{1}{N}\sum_{j=0}^{N-1}\alpha_j$ represents the mean of the amplitudes of the subspace $\sum_{j=0}^{N-1}\alpha_j \left(|j\rangle \otimes |0\rangle\right)$

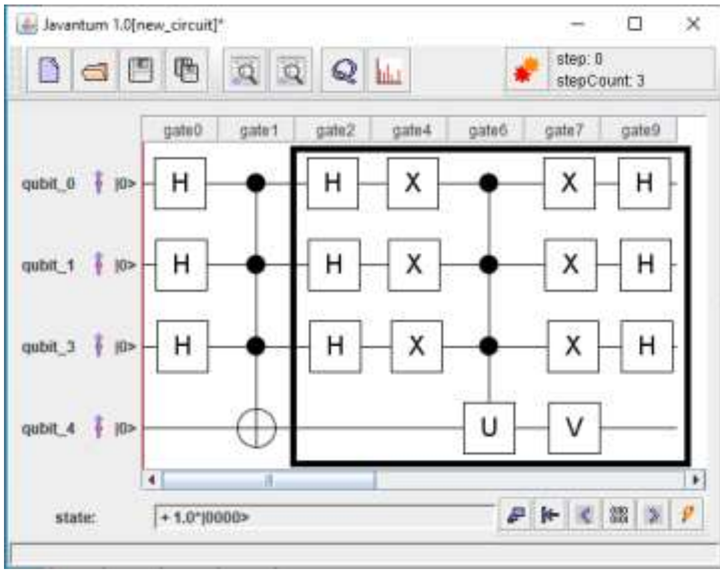


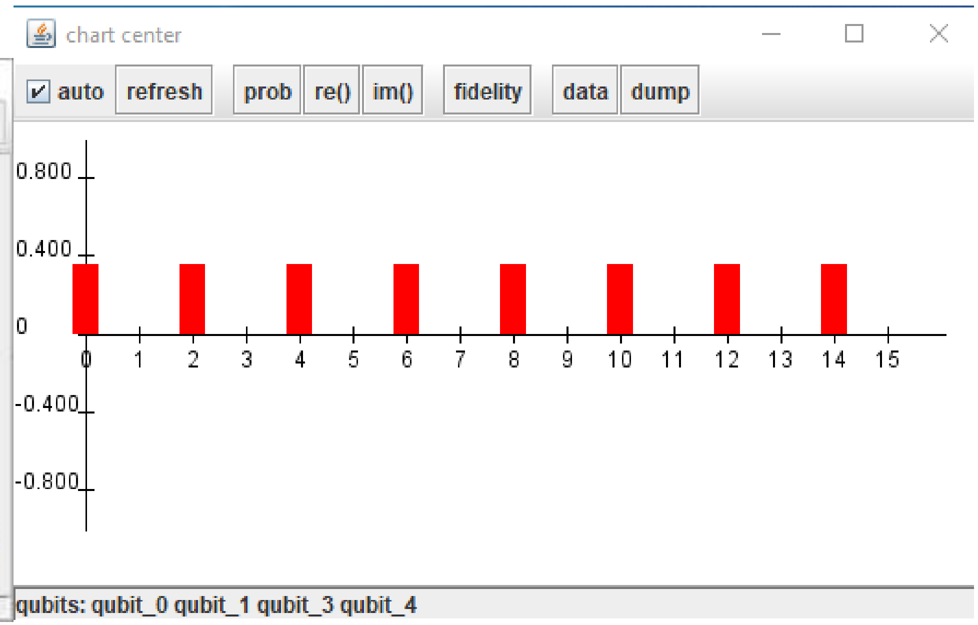
Initialization



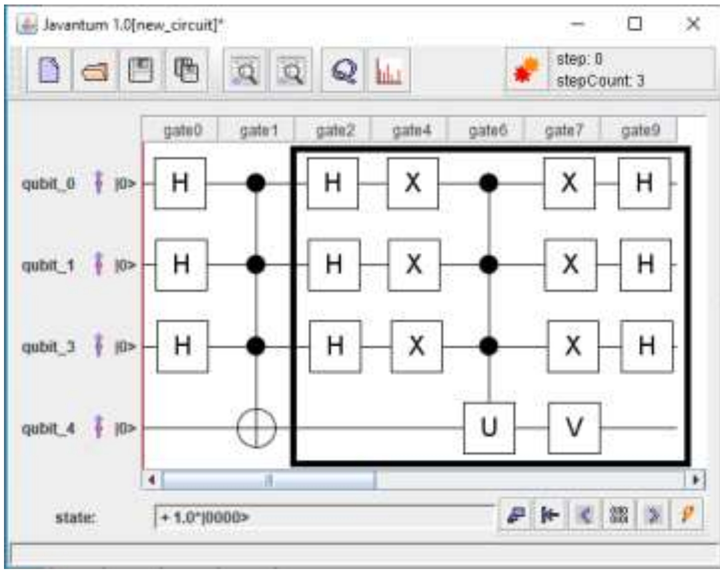


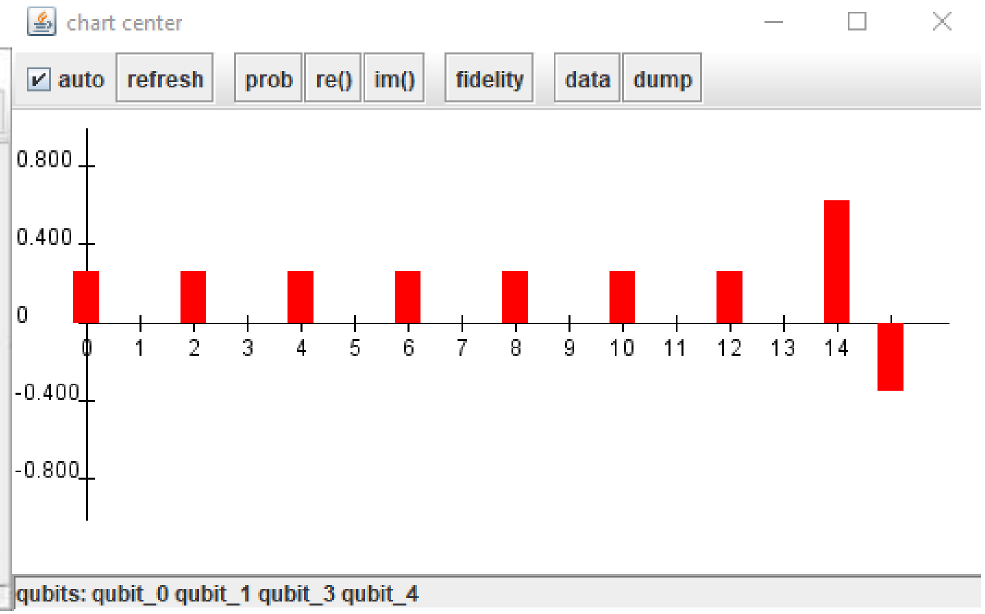
Superposition



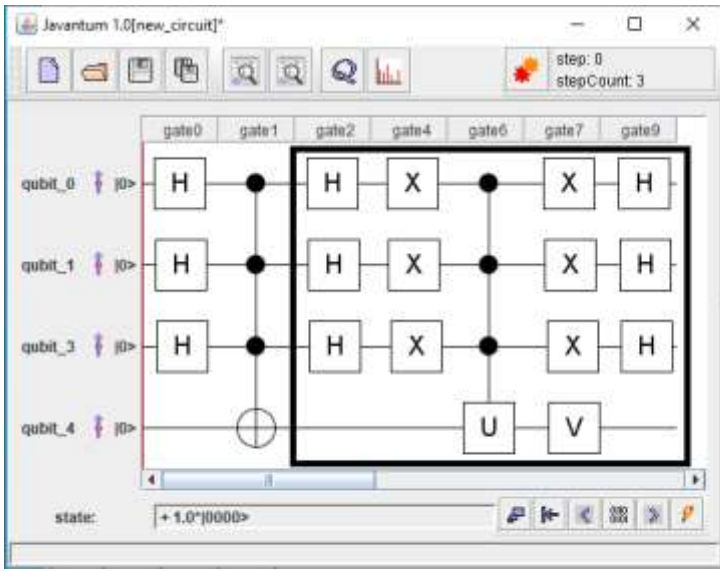


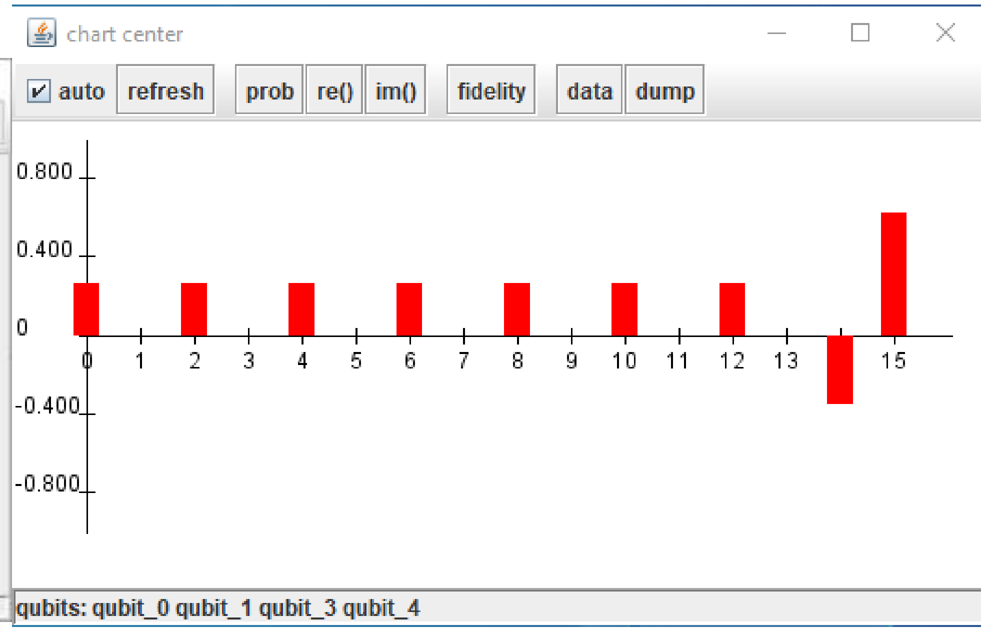
After 1st Iteration



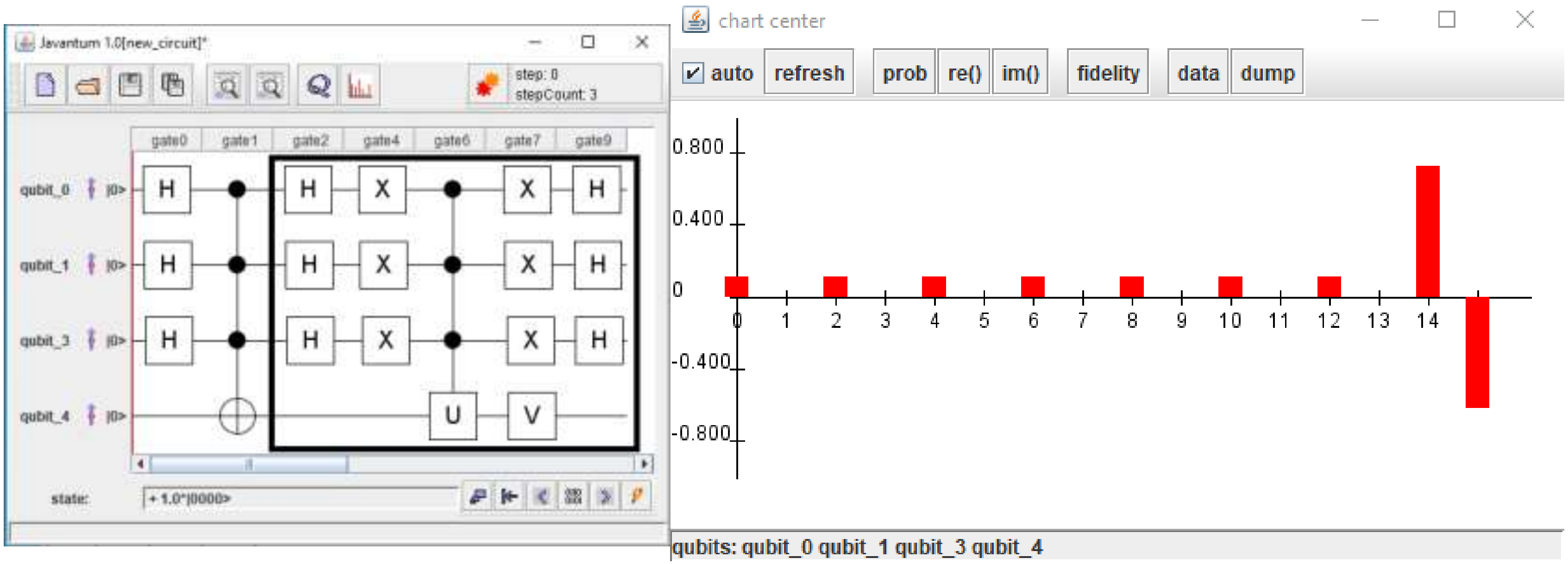


Itr 2: Apply U_f

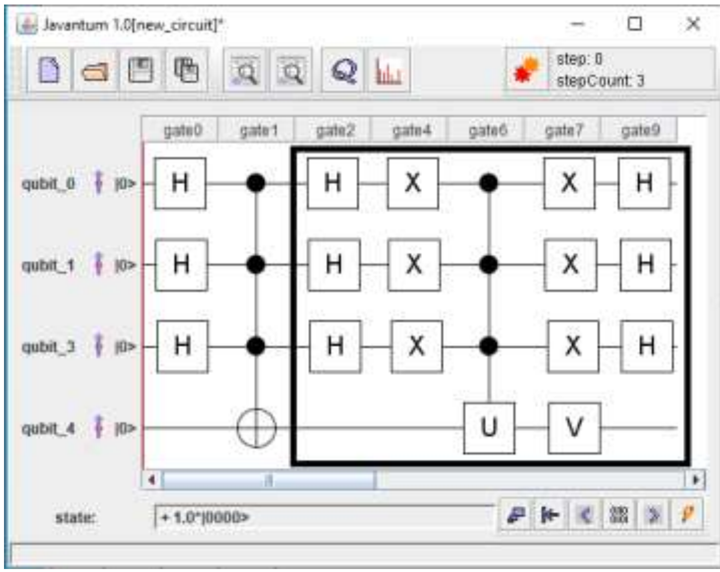


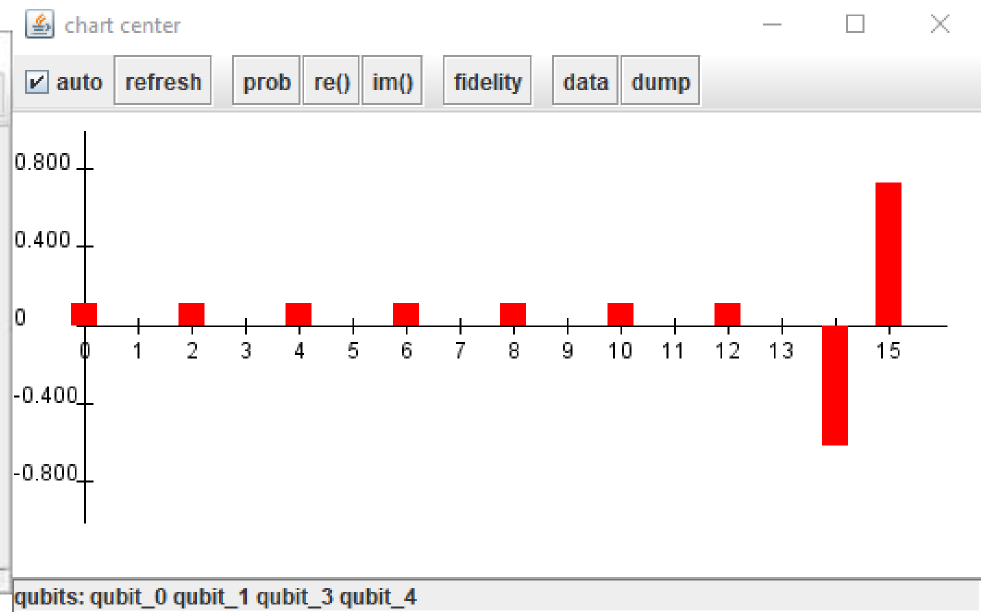


Itr 2: Apply P_{inv}

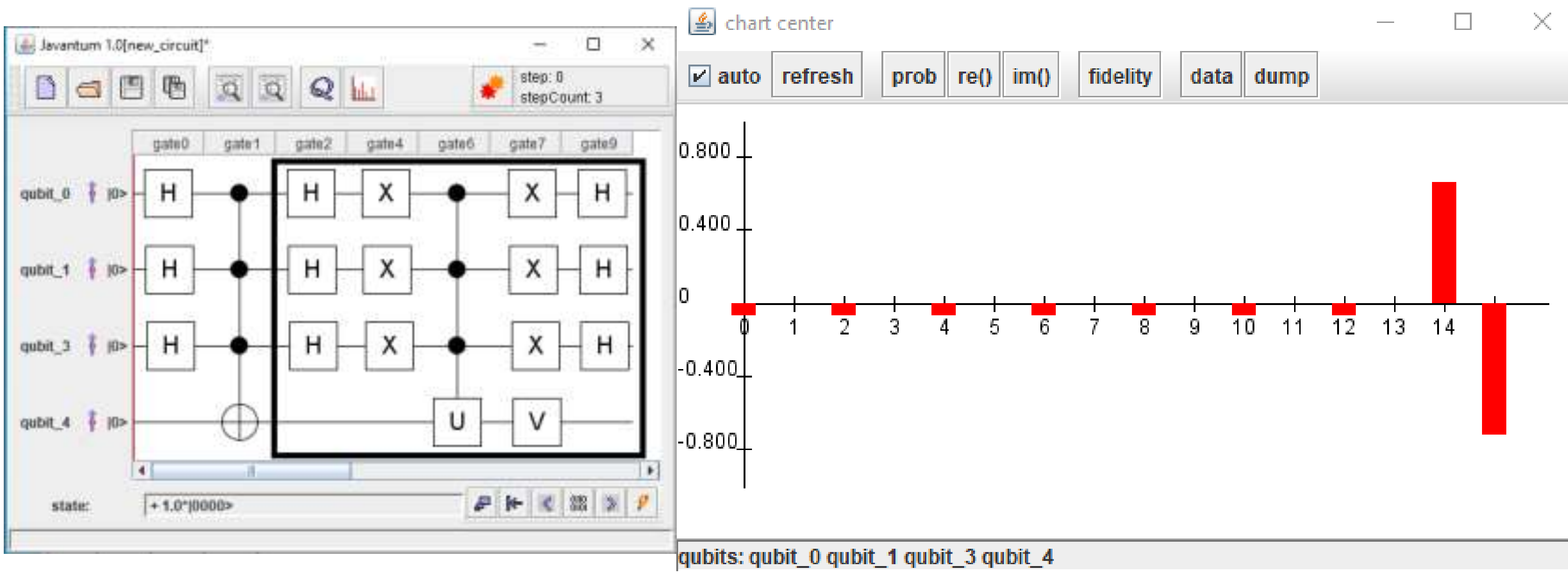


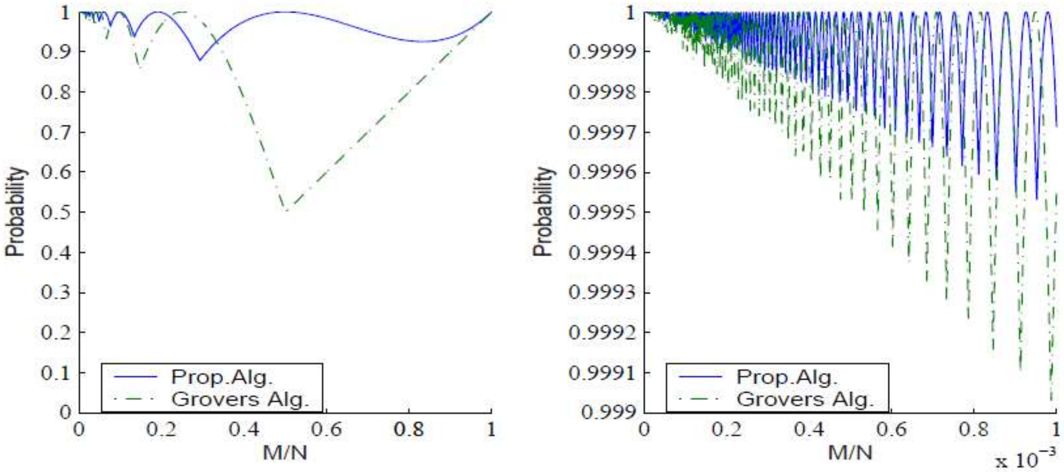
Itr 3: Apply U_f



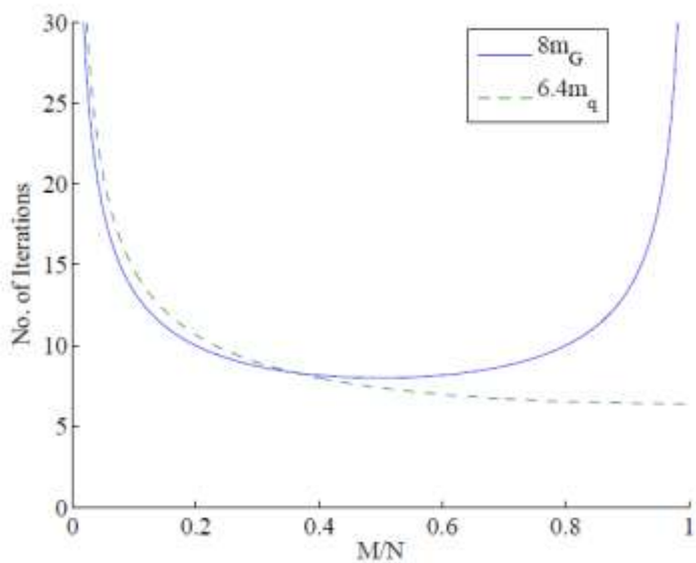


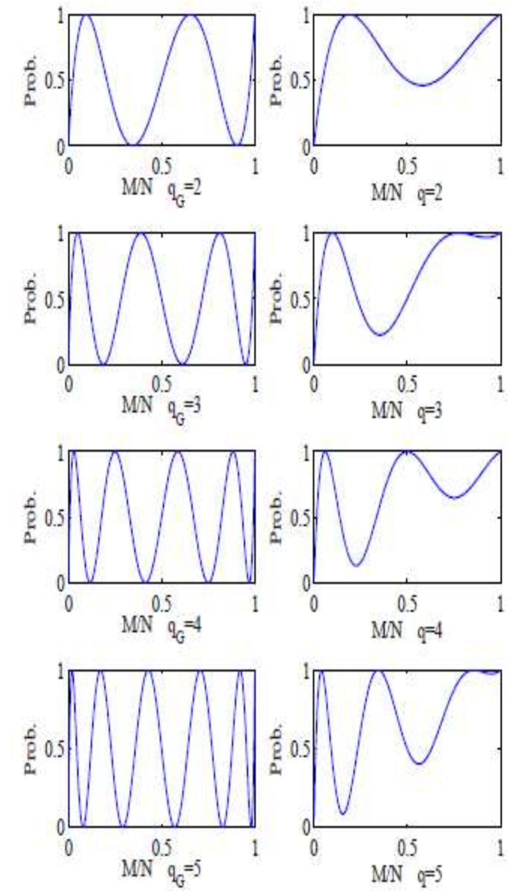
Itr 3: Apply P_{inv}





Probability of success using the q_G and q for both algorithms: a. $0 < M/N \leq 1$ (left), b. $M/N < 1 \times 10^{-3}$ (right).





Probability of success after 2,…,5 iterations: Grover's algorithm (left), the proposed algorithm (right).

A different kind of quantum search

Lov K. Grover *
lkgrover@bell-labs.com
Bell Laboratories, Lucent Technologies,
600-700 Mountain Avenue, Murray Hill, NJ 07974

Abstract

The quantum search algorithm consists of an alternating sequence of selective inversions and diffusion type operations, as a result of which it can find a target state in an unsorted database of size N in only $\sqrt{N}$ queries. This paper shows that by replacing the selective inversions by selective phase shifts of $\frac{\pi}{3}$, the algorithm gets transformed into something similar to a classical search algorithm. Just like classical search algorithms the algorithm has a fixed point in state-space toward which it preferentially converges. In contrast, the quantum search algorithm moves uniformly in a two-dimensional state space. This feature leads to robust search algorithms and also to conceptually new schemes for error correction.

1 Introduction

> The quantum search algorithm is like baking a souffle . . . .
> you have to stop at just the right time or else it gets burnt [1]

Search algorithms can be described as a rotation of the state vector in 2-dimensional Hilbert space defined by the initial and the target vectors. As we describe later, any iterative quantum procedure *has* to be a continuos rotation in state space. In the original quantum search algorithm, the state vector uniformly goes from the initial to the target and unless we stop

*Research was partly supported by NSA & ARO under contract DAAG55-98-C-0040.

https://arxiv.org/abs/quant-ph/0503205

the same transformation. In amplitude amplification (2), exactly the same transformation is repeated and so unitarity does not permit any fixed point. In the phase shift algorithm (4), which is very similar to amplitude amplification, the transformation repeated in each step is slightly different due to the presence of each of the four operations $R_s, R_t, R_s^\dagger, R_t^\dagger$ and it hence gets around the unitarity condition that prevents amplitude amplification from having a fixed point.

5 Quantum searching amidst uncertainty

The original quantum search algorithm is known to be the best possible algorithm for exhaustive searching [6], [7] therefore no algorithm will be able to improve its performance. However, for applications other than exhaustive searching for a single item, this paper demonstrates that suitably modified algorithms may indeed provide better performance.

Consider the situation where a large fraction of the states are marked, but the precise fraction of marked states is not known. The goal is to find a single marked state with as high a probability as possible in a single query. For concreteness, say some unknown fraction, f , of the states are marked, with f uniformly distributed between 75% and 100% with equal probability.

In the following we show that the probability of failure for the new scheme is approximately one fourth that of the best (possible) classical scheme. Also,

Quantum Searching The best quantum search based algorithm for this problem that I could find in the literature was by Ahmed Younes et al [12]. This finds a solution with a probability of $(1-\cos\theta)\left(\frac{\sin^2(q+1)\theta}{\sin^2\theta}+\frac{\sin^2 q\theta}{\sin^2\theta}\right)$,

problem that I could find in the literature was by Ahmed Younes et al [12]. This finds a solution with a probability of $(1-\cos\theta)\left(\frac{\sin^2(q+1)\theta}{\sin^2\theta}+\frac{\sin^2 q\theta}{\sin^2\theta}\right)$,

Appl. Math. Inf. Sci. 7, No. 1, 93-98 (2013)

Applied Mathematics & Information Sciences
An International Journal

Towards More Reliable Fixed Phase Quantum Search Algorithm

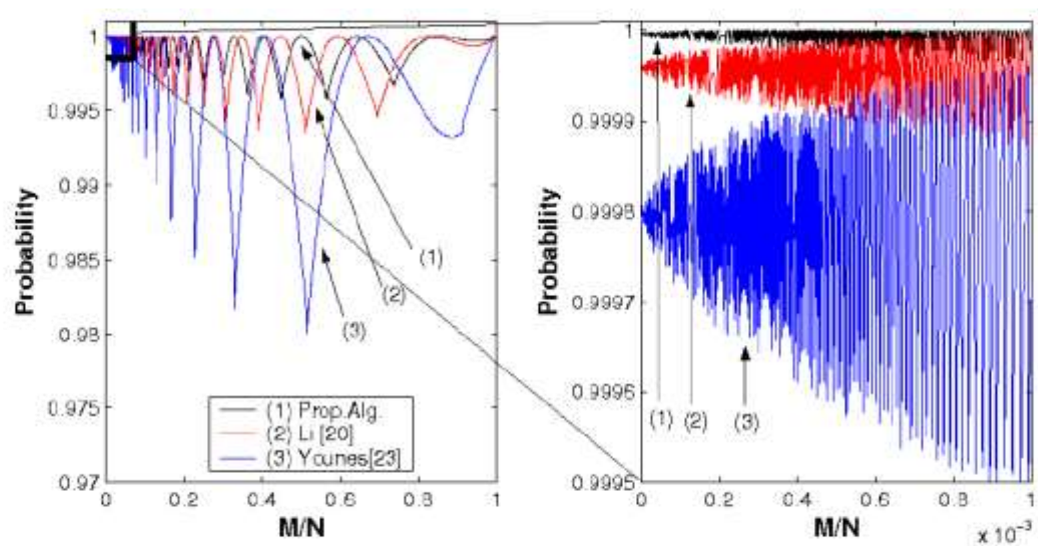
Ahmed Younes

Department of Mathematics and Computer Science, Faculty of Science, Alexandria University, Egypt

Received: 122 Jun 2012; Revised 21 Sep. 2012 ; Accepted 25 Sep. 2012
Published online: 1 Jan. 2013

Highlight

- **Fixed Phase**: F
  phase shifts se
- **Performance**:
  O(N/M) for sea
- **Applicability**:
  matches efficie
- **Significance**: I
  construction f



Comparing the probability of success of the proposed algorithm, Li [20] and Younes [23] algorithms after the required number of iterations for $0 < M \leq N$ (left) and for small M/N (right).

Journal of the Physical Society of Japan **88**, 124002 (2019)
https://doi.org/10.7566/JPSJ.88.124002

Different Fixed-Phases for Quantum Search Operators

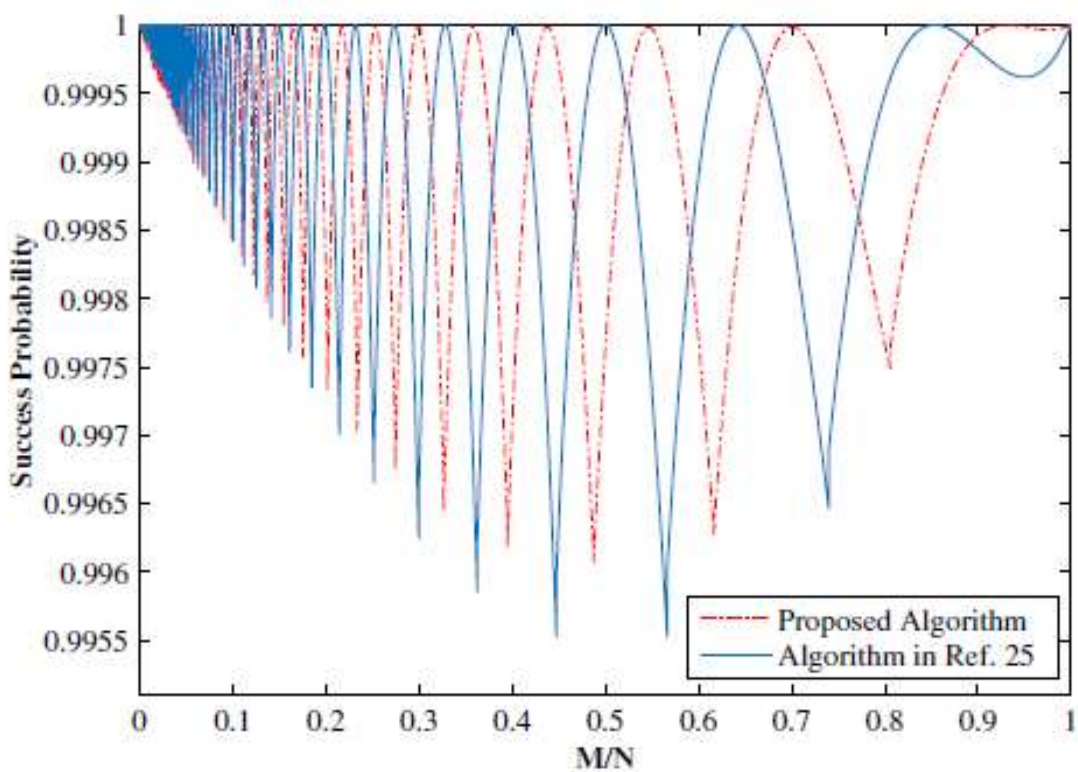
Sahar Q. Saleh[1*] and Ahmed Younes[1,2]

[1]*Department of Mathematics and Computer Science, Faculty of Science, Alexandria University, Egypt*
[2]*School of Computer Science, University of Birmingham, Birmingham B15 2TT, U.K.*

ıre.

b% for

Algorit	Large DB $N > 10^2$
Propos Algorit	99.61
	99.60
	99.59
	99.58
Ma et a	99.55
Youne	99.58
Li and l	99.34
Younes	98.00
Younes et	87.88
Ma et a	52.71
Grove	50.00



symmetry

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Article

Quantum Pattern Classification in a Three-Qubit System

Menna Elmasry [1,2,*], Ahmed Younes [1,2], Islam Elkabani [1,2,3], Ashraf Elsayed [1,2,3]

check for updates

Citation: Elmasry, M.; Younes, A.; Elkabani, I.; Elsayed, A. Quantum Pattern Classification in a Three-Qubit System. *Symmetry* **2023**, *15*, 883. https://doi.org/10.3390/sym15040883

Academic Editors: Durdu Guney and David Petrosyan

Received: 20 February 2023
Revised: 29 March 2023
Accepted: 6 April 2023
Published: 8 April 2023

[1] Department of Mathematics and Computer Science, Faculty of Science, Alexandria University, Alexandria 21511, Egypt; ayounes@alexu.edu.eg (A.Y.); islam.kabani@alexu.edu.eg (I.E.); ashraf.elsayed@alexu.edu.eg (A.E.)
[2] Alexandria Quantum Computing Group, Faculty of Science, Alexandria University, Alexandria 21511, Egypt
[3] Faculty of Computer Science and Engineering, Al Alamein International University, Al Alamein 51718, Egypt
[*] Correspondence: menna@alexu.edu.eg

- **Objective:** The study investigates the effectiveness of three quantum search algorithms—Grover's, partial diffusion, and fixed-phase algorithms—in **classifying patterns** in a three-qubit system.
- **Results:** The **partial diffusion operator outperformed** the other algorithms in incomplete superposition input states, achieving a 100% probability of correct classification in certain iterations.

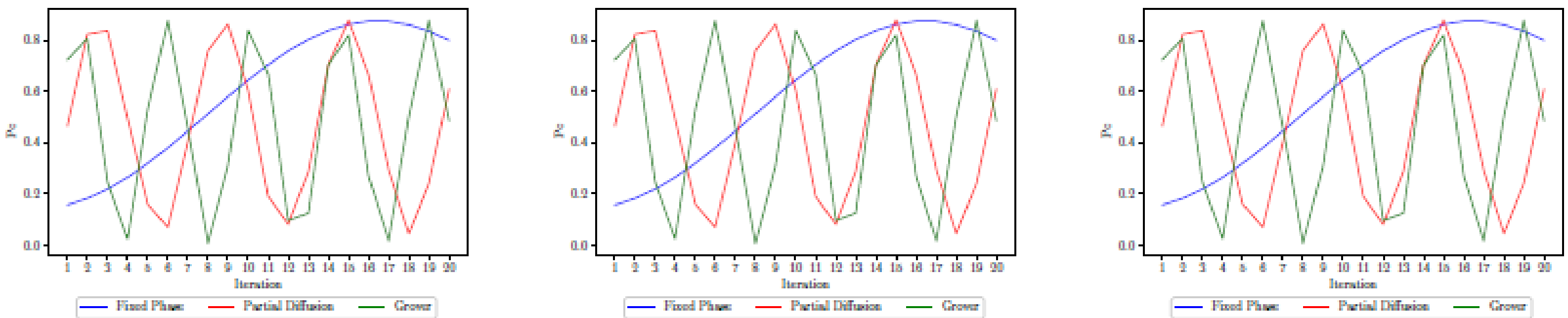

Figure . The probability of correct classification P_C after 20 iterations of Grover's, partial diffusion, and fixed-phase operators applied to $|\psi_{exc}\rangle = \frac{1}{\sqrt{7}}\{|000\rangle + |001\rangle + |011\rangle + |100\rangle + |101\rangle + |110\rangle + |111\rangle\}$, $|\psi_{exc}\rangle = \frac{1}{\sqrt{7}}\{|000\rangle + |001\rangle + |010\rangle + |100\rangle + |101\rangle + |110\rangle + |111\rangle\}$, and $|\psi_{exc}\rangle = \frac{1}{\sqrt{7}}\{|000\rangle + |001\rangle + |010\rangle + |011\rangle + |100\rangle + |101\rangle + |110\rangle\}$, respectively.

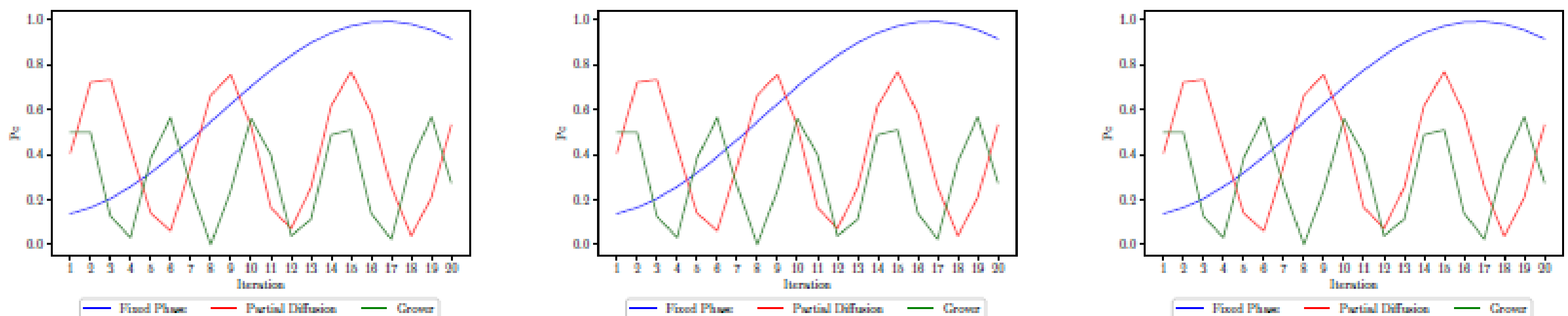

Figure . The probability of correct classification P_C after 20 iterations of Grover's, partial diffusion, and fixed-phase operators applied to $\left|\psi_{phi}\right\rangle = \frac{1}{\sqrt{8}}\{|000\rangle + |001\rangle - |010\rangle + |011\rangle + |100\rangle + |101\rangle + |110\rangle + |111\rangle\}$, $\left|\psi_{phi}\right\rangle = \frac{1}{\sqrt{8}}\{|000\rangle + |001\rangle + |010\rangle - |011\rangle + |100\rangle + |101\rangle + |110\rangle + |111\rangle\}$, and $\left|\psi_{phi}\right\rangle = \frac{1}{\sqrt{8}}\{|000\rangle + |001\rangle + |010\rangle + |011\rangle + |100\rangle + |101\rangle + |110\rangle - |111\rangle\}$, respectively.

Hussein et al., *Cogent Engineering* (2021), 8: 1882116
https://doi.org/10.1080/23311916.2021.1882116

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Received: 15 September 2020
Accepted: 24 December 2020

*Corresponding author: Hager Hussein, Department of Software Engineering, College of Computing and Information Technology, Arab Academy for Science and Technology, Alexandria, Egypt
E-mail: hager.hussein1@aast.edu; hager.hussein@gmail.com

Reviewing editor:
Duc Pham, chool of Mechanical Engineering, University of Birmingham, Birmingham, UK

FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Quantum algorithm for solving the test-suite minimization problem

Hager Hussein[1*], Ahmed Younes[2,3] and Walid Abdelmoez[1]

Highlights

- **Objective**: Proposes a quantum algorithm to minimize test suites in software engineering.
- **Method**: Utilizes amplitude amplification and two quantum search algorithms to efficiently find the minimum number of test cases needed to cover all requirements.
- **Outcome**: Achieves high probability solutions in O(√2^n) time, enhancing software testing efficiency and reducing redundancy in test cases.

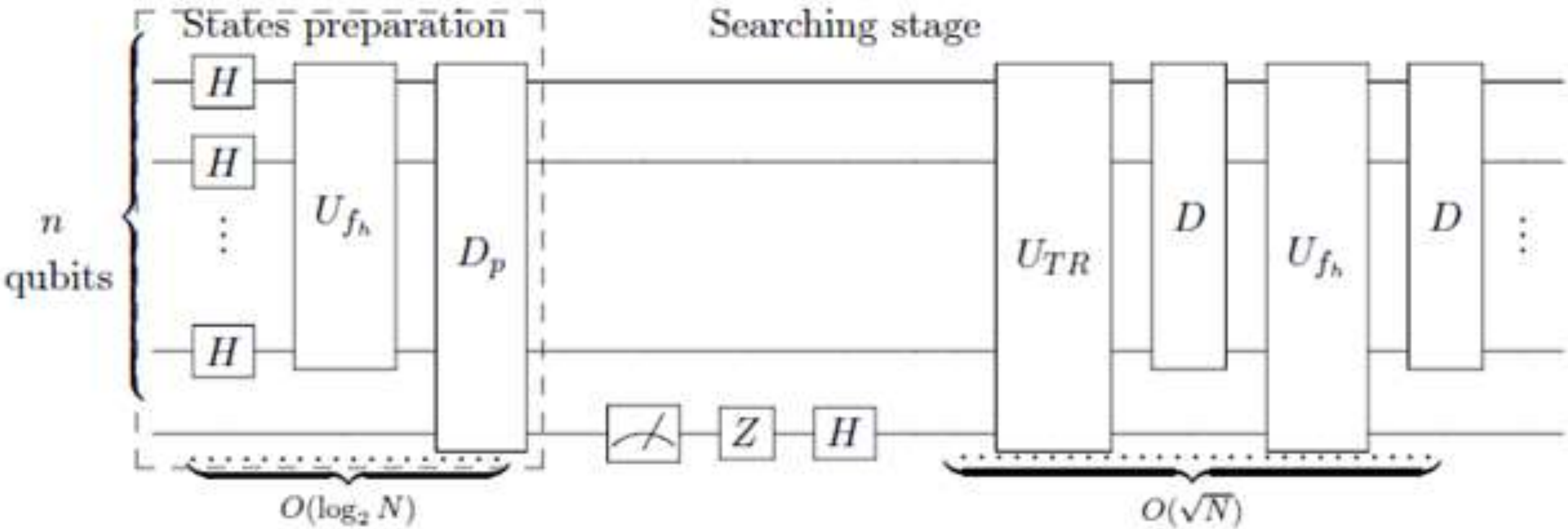

Figure 1. Quantum circuit for the proposed algorithm.

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Efficient quantum algorithms for set operations

Rehab Elgendy[1✉], Ahmed Younes[2,3,4], H. M. Abu-Donia[1,4] & R. M. Farouk[1,4]

Scientific Reports | (2024) 14:7015 | https://doi.org/10.1038/s41598-024-56860-2 nature portfolio 1

Highlights

- The paper presents four quantum algorithms for **set operations** on Boolean functions: **True Intersection, False Intersection, Difference, and Union**.
- Algorithms utilize amplitude amplification techniques, achieving O(√N) time complexity.
- Proposed algorithms outperform classical methods and enhance applications in **database systems, cryptography, and machine learning**.

True Intersection

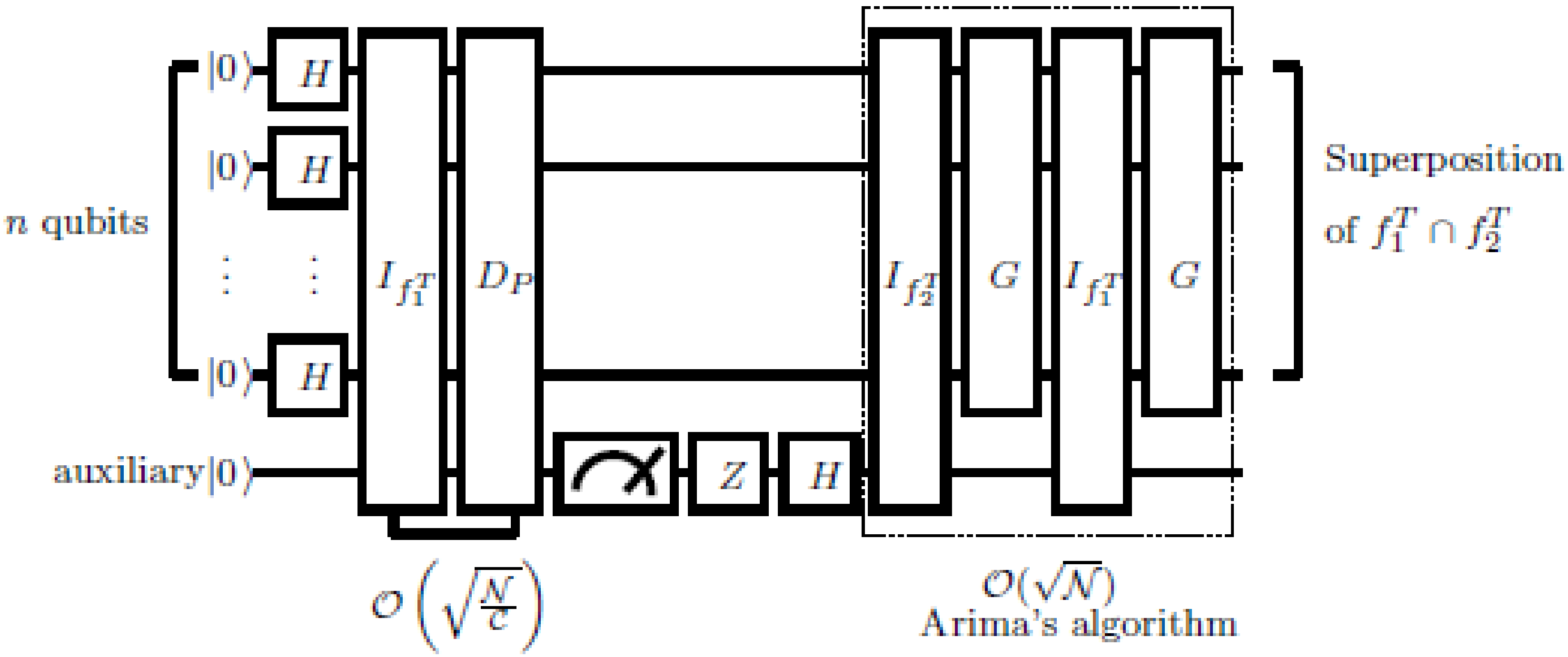

Figure 1. Quantum circuit for the proposed true intersection algorithm.

False Intersection

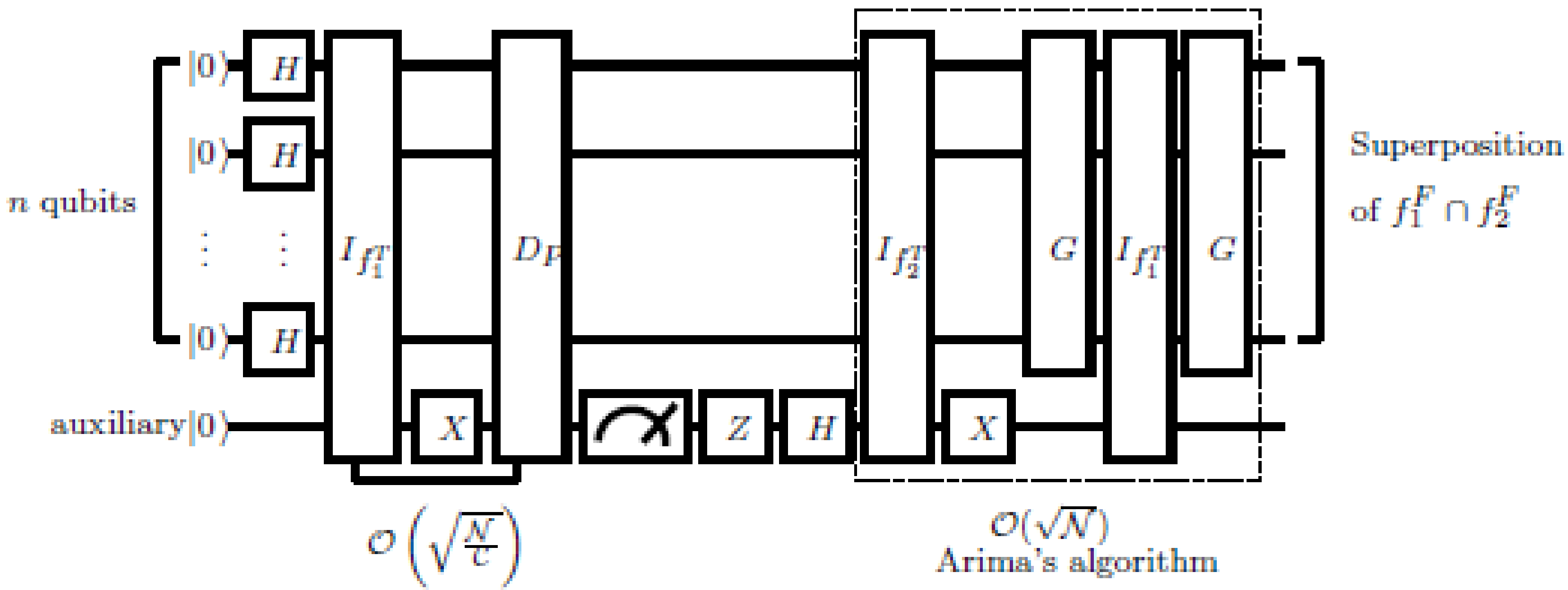

Figure 2. Quantum circuit for the proposed false intersection algorithm.

Difference

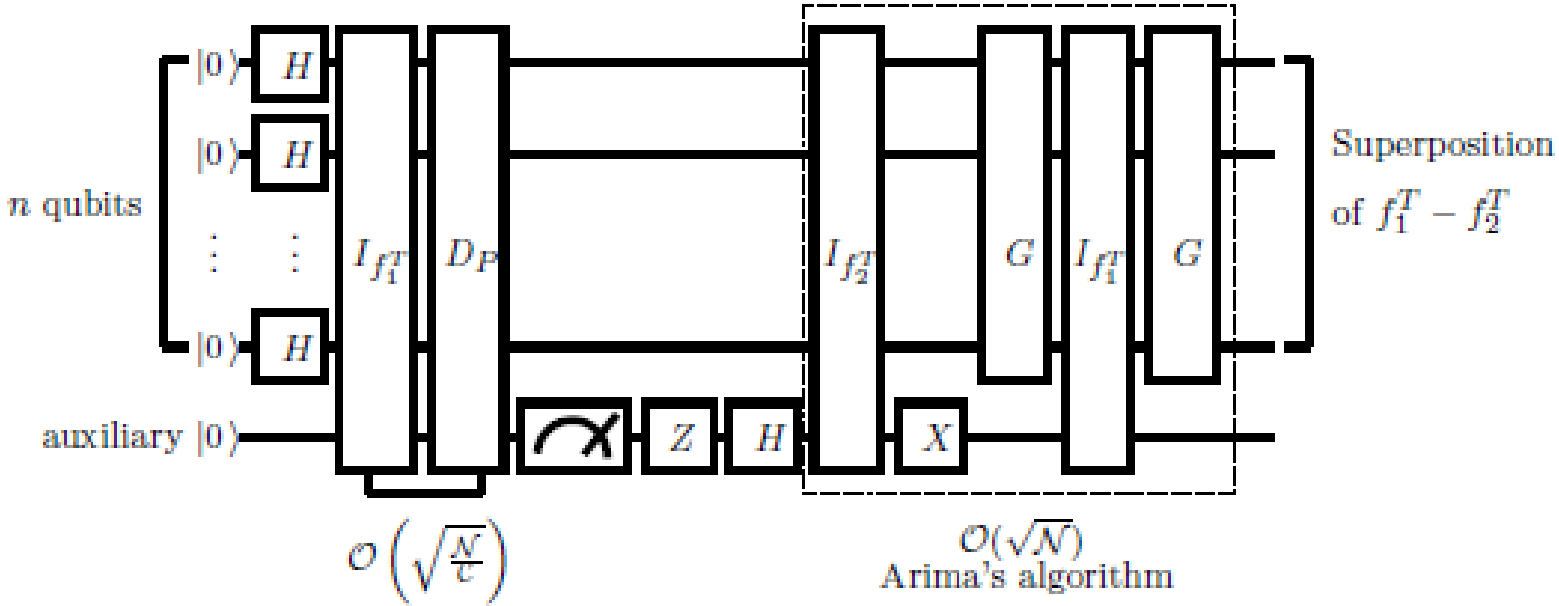

Figure 3. Quantum circuit for the proposed difference algorithm.

Union

$$f_1 \cup f_2 = ((f_1 \oplus 1) \cap (f_2 \oplus 1)) \oplus 1 = f \oplus 1$$

$$f = ((f_1 \oplus 1) \cap (f_2 \oplus 1))$$

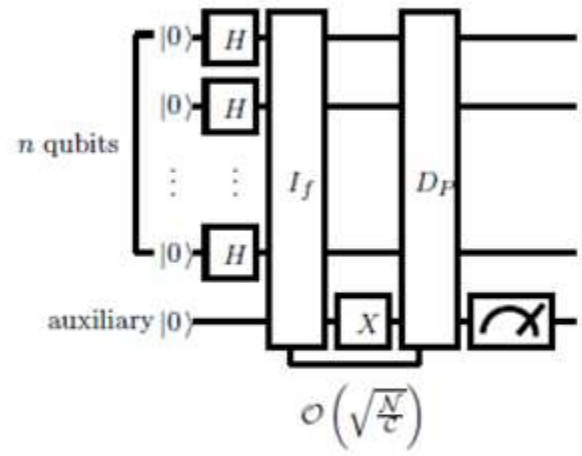

Figure 4. Quantum circuit to find the result of $f \oplus 1$.

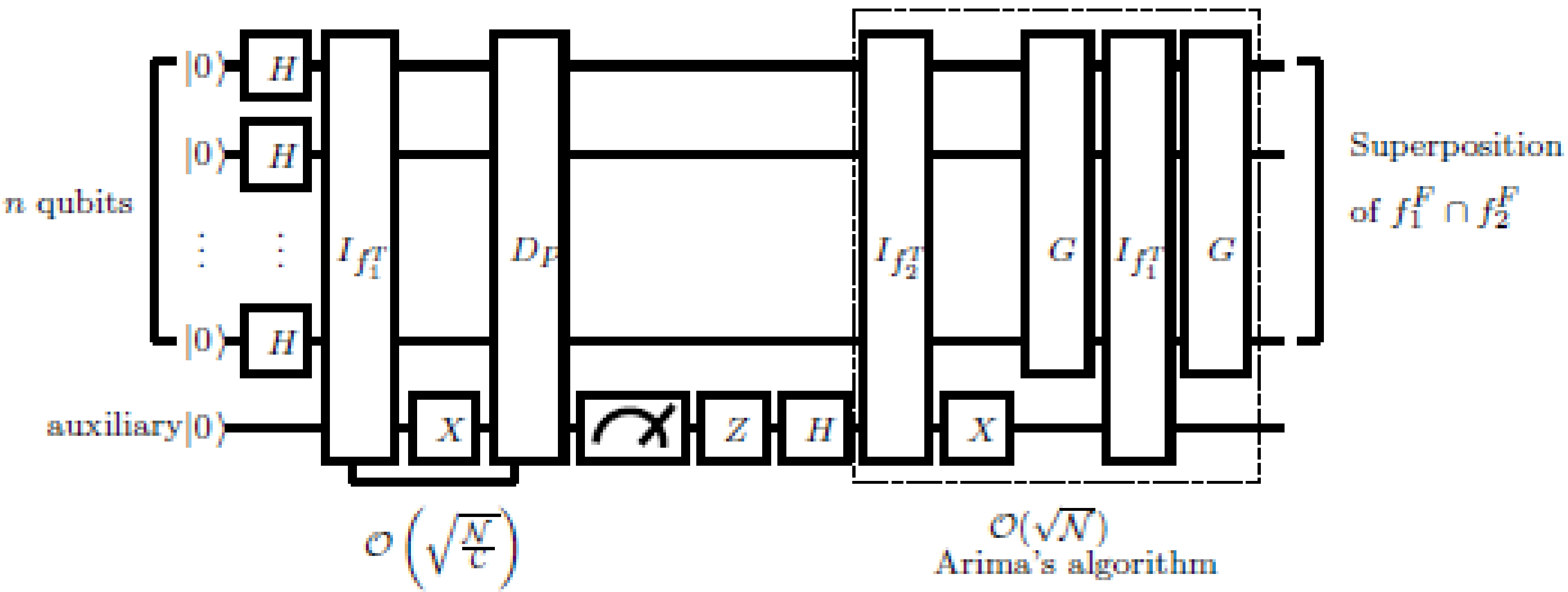

Figure 2. Quantum circuit for the proposed false intersection algorithm.

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Conferences > 2024 International Conference...

Quantum Answer Set Programming Solver Using Amplitude Amplification

Publisher: IEEE

Esraa Ebdelrehime ; Ahmed Younes ; Islam Elkabani **All Authors**

Published in: 2024 International Conference on Machine Intelligence and Smart Innovation (ICMISI)

Date of Conference: 12-14 May 2024

Date Added to IEEE *Xplore*: 11 July 2024

ISBN Information:

DOI: 10.1109/ICMISI61517.2024.10580520

Publisher: IEEE

Conference Location: Alexandria, Egypt

Highlights

- Objective: Propose a Quantum Answer Set Programming Solver (QASP) for NP-hard combinatorial search problems.
- Methodology: Reduces problems to MAX-3-SAT, solved using quantum algorithms with $O(\sqrt{2^n/m})$ steps.
- Advantages: Outperforms classical solvers and quantum annealing in efficiency and scalability.

Hamiltonian cycle problem

Th
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N-queen problem

The aim of this problem is to place N queens on an N x N

SAT (Boolean Satisfiability)

A Boolean formula is a logical expression that is composed of Boolean literals, logical operators such as AND, OR, and NOT, parentheses to group expressions and clauses, where each clause is a disjunction of literals (a variable or its negation).

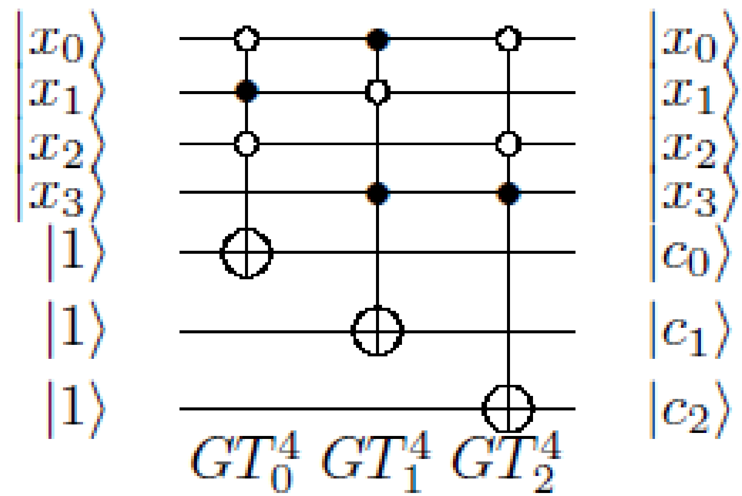
An n input k-CNF Boolean formula,

$$f(x_0, x_1, \dots, x_{n-1}) = C_0 \wedge C_1 \wedge \dots \dots \wedge C_{m-1}.$$

$$f(x_0, x_1, x_2) = c_0 \wedge c_1 \wedge c_2 \wedge c_3,$$

where,

$$c_0 = (\neg x_0 \vee \neg x_1 \vee \neg x_2),$$
$$c_1 = (\neg x_0 \vee x_1 \vee x_2),$$
$$c_2 = (x_0 \vee \neg x_1 \vee x_2),$$
$$c_3 = (x_0 \vee x_1 \vee x_2),$$



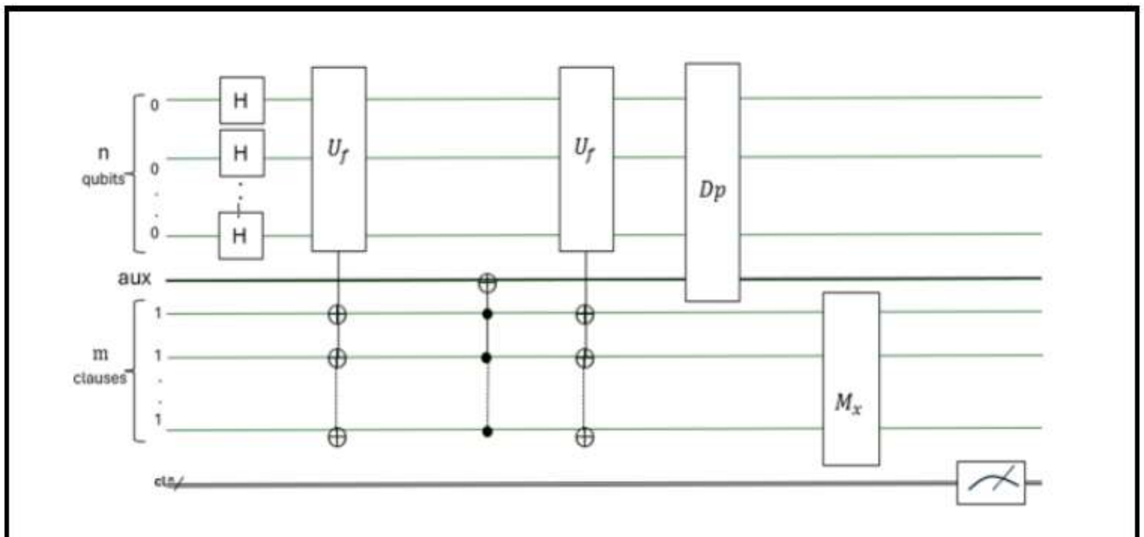


Figure : Quantum circuit for the proposed solver

Information Sciences 181 (2011) 329–334

Contents lists available at ScienceDirect

Information Sciences

journal homepage: www.elsevier.com/locate/ins

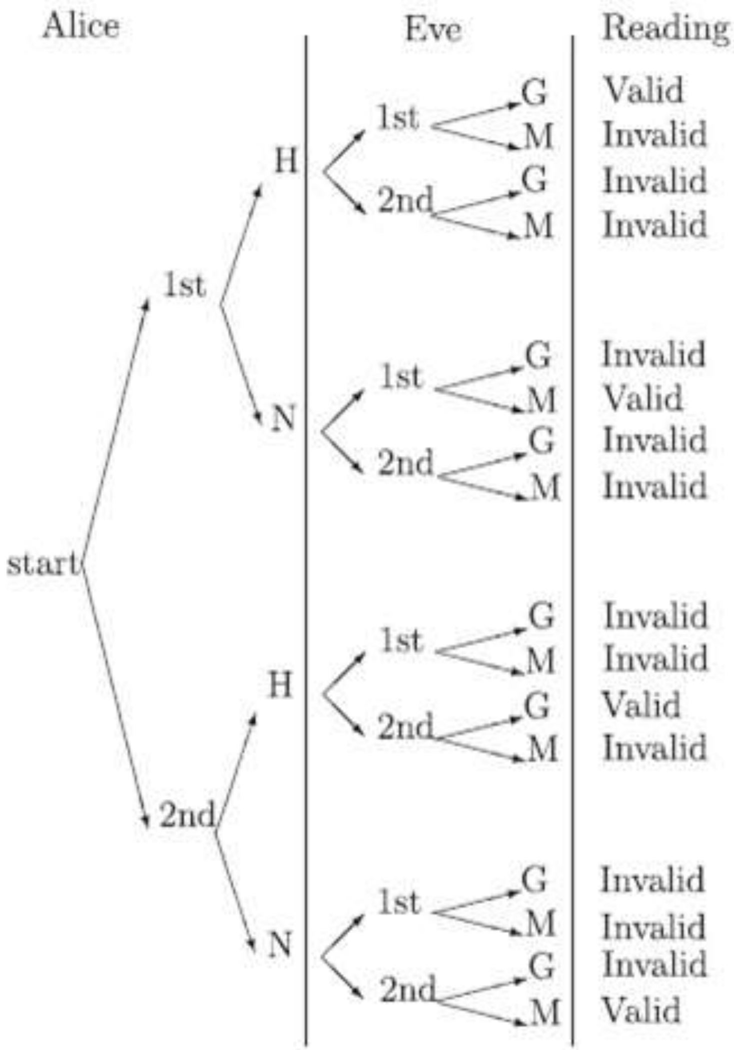
Enhancing the security of quantum communication by hiding the message in a superposition

A. Younes

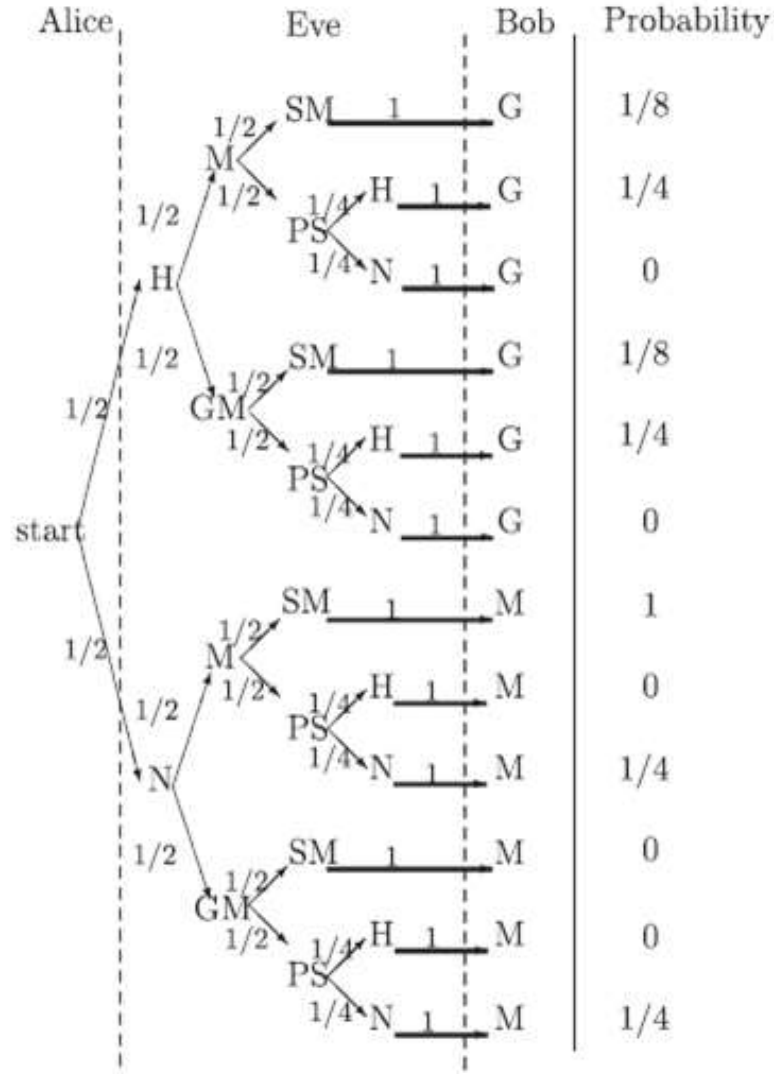
Department of Mathematics and Computer Science, Faculty of Science, Alexandria University, Alexandria, Egypt

Highlights

1. **Quantum State Hiding** of specific quantum states in superpositions, enhancing the security of encrypted messages during transmission.
2. **Fast Process** as the hiding and unhiding process is efficient, with a time complexity of O(1) for preparing a single qubit message.
3. **Eavesdropping Resistance** to Guarantee that any eavesdropper has a maximum chance of 25% to correctly guess the hidden message, ensuring high security.
4. **Flexible Protocol** because the transmission protocol allows for the use of multiple quantum channels and can be combined with existing encryption algorithms for improved security.



Probability of successful eavesdropping.



Tree of actions in the presence of eavesdropping.

Hiding quantum states

$$D_p = \left(W^{\otimes 2} \otimes I_1\right)(2|0\rangle\langle 0| - I_3)\left(W^{\otimes 2} \otimes I_1\right),$$

$$|\psi\rangle = \sum_{k=0}^{7} \delta_k |k\rangle = \sum_{j=0}^{3} \alpha_j (|j\rangle \otimes |0\rangle) + \sum_{j=0}^{3} \beta_j (|j\rangle \otimes |1\rangle),$$

where $\{\alpha_j = \delta_k : k \text{ even}\}$ and $\{\beta_j = \delta_k : k \text{ odd}\}$. Applying D_p on $|\psi\rangle$ gives,

$$D_p|\psi\rangle = D_p \sum_{k=0}^{7} \delta_k |k\rangle = \left(W^{\otimes 2} \otimes I_1\right)(2|0\rangle\langle 0| - I_3)\left(W^{\otimes 2} \otimes I_1\right) \sum_{k=0}^{7} \delta_k |k\rangle$$

$$= \sum_{j=0}^{3} (2\langle\alpha\rangle - \alpha_j)(|j\rangle \otimes |0\rangle) - \sum_{j=0}^{3} \beta_j (|j\rangle \otimes |1\rangle),$$

Showing hidden states

$$G = W^{\otimes 2}(2|0\rangle\langle 0| - I_2)W^{\otimes 2},$$

$$|\psi\rangle = \sum_{j=0}^{3} \alpha_j |j\rangle.$$

Applying the Grover's operator, G, on $|\psi\rangle$ gives,

$$G|\psi\rangle = \sum_{j=0}^{3} [-\alpha_j + 2\langle\alpha\rangle]|j\rangle,$$

where, $\langle\alpha\rangle = \frac{1}{4}\sum_{j=0}^{3}\alpha_j$ is the mean of the amplitudes of the states in the superposition,

$$\alpha_j \to [-\alpha_j + 2\langle\alpha\rangle].$$

To understand the purpose of using G, consider the following cases:

1– If the system is in the form,

$$|\psi\rangle = \frac{1}{2}(|00\rangle + |01\rangle + |10\rangle + |11\rangle),$$

then $\langle\alpha\rangle = \frac{1}{2}$ and applying G has no effect on the system.

2– If the system is in the form,

$$|\psi\rangle = |x\rangle,$$

such that $x \in \{00, 01, 10, 11\}$ then $\langle\alpha\rangle = \frac{1}{4}$.

3– If the system is in the form,

$$|\psi\rangle = \frac{1}{\sqrt{2}}(|x\rangle + |y\rangle),$$

PLOS ONE

OPEN ACCESS

Citation: Elias B, Younes A (2021) Enhanced quantum signature scheme using quantum amplitude amplification operators. PLoS ONE 16(10): e0258091. https://doi.org/10.1371/journal.pone.0258091

Editor: M. Usman Ashraf, University of Management and Technology, PAKISTAN

Received: December 17, 2020

Accepted: September 19, 2021

Published: October 8, 2021

RESEARCH ARTICLE

Enhanced quantum signature scheme using quantum amplitude amplification operators

Basma Elias[1,2]*, **Ahmed Younes**[2,3,4]

1 Department of Mathematics, Faculty of Education, Alexandria University, Alexandria, Egypt, **2** Academy of Scientific Research and Technology(ASRT), Cairo, Egypt, **3** Department of Mathematics and Computer Science, Faculty of Science, Alexandria University, Alexandria, Egypt, **4** School of Computer Science, University of Birmingham, Birmingham, United Kingdom

- Quantum signature is the use of the principles of quantum computing to establish a trusted communication between two parties

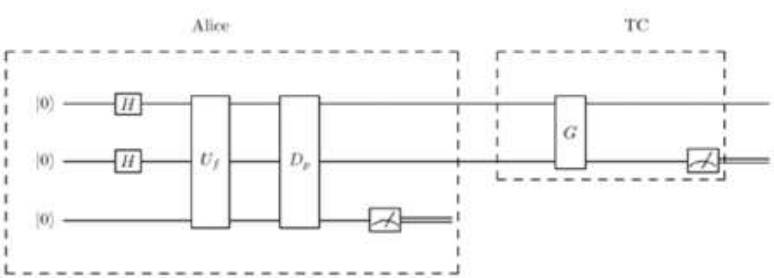


Fig . A quantum circuit to send binary-1 on the second qubit where the data is hidden.

https://doi.org/10.1371/journal.pone.0258091.g004

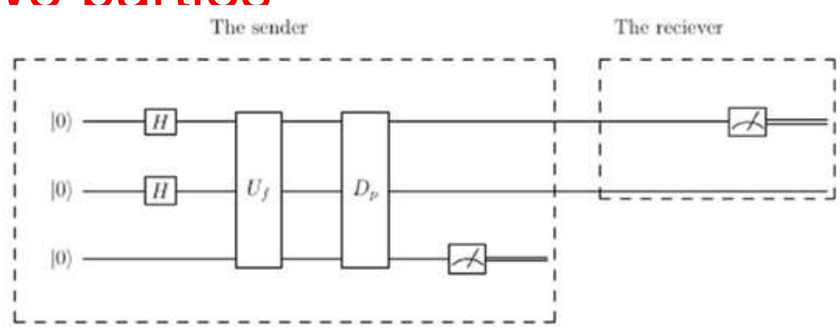


Fig . A quantum circuit to send the data on the first qubit where the data is not hidden.

https://doi.org/10.1371/journal.pone.0258091.g005

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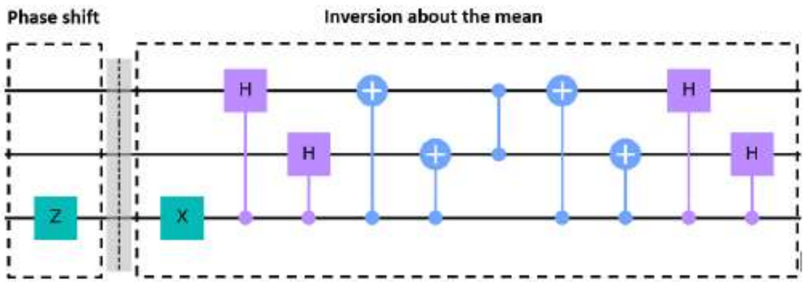
Multidisciplinary | Rapid Review | Open Access Journal

Received April 4, 2022, accepted May 3, 2022, date of publication May 9, 2022, date of current version May 13, 2022.
Digital Object Identifier 10.1109/ACCESS.2022.3173645

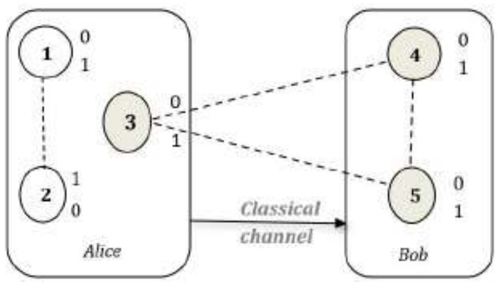
A Secured Quantum Two-Bit Commitment Protocol for Communication Systems

MANAL KHAWASIK[1], WAGDY ELSAYED[1], MAGDI RASHAD[2], AND AHMED YOUNES[1,3,4]
[1]Department of Mathematics and Computer Science, Faculty of Science, Alexandria University, Alexandria 21544, Egypt
[2]Department of Computer Science, Faculty of Computers and Information Systems, Mansoura University, Mansoura 35516, Egypt
[3]School of Computer Science, University of Birmingham, Birmingham B15 2TT, U.K.
[4]Alexandria Quantum Computing Group, Faculty of Science, Alexandria University, Alexandria 21544, Egypt
Corresponding author: Manal Khawasik (manal.khawasik@alexu.edu.eg)

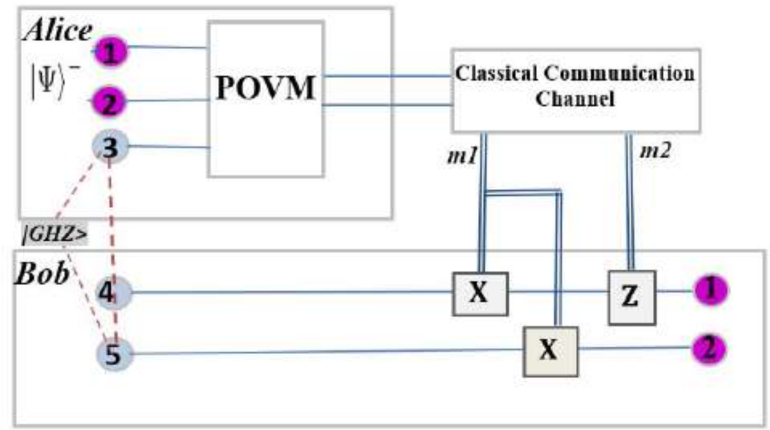
- **Focus**: Proposes a secure quantum two-bit commitment protocol involving a committer (Alice) and a receiver (Bob) using quantum and classical channels.
- **Key Phases**: Commitment and revealing phases ensuring binding and concealing conditions.
- **Security**: Utilizes quantum states in superposition and unitary transformations to prevent cheating and eavesdropping.
- **Verification**: Success verified by comparing outputs from both parties.



The circuit implementation of the partial diffusion operator $\mathcal{D}_{\mathcal{P}}$. The phase shift is performed on the subsystem that is entangled with the third qubit in state $|1\rangle$, followed by the inversion about the mean that is performed on the subsystem entangled by $|0\rangle$.



A two-qubit teleportation scenario. Alice comprises the first three particles where particle 3 is entangled with Bob in a *GHZ* state. The solid line represents the classical channel whereas the dashed lines denote the *GHZ* state.



A description of the two-qubit teleportation scheme using *GHZ* state as a quantum channel where the solid lines represent the quantum paths whereas the double solid lines denote the classical paths.

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MDPI

Article

A Secured Half-Duplex Bidirectional Quantum Key Distribution Protocol against Collective Attacks

Manal Khawasik [1,2,*], Wagdy Gomaa El-Sayed [1], M. Z. Rashad [3] and Ahmed Younes [1,2,4]

check for updates

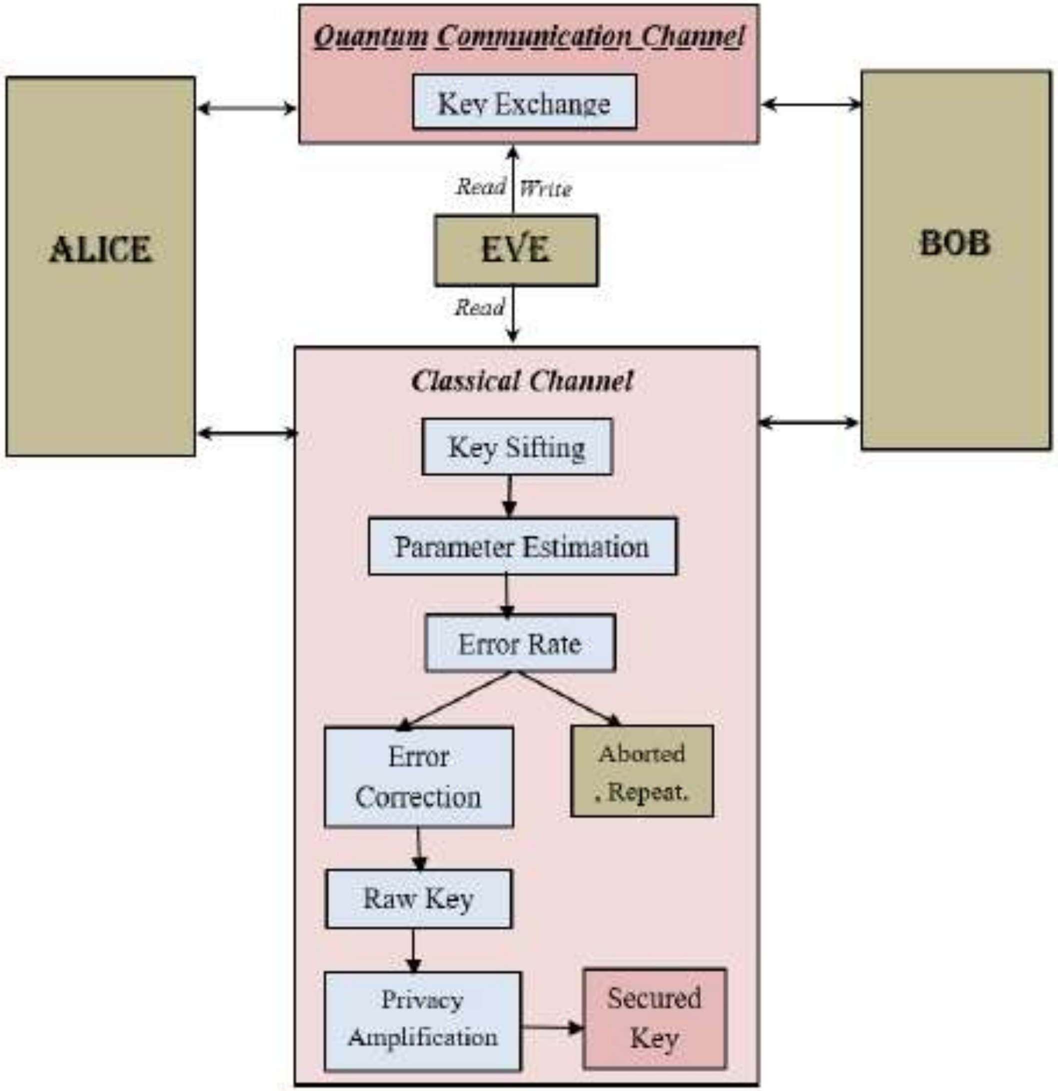
Citation: Khawasik, M.; El-Sayed, W.G.; Rashad, M.Z.; Younes, A. A Secured Half-Duplex Bidirectional Quantum Key Distribution Protocol against Collective Attacks. *Symmetry* **2022**, *14*, 2481. https://doi.org/10.3390/sym14122481

Received: 20 October 2022
Accepted: 17 November 2022
Published: 23 November 2022

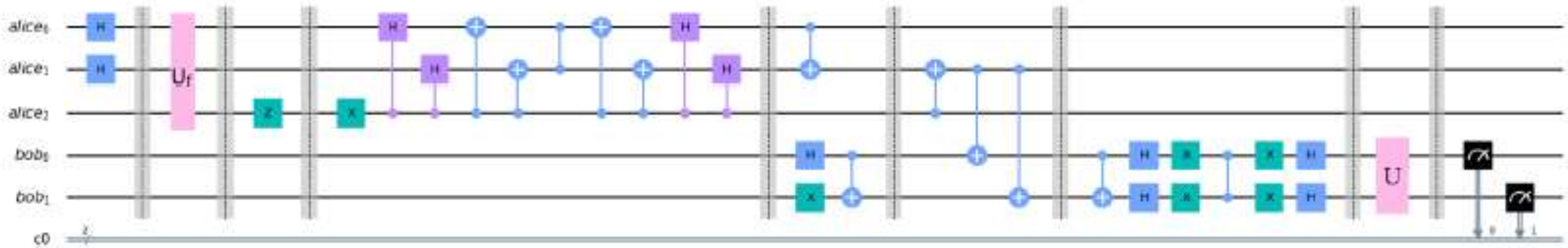
1 Department of Mathematics and Computer Science, Faculty of Science, Alexandria University, Alexandria 21544, Egypt
2 Alexandria Quantum Computing Group, Faculty of Science, Alexandria University, Alexandria 21544, Egypt
3 Department of Computer Science, Faculty of Computers and Information Systems, Mansoura University, Mansoura 35516, Egypt
4 School of Computer Science, University of Birmingham, Birmingham B15 2TT, UK
* Correspondence: manal.khawasik@alexu.edu.eg

Highlights

- **Protocol Design**: Uses a two-qubit state for encoding, with one qubit for the data and the other for the measurement basis. A partial diffusion operator hides the qubit state.
- **Security Against Collective Attacks**: Utilizes unitary transformations and the partial diffusion operator to prevent undetected interception and measurement.
- **Performance and Efficiency**: Achieves a high ratio of key bits to qubits, enhancing practical efficiency.



Main stages of the QKD protocol. The two parties share a quantum communication channel for key exchange, in addition to an authorized classical channel.



The circuit implementation of the forward direction in the proposed QKD protocol.

Table 4. Comparison of proposed half-duplex bidirectional QKD protocol.

	Lin et al. Protocol	Pan et al. Protocol	Proposed Protocol
Initial quantum resource	Reflection single photons	Two-physical qubit entangled state	Superposition of two states entangled with a GHZ state
Number of initial quantum states	Two	Three	Two
Qubit efficiency	$\frac{1}{24}$	$\frac{1}{18}$	$\frac{1}{14}$

Synthesis and Optimization of Quantum Circuits

INT. J. ELECTRONICS, VOL. 91, NO. 7, JULY 2004, 431–444

Taylor & Francis
Taylor & Francis Group

Representation of Boolean quantum circuits as Reed–Muller expansions

AHMED YOUNES* and JULIAN F. MILLER†

In this paper we show that there is a direct correspondence between Boolean quantum operations and certain forms of classical (non-quantum) logic known as Reed–Muller expansions. This allows us to readily convert Boolean circuits into their quantum equivalents. A direct result of this is that the problem of synthesis and optimization of Boolean quantum circuits can be tackled within the field of Reed–Muller logic.

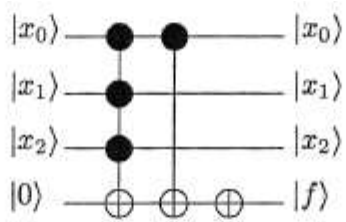


Figure : Quantum circuit implementation for $f(x_0, x_1, x_2) = \overline{x}$

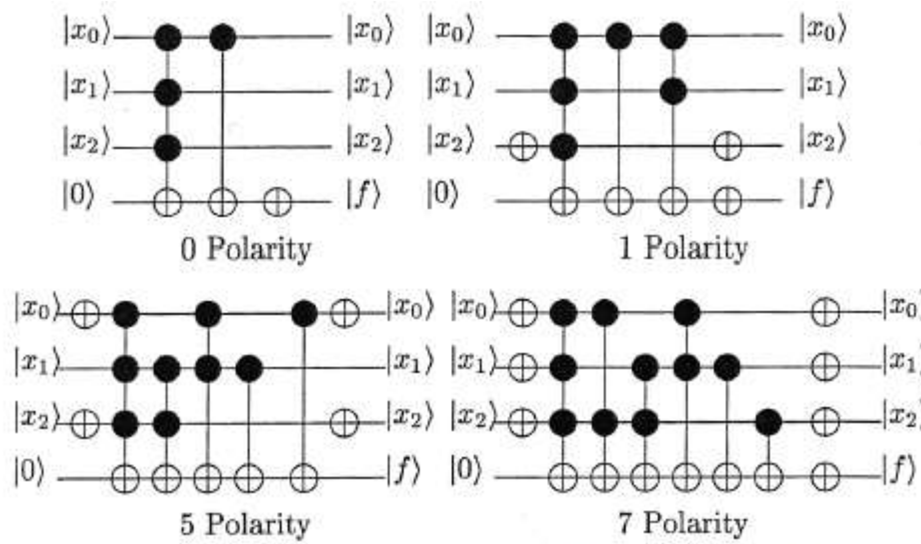
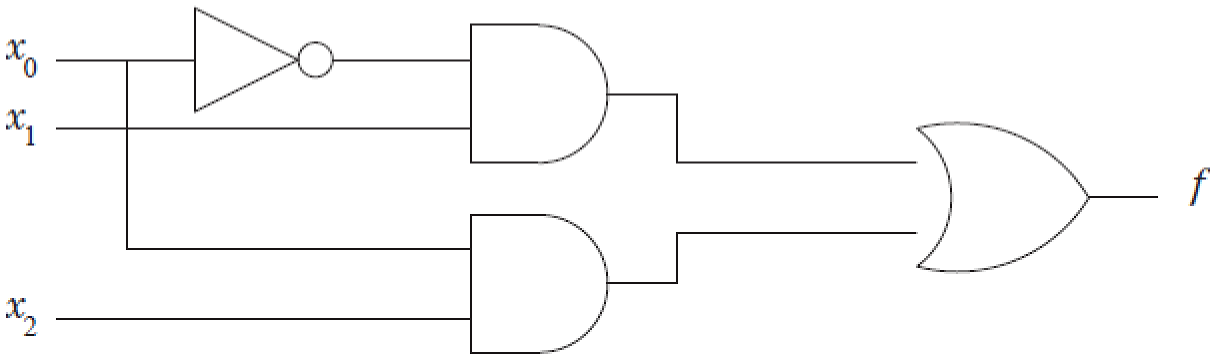


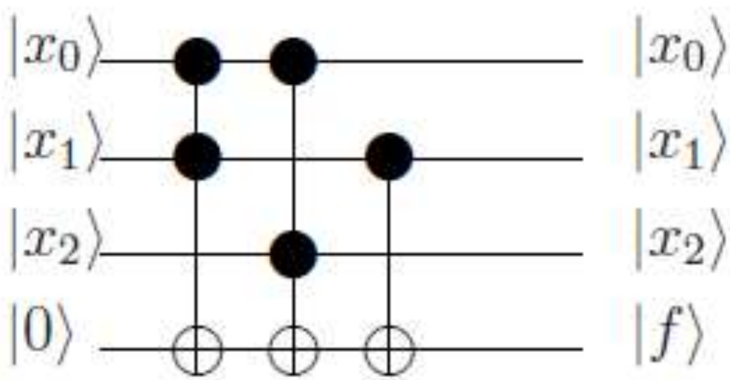
Figure 5. Quantum circuits for the Boolean function $f(x_0, x_1, x_2) = \overline{x}_0 + x_1 x_2$ with different

Boolean Quantum Circuits

$$f = \overline{x_0} x_1 + x_0 x_2$$



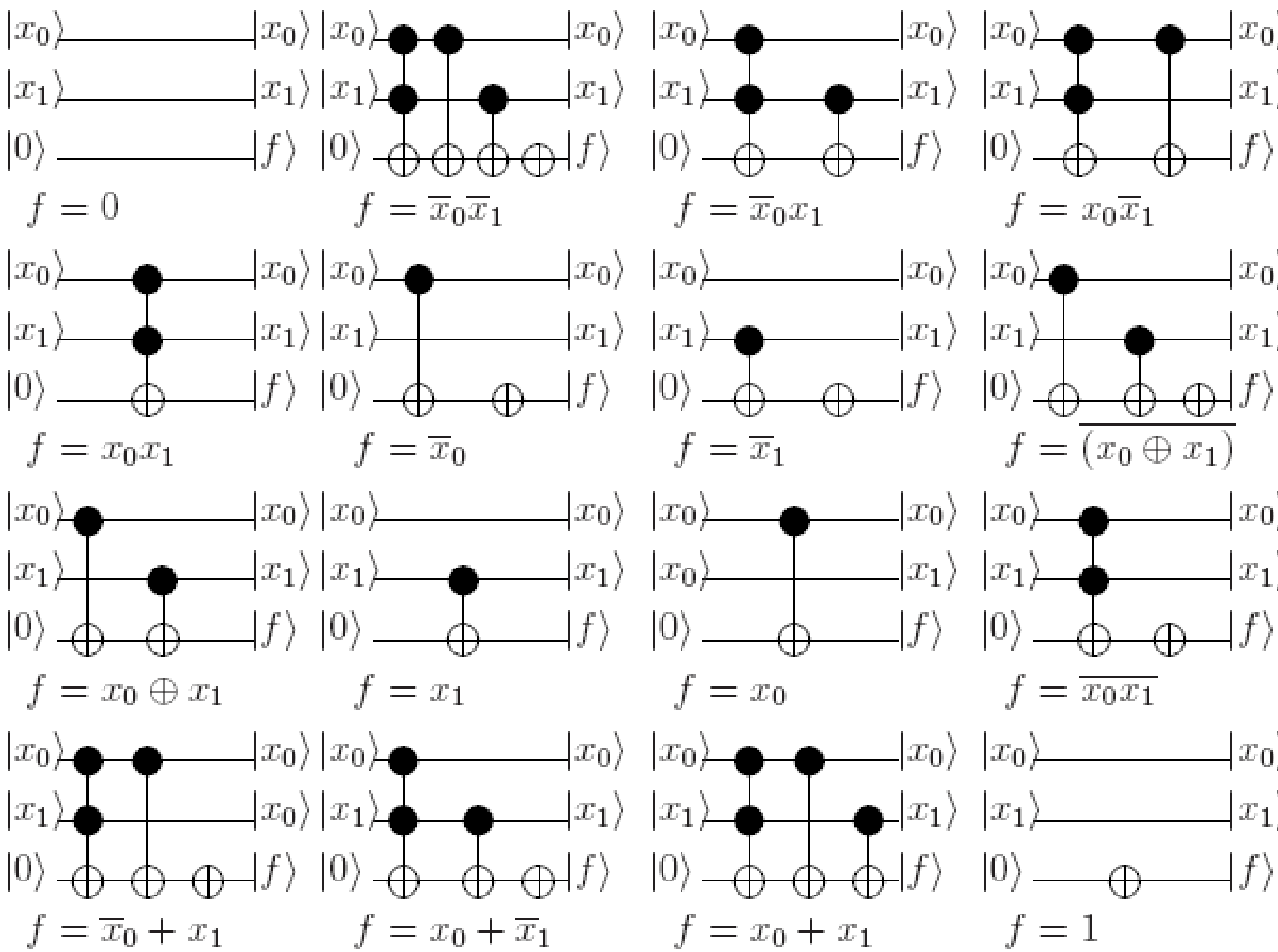
Digital circuit



Quantum circuit

x_0	x_1	x_2	f
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	0
1	1	1	1

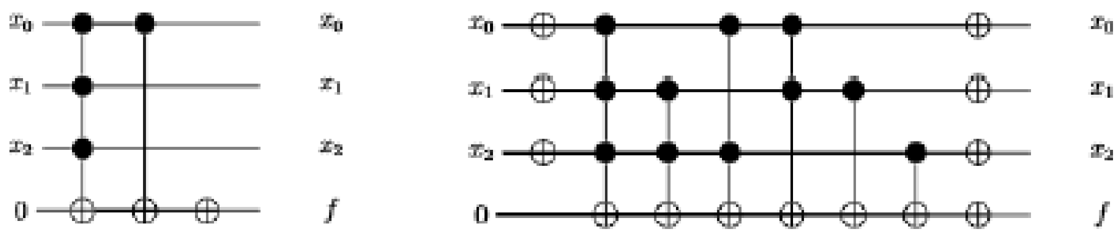
Two-qubits Boolean Circuits



ICaTAS 2019 IOP Publishing
Journal of Physics: Conference Series 1447 (2020) 012031 doi:10.1088/1742-6596/1447/1/012031

Enhancing the quantum cost of Reed-Muller Based Boolean quantum circuits using genetic algorithms

M Shaban[1,a], A Younes[2,3,b] and A Elsayed[2,c]



(a) (b)

Figure : Different Polarities for $f = x_0x_1x_2 \oplus x_0 \oplus 1$ and its quantum costs, (a) 0-Polarity, Quantum Cost = 15, $f = x_0x_1x_2 \oplus x_0 \oplus 1$, (b) 7-Polarity, Quantum Cost = 37 $f = x_0'x_1'x_2' \oplus x_0'x_2' \oplus x_1'x_2' \oplus x_0'x_1' \oplus x_1' \oplus x_2' \oplus 1$.

Appl. Math. Inf. Sci. 9, No. 5, 2579-2588 (2015) 2579
Applied Mathematics & Information Sciences
An International Journal
http://dx.doi.org/10.12785/amis/090542

On the Universality of n-bit Reversible Gate Libraries

Ahmed Younes[1,2,*]

[1] Department of Mathematics and Computer Science, Faculty of Science, Alexandria University, Alexandria, Egypt
[2] School of Computer Science, University of Birmingham, United Kingdom

Received: 10 Feb. 2015, Revised: 12 May 2015, Accepted: 13 May 2015
Published online: 1 Sep. 2015

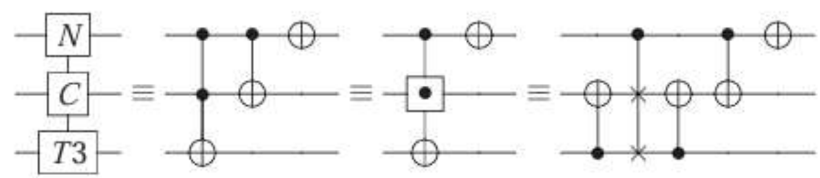


Fig. : Realization of $G3$ gate using different gates.

Journal of Circuits, Systems, and Computers
Vol. 19, No. 7 (2010) 1423–1434

DOI: 10.1142/S0218126610006736

REDUCING QUANTUM COST OF REVERSIBLE CIRCUITS FOR HOMOGENEOUS BOOLEAN FUNCTIONS*

AHMED YOUNES
Mathematics and Computer Science, Faculty of Science,
Alexandria University, Alexandria, Egypt
ayounes2@yahoo.com
A.Younes@sci.alex.edu.eg

International Journal of Theoretical Physics (2019) 58: 167–183
https://doi.org/10.1007/s10773-018-3921-1

New Design of Reversible Full Adder/Subtractor Using *R* Gate

Rasha Montaser[1] · Ahmed Younes[1,2] · Mahmoud Abdel-Aty[3,4]

Received: 23 June 2018 / Accepted: 5 October 2018 / Published online: 17 October 2018

Journal of Circuits, Systems, and Computers
Vol. 23, No. 3 (2014) 1450040 (22 pages)

DOI: 10.1142/S0218126614500406

TIGHT BOUNDS ON THE SYNTHESIS OF 3-BIT REVERSIBLE CIRCUITS: NFFr LIBRARY*

AHMED YOUNES
Mathematics and Computer Science, Faculty of Science,
Alexandria University, Alexandria, Egypt
ayounes2@yahoo.com; ayounes@alexu.edu.eg

Received 27 April 2013
Accepted 24 October 2013
Published 16 December 2013

International Journal of Theoretical Physics (2019) 32:2531–2549
https://doi.org/10.1007/s10773-019-04143-2

An Improved Design of *n*-Bit Universal Reversible Gate Library

Mohamed Osman[1] · Ahmed Younes[2,3] · Galal Ismail[4] · Roushdy Farouk[4]

Received: 14 December 2018 / Accepted: 6 May 2019 / Published online: 1 June 2019

Quantum Inf Process (2015) 14:1249–1263
DOI 10.1007/s11128-015-0929-9

Improving the quantum cost of NCT-based reversible circuit

Rasha Montaser · Ahmed Younes ·
Mahmoud Abdel-Aty

Quantum Inf Process (2017) 16:160
DOI 10.1007/s11128-017-1609-8

Reversible circuit synthesis by genetic programming using dynamic gate libraries

Mustapha Y. Abubakar[1,2] · Low Tang Jung[1] ·
Nordin Zakaria[1] · Ahmed Younes[3] ·
Abdel-Haleem Abdel-Aty[4]

Quantum Inf Process (2018) 17:104
https://doi.org/10.1007/s11128-018-1874-1

Improving the quantum cost of reversible Boolean functions using reorder algorithm

Taghreed Ahmed[1] · Ahmed Younes[1,2] Ashraf Elsayed[1]

International Journal of Theoretical Physics (2019) 32:2531–2549
https://doi.org/10.1007/s10773-019-04143-2

An Improved Design of *n*-Bit Universal Reversible Gate Library

Mohamed Osman[1] · Ahmed Younes[2,3] · Galal Ismail[4] · Roushdy Farouk[4]

symmetry MDPI

Article

Synthesis Strategy of Reversible Circuits on DNA Computers

Mirna Rofail [1,*] and Ahmed Younes [1,2]

symmetry MDPI

Article

Optimization of Reversible Circuits Using Toffoli Decompositions with Negative Controls

Mariam Gado [1,2,*] and Ahmed Younes [1,2,3]

IOP Publishing Phys. Scr. 100 (2025) 015102 https://doi.org/10.1088/1402-4896/ad943d

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Physica Scripta

PAPER

RECEIVED
11 July 2024

REVISED
14 November 2024

ACCEPTED FOR PUBLICATION
18 November 2024

PUBLISHED
29 November 2024

Multi-strategy based quantum cost reduction of quantum boolean circuits

Taghreed Ahmed[1,*], Ahmed Younes[1,2] and Islam Elkabani[1,3]

Applications of Partial Negation Operator

The Partial Negation Operator

Let X be the Pauli-X gate

$$X = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}.$$

|0> → |1>
|1> → |0>

The c^{th} partial negation operator V is the c^{th} root of the X gate and can be calculated using diagonalization as follows,

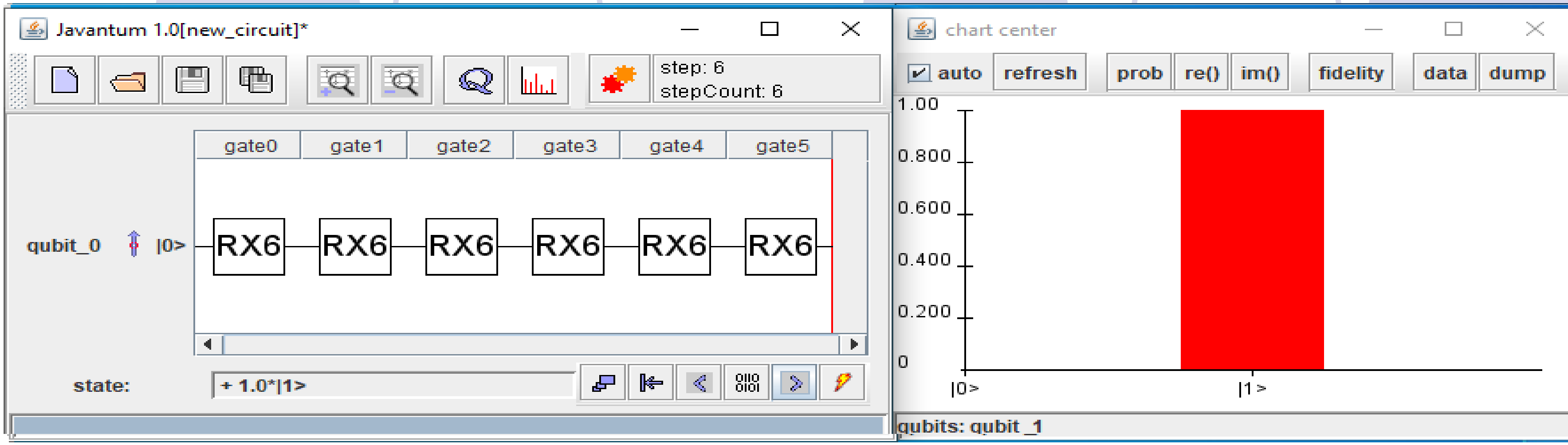
$$V = \sqrt[c]{X} = \frac{1}{2}\begin{bmatrix} 1+t & 1-t \\ 1-t & 1+t \end{bmatrix},$$

where $t = \sqrt[c]{-1}$, and applying V for d times on a qubit is equivalent to the operator,

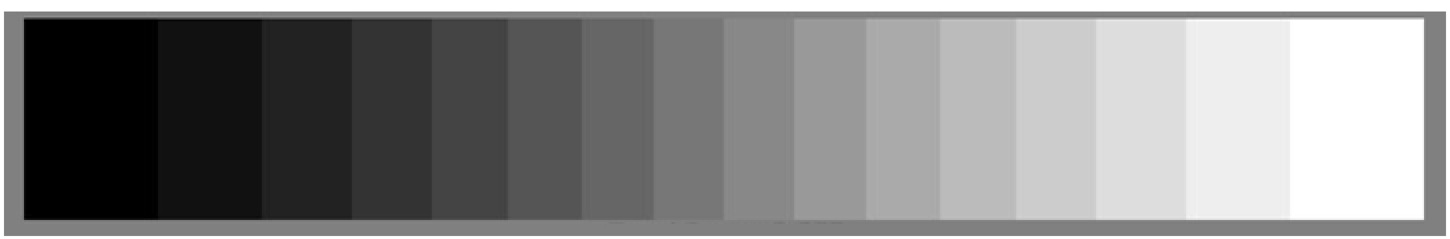
$$V^d = \frac{1}{2}\begin{bmatrix} 1+t^d & 1-t^d \\ 1-t^d & 1+t^d \end{bmatrix},$$

such that if $d = c$, then $V^d = X$.

Scaling the Negation



Gray Scale Levels



Quantum Image Processing

Multimedia Tools and Applications (2021) 80:34019–34034
https://doi.org/10.1007/s11042-021-11355-4

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Efficient representations of digital images on quantum computers

Norhan Nasr[1] · Ahmed Younes[1,2] · Ashraf Elsayed[1]

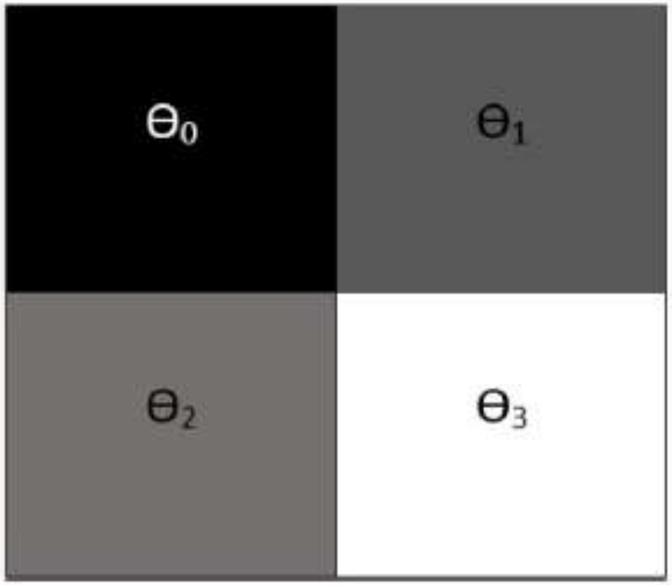
Received: 27 September 2020 / Revised: 9 February 2021 / Accepted: 26 July 2021 /
Published online: 31 August 2021

Abstract

Quantum image processing is the use of quantum computing to store, transmit, and process digital images on quantum computers. This paper introduces two enhanced quantum image representations to store quantum images. The first enhanced quantum representation based on the flexible representation for quantum images (EFRQI) is an amplitude representation that uses the partial negation operator to store the values of the pixels of $2^n \times 2^n$ image in the amplitudes of the qubits. The second enhanced quantum representation based on the novel enhanced quantum representation of digital images (ENEQR) is a basis state representation that uses the CNOT gate to store the values of the pixels in a qubit sequence. The proposed methods have better time complexity and quantum cost when compared with related models in the literature.

Keywords Quantum image processing · Quantum mechanics · Digital images · Quantum image representation

Representations of Digital Images on Quantum Computers

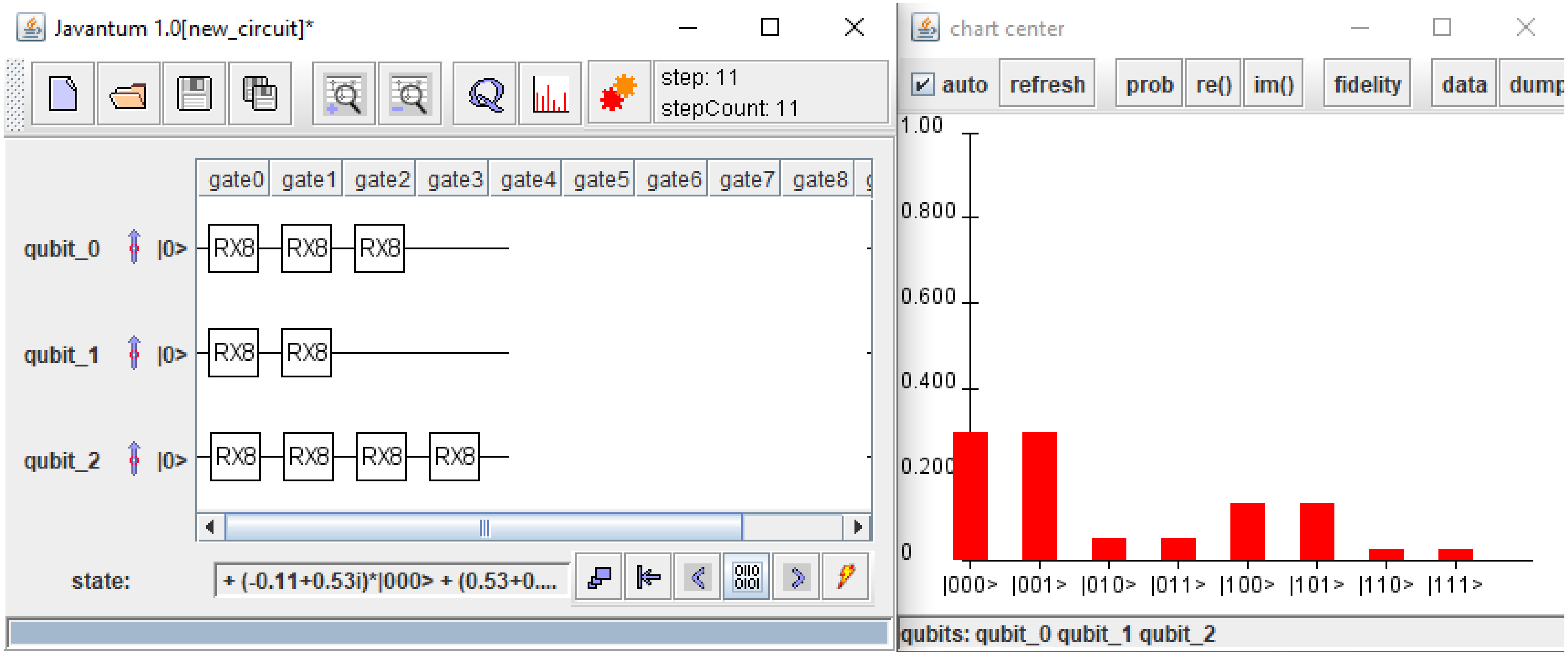


$$|\Psi_1\rangle = \frac{1}{2}[(cos\theta_0\,|0\rangle + sin\theta_0\,|1\rangle)\,|00\rangle$$
$$+\,(cos\theta_1\,|0\rangle + sin\theta_1\,|1\rangle)\,|01\rangle$$
$$+\,(cos\theta_2\,|0\rangle + sin\theta_2\,|1\rangle)\,|10\rangle$$
$$+\,(cos\theta_3\,|0\rangle + sin\theta_3\,|1\rangle)\,|11\rangle]$$

Fig. An example of 2×2 image and its representation with the FRQI model

FRQI : Flexible representation of quantum images.

Quantum RGB Pixel



Data Encoding

IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received December 31, 2021, accepted February 8, 2022, date of publication February 11, 2022, date of current version February 22, 2022.

Digital Object Identifier 10.1109/ACCESS.2022.3151196

Preparation of Quantum Superposition Using Partial Negation

SARA ANWER[1,2], AHMED YOUNES[1,2], ISLAM ELKABANI[1,2], AND ASHRAF ELSAYED[1,2,3]

[1]Department of Mathematics and Computer Science, Faculty of Science, Alexandria University, Alexandria 21511, Egypt
[2]Alexandria Quantum Computing Group, Faculty of Science, Alexandria University, Alexandria 21511, Egypt
[3]Faculty of Computer Science and Engineering, AlAlamein International University, AlAlamein 51718, Egypt

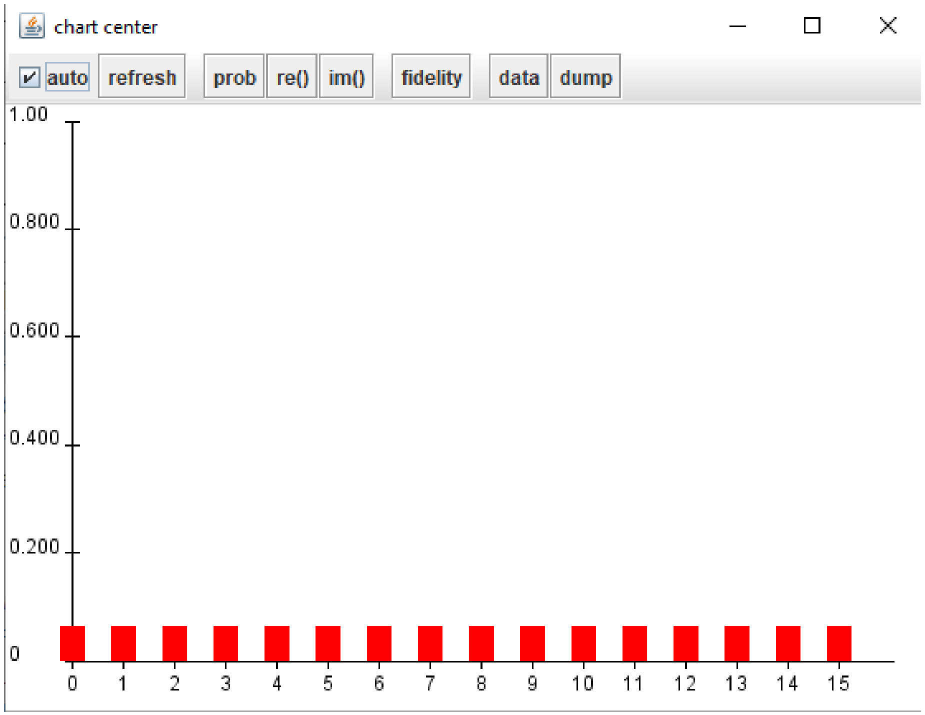
Corresponding author: Sara Anwer (sara.anwar@alexu.edu.eg)

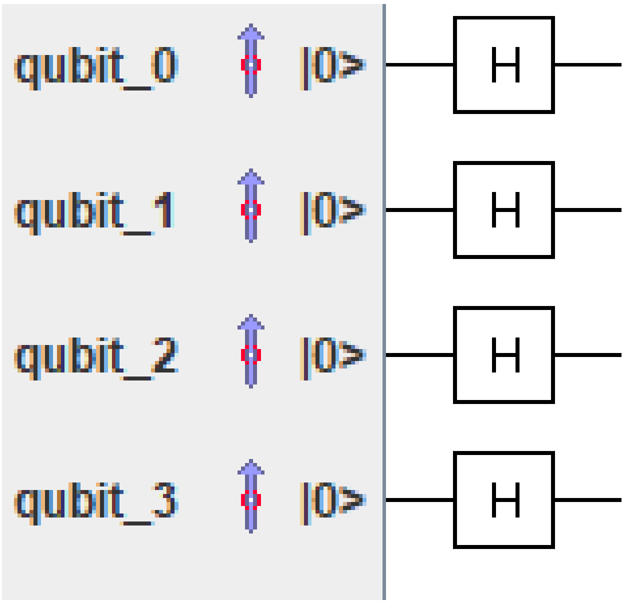
This work was supported by the Academy of Scientific Research and Technology (ASRT), Egypt, under Grant 6558.

ABSTRACT The preparation of a quantum superposition is the key to the success of many quantum algorithms and quantum machine learning techniques. The preparation of an incomplete or a non-uniform quantum superposition with certain properties is a non-trivial task. In this paper, an n-qubits variational quantum circuit using partial negation and controlled partial negation operators is proposed to prepare a quantum superposition from a given space of probability distributions. The speed of the preparation process and the accuracy of the prepared superposition has special importance to the success of any quantum algorithm. The proposed method can be used to prepare the required quantum superposition in $\mathcal{O}(n)$ steps and with high accuracy when compared with relevant methods in literature.

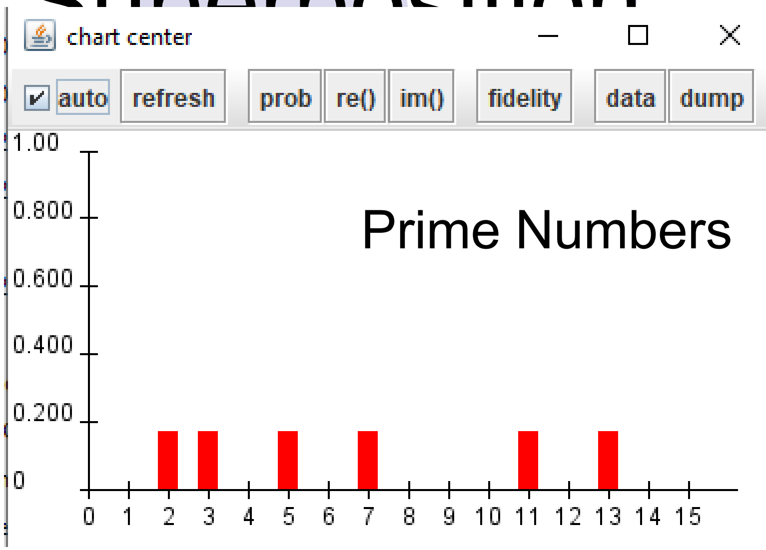
INDEX TERMS Quantum superposition, quantum state, partial negation, data encoding, prepared amplitudes, acquired amplitudes.

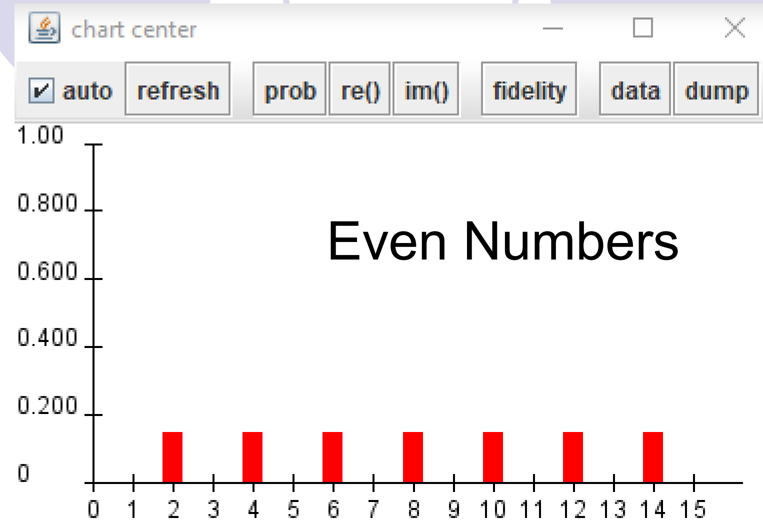
Preparation of Complete Superposition

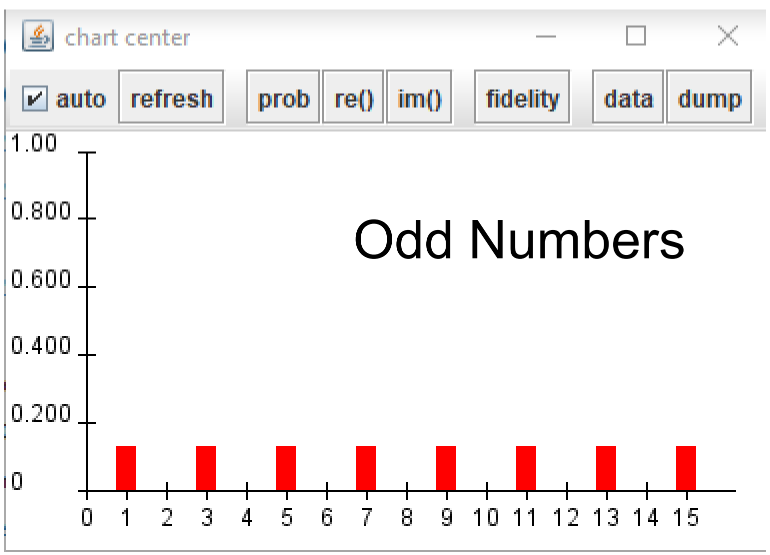


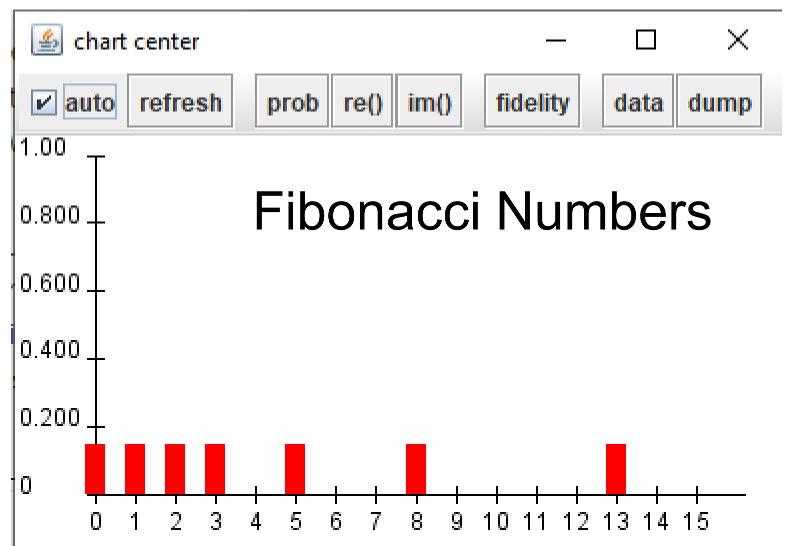


Preparation of Incomplete Superposition

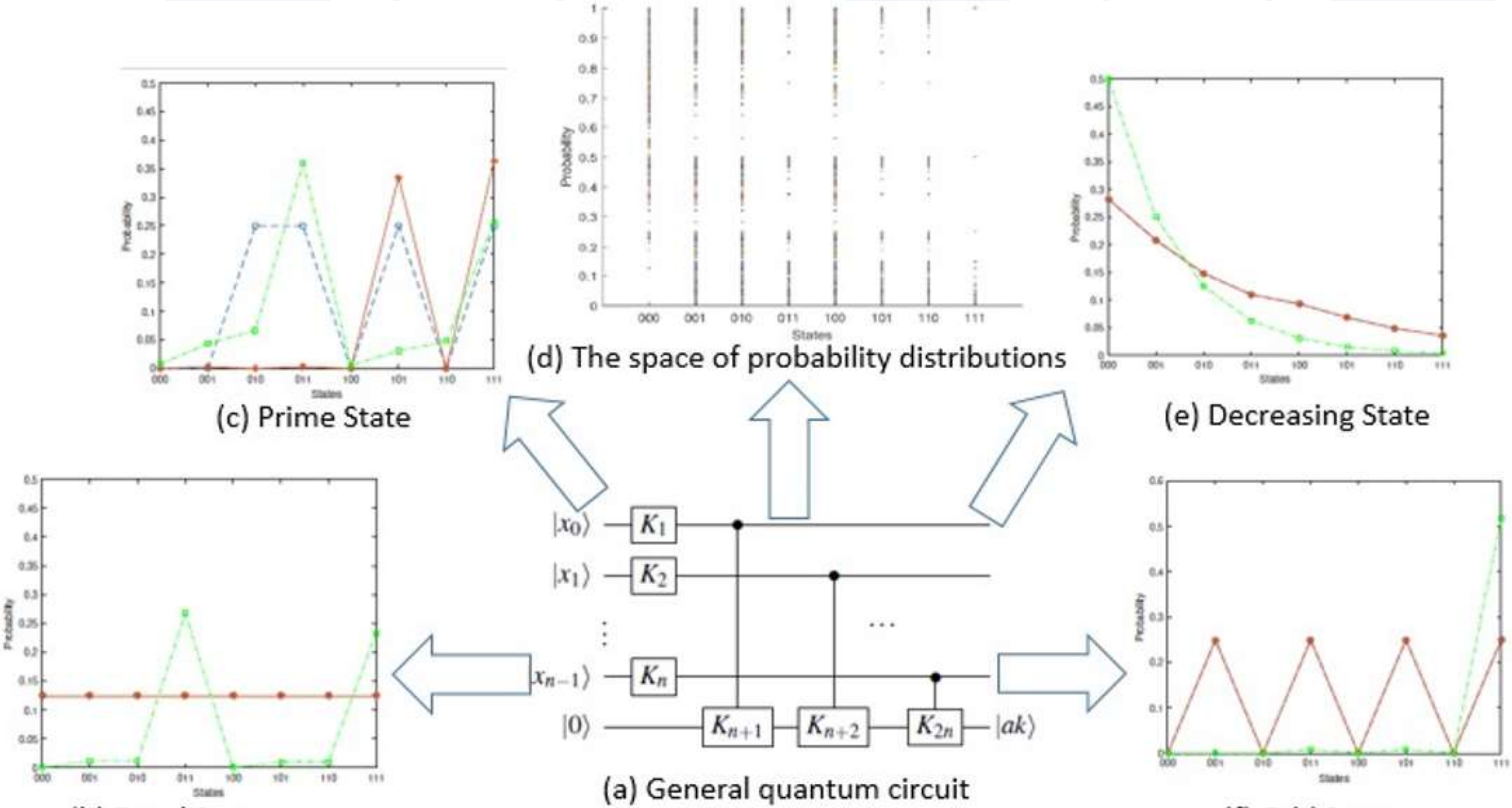








Preparation of Quantum Superposition Using Partial Negation



(d) The space of probability distributions

(c) Prime State

(e) Decreasing State

(b) Equal State

(a) General quantum circuit

(f) Odd State

The Variational Circuit

Algorithm 1 Quantum State Preparation Algorithm

Given a system $|\psi\rangle$, and the vector of amplitudes $(a_1, a_2, \ldots, a_{2^n})$

1: Initialize $|ak\rangle$ in state $|0\rangle$

2: Prepare $|\phi\rangle = (|\psi\rangle \otimes |ak\rangle)$

3: Let *AcquiredAmplitude* = a'= []

4: Let *AcquiredGates*=[]

5: Apply K with unknown parameters on $|\psi\rangle$ 6: Then apply C_k on $|\phi\rangle$

7: The amplitudes of $|\phi\rangle$ is required to solve the system of equations

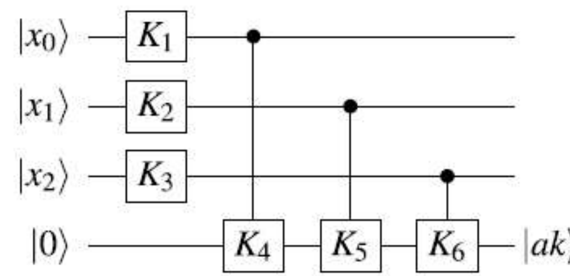
8: Solve the system of non-linear equations generated by steps 1 to 7 using Levenberg-Marquardt algorithm

9: Save the result from the system in *AcquiredGates*

10: Apply the gates on the state $|\phi\rangle$

11: Calculate the *AcquiredAmplitude* using eq.(10)

12: Measure the accuracy of the method by using the relative error



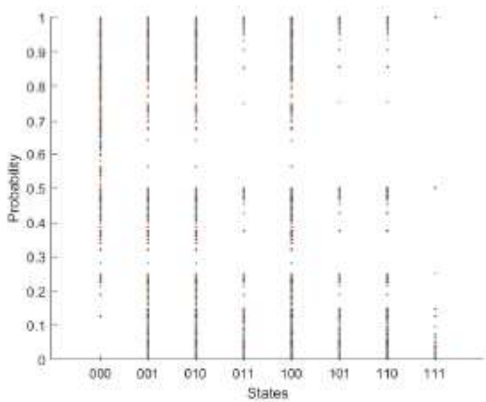
$$K_1 = \begin{bmatrix} c_1 & c_2 \\ c_2 & c_1 \end{bmatrix}, \quad K_3 = \begin{bmatrix} c_5 & c_6 \\ c_6 & c_5 \end{bmatrix}, \quad K_5 = \begin{bmatrix} c_9 & c_{10} \\ c_{10} & c_9 \end{bmatrix},$$

$$K_2 = \begin{bmatrix} c_3 & c_4 \\ c_4 & c_3 \end{bmatrix}, \quad K_4 = \begin{bmatrix} c_7 & c_8 \\ c_8 & c_7 \end{bmatrix}, \quad K_6 = \begin{bmatrix} c_{11} & c_{12} \\ c_{12} & c_{11} \end{bmatrix},$$

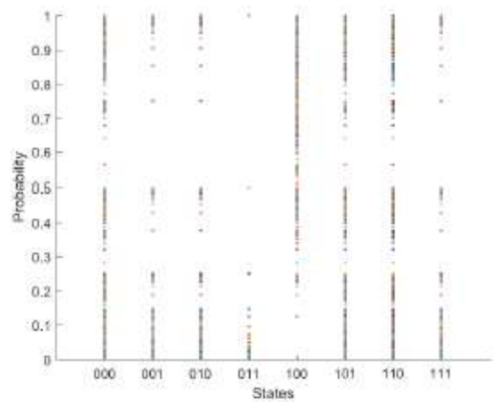
Quantum circuit with unknown r^{th} roots for 3 qubits.

States	Prepared Amplitudes	Acquired Amplitudes	Relative Error
Equal States (complex values)	$-0.2500 + 0.2500i\|0\rangle$	$-0.2500 + 0.2500i\|0\rangle$	6.9593×10^{-11}
	$+0.2500 + 0.2500i\|1\rangle$	$+0.2500 + 0.2500i\|1\rangle$	
	$+0.2500 + 0.2500i\|2\rangle$	$+0.2500 + 0.2500i\|2\rangle$	
	$+0.2500 - 0.2500i\|3\rangle$	$+0.2500 - 0.2500i\|3\rangle$	
	$+0.2500 + 0.2500i\|4\rangle$	$+0.2500 + 0.2500i\|4\rangle$	
	$+0.2500 - 0.2500i\|5\rangle$	$+0.2500 - 0.2500i\|5\rangle$	
	$+0.2500 - 0.2500i\|6\rangle$	$+0.2500 - 0.2500i\|6\rangle$	
	$-0.2500 - 0.2500i\|7\rangle$	$-0.2500 - 0.2500i\|7\rangle$	
Decreasing States (complex values)	$-0.1500 + 0.5100i\|0\rangle$	$-0.1503 + 0.5103i\|0\rangle$	7.5342×10^{-4}
	$+0.4400 + 0.1200i\|1\rangle$	$+0.4404 + 0.1222i\|1\rangle$	
	$+0.3680 + 0.1110i\|2\rangle$	$+0.3698 + 0.1089i\|2\rangle$	
	$+0.0900 - 0.3200i\|3\rangle$	$+0.0885 - 0.3190i\|3\rangle$	
	$+0.2920 + 0.0920i\|4\rangle$	$+0.2918 + 0.0900i\|4\rangle$	
	$+0.0760 - 0.2500i\|5\rangle$	$+0.0733 - 0.2519i\|5\rangle$	
	$+0.0610 - 0.2130i\|6\rangle$	$+0.0652 - 0.2114i\|6\rangle$	
	$-0.1830 - 0.0510i\|7\rangle$	$-0.1825 - 0.0531i\|7\rangle$	
Increasing States (complex values)	$-0.1830 - 0.0510i\|0\rangle$	$-0.182 - 0.0507i\|0\rangle$	2.5487×10^{-4}
	$+0.0610 - 0.2130i\|1\rangle$	$+0.0631 - 0.2108i\|1\rangle$	
	$+0.0760 - 0.2500i\|2\rangle$	$+0.0713 - 0.2515i\|2\rangle$	
	$+0.2920 + 0.0920i\|3\rangle$	$+0.2914 + 0.0887i\|3\rangle$	
	$+0.0900 - 0.3200i\|4\rangle$	$+0.0869 - 0.3185i\|4\rangle$	
	$+0.3680 + 0.1110i\|5\rangle$	$+0.3691 + 0.1083i\|5\rangle$	
	$+0.4400 + 0.1200i\|6\rangle$	$+0.4402 + 0.1223i\|6\rangle$	
	$-0.1500 + 0.5100i\|7\rangle$	$-0.1524 + 0.5101i\|7\rangle$	

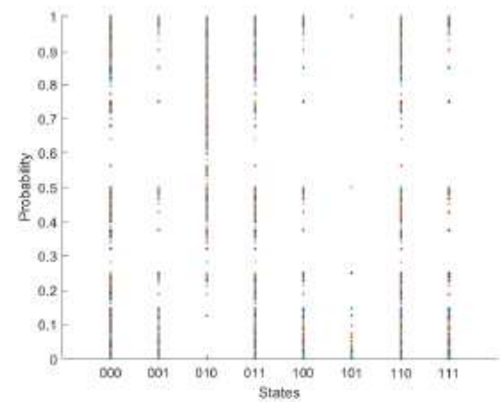
The Space of Probability Distributions using the r^{th} Root over 3 Qubits



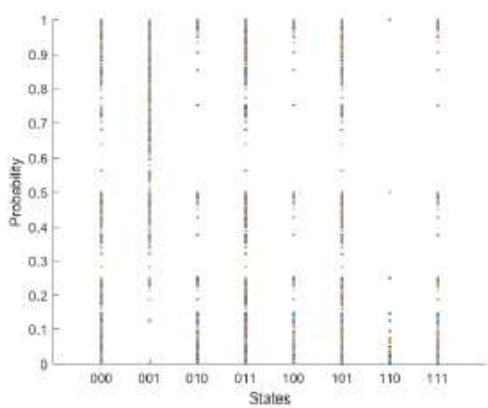
(a) *The space of the probability distributions that can be prepared using the proposed variational circuit.*



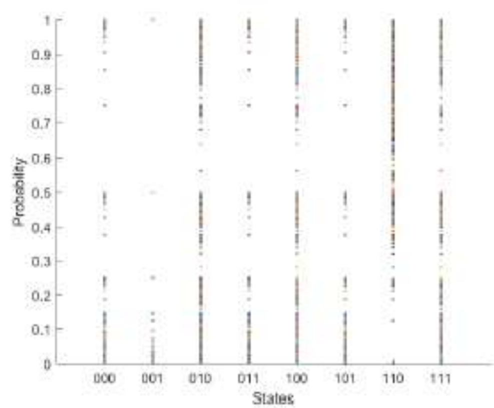
(b) *The space of probability distributions by appending the NOT gate on the first qubit.*



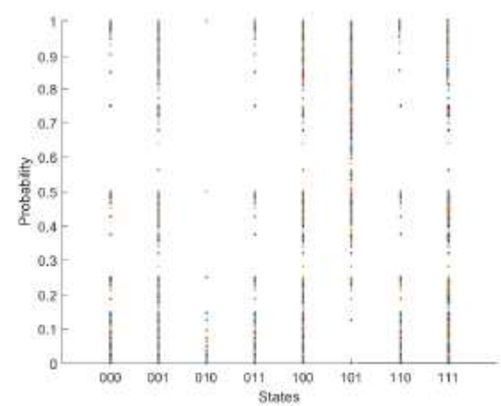
(c) *The space of probability distributions by appending the NOT gate on the second qubit.*



(d) *The space of probability distributions by appending the NOT gate on the third qubit.*



(e) *The space of probability distributions by appending the NOT gate on the first and second qubits.*



(f) *The space of probability distributions by appending the NOT gate on the first and third qubits.*

Comparison between the complexity of the proposed method and the other algorithms where *n* is number of qubits.

Algorithm	Circuit Depth	No.of auxiliary qubit
Equal State	$\mathcal{O}(n^3)$	-
Prime State	$\mathcal{O}(n^2)$	-
Universal Gate	$\mathcal{O}(2^n)$	-
The Sequential Algorithm	$\mathcal{O}(n^2)$	$\mathcal{O}(n)$
QAE	$\mathcal{O}(n)$	$\mathcal{O}(n)$
The Proposed Method	$\mathcal{O}(n)$	$\mathcal{O}(1)$

Reading Quantum Data

Annals of Physics 380 (2017) 93–105

Contents lists available at ScienceDirect

Annals of Physics

journal homepage: www.elsevier.com/locate/aop

Reading a single qubit system using weak measurement with variable strength

Ahmed Younes *

Department of Mathematics and Computer Science, Faculty of Science, Alexandria University, Egypt
School of Computer Science, University of Birmingham, Birmingham, B15 2TT, United Kingdom

H I G H L I G H T S

- Propose a quantum algorithm to read a qubit without applying sharp measurement.
- A reversal weak measurement is used to decrease the introduced disturbance.
- Amplitudes move in a random walk manner with a reversal effect.
- The strength of weak measurement can be controlled using dummy (virtual) qubits.

Reading the Contents of a Single Qubit

- Qubit is usually read using sharp measurement.
- Sharp measurement is irreversible operation.

Given a qubit $|\psi\rangle$ with unknown ϕ as follows,

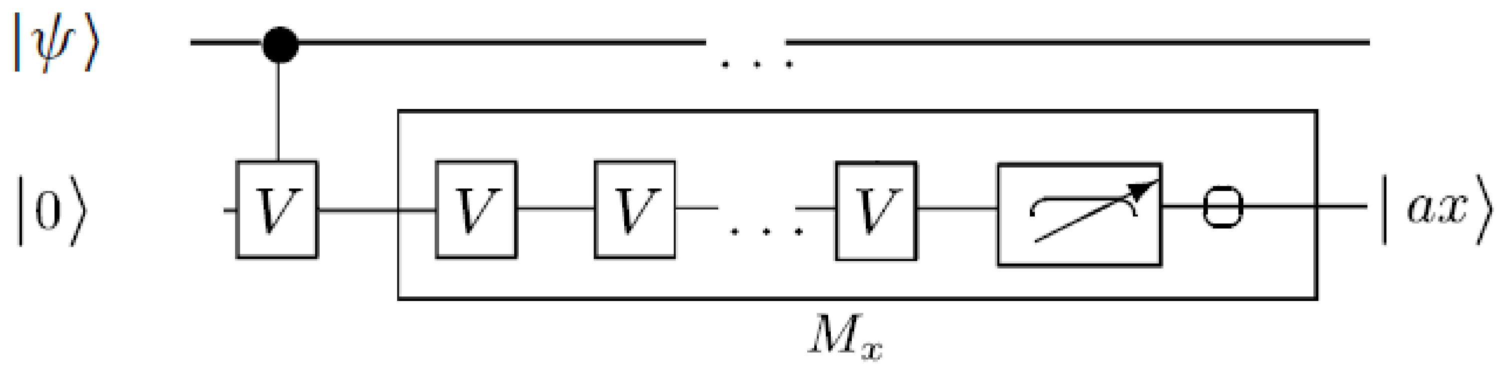
$$|\psi\rangle = \cos(\phi)\,|0\rangle + \sin(\phi)\,|1\rangle\,.$$

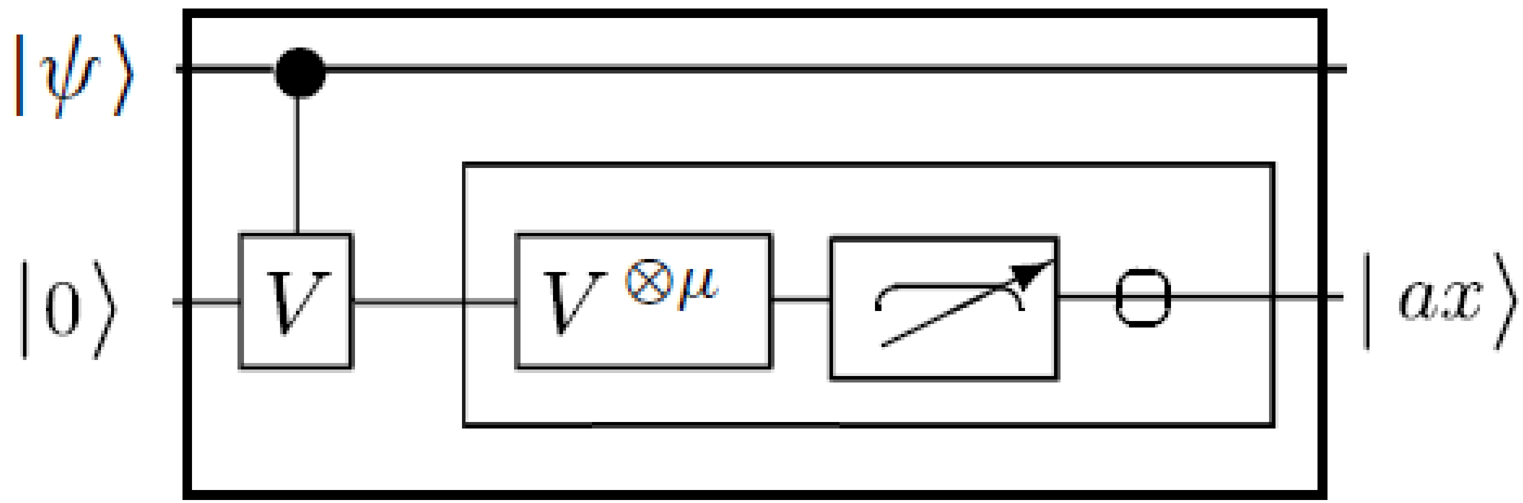
projective measurement will make the qubit collapses to either

$|0\rangle$ with probability $\cos^2(\phi)$

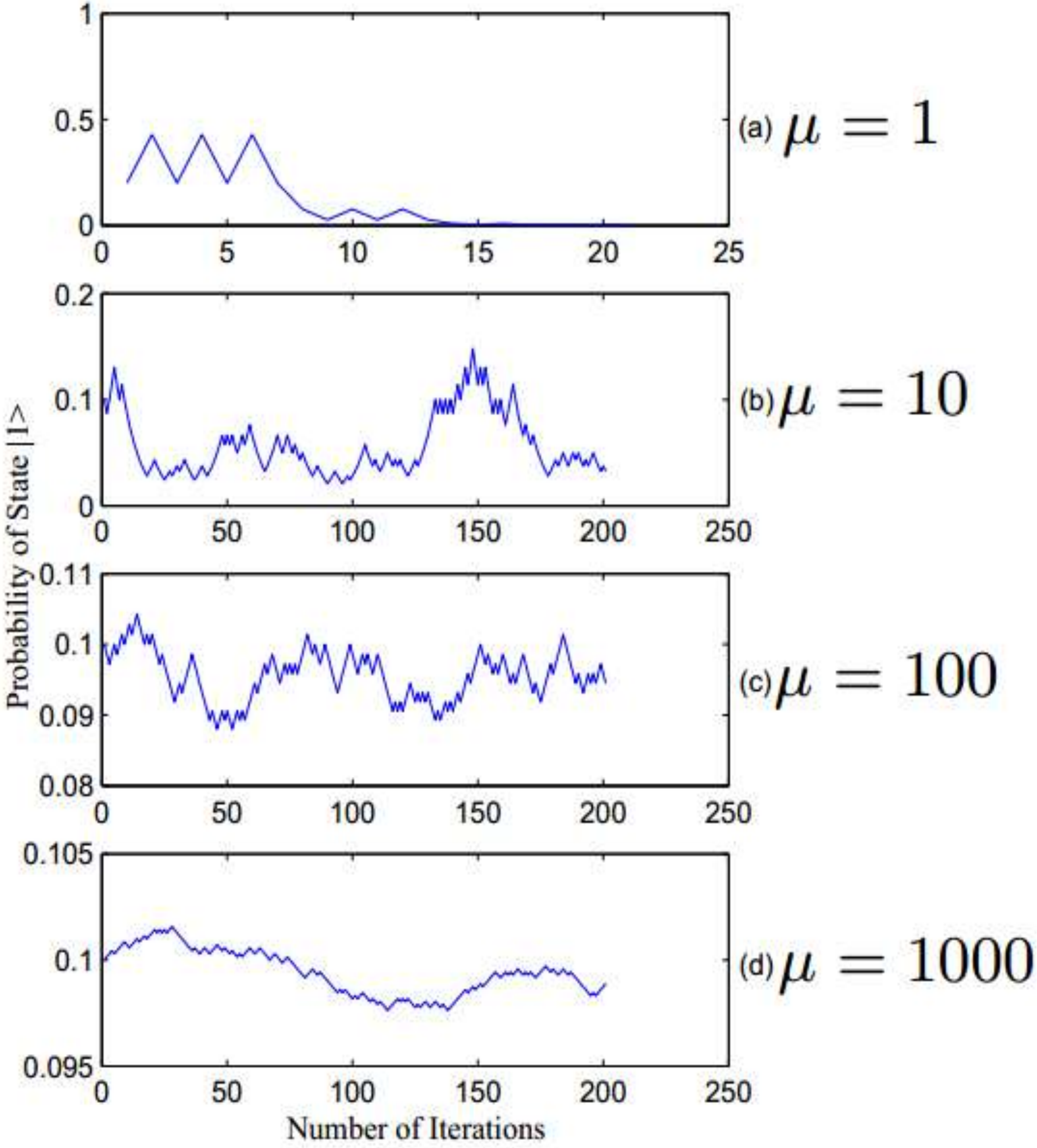
or to $|1\rangle$ with probability $\sin^2(\phi)$.

The Algorithm - Simplified





Measurement Based Quantum Random Walks



The scale of the measurement process is based upon the number of steps that the random walk should move starting from $\Pr_0(|\psi_0\rangle) = \cos^2(\varphi)$ to reach after $j \geq 1$ steps to $\Pr_j(|\psi_0\rangle) = 1 - \epsilon$ for small $\epsilon > 0$, so

$$\Pr_j(|\psi_0\rangle) = \frac{\tan^{2\Delta j}(\theta_0)}{\tan^2(\varphi) + \tan^{2\Delta j}(\theta_0)} \geq 1 - \epsilon,$$

then,

$$\begin{aligned}\Delta j &\geq \frac{\log\left(\tan^2(\varphi)\left(\frac{1-\epsilon}{\epsilon}\right)\right)}{\log(\tan^2(\theta_0))}\\ &\geq \frac{\log\left(\tan^2(\varphi)\left(\frac{1-\epsilon}{\epsilon}\right)\right)}{\log(\cos^2(\theta_1)) - \log(\cos^2(\theta_0))},\end{aligned}$$

and since $\theta_0 = \frac{\pi\mu}{4\mu+2}$ and $\theta_1 = \frac{\pi(\mu+1)}{4\mu+2}$ then

$$\begin{aligned}\Delta j &\geq \frac{\log\left(\tan^2(\varphi)\left(\frac{1-\epsilon}{\epsilon}\right)\right)}{\left(\frac{\pi\mu}{4\mu+2}\right)^2 - \left(\frac{\pi(\mu+1)}{4\mu+2}\right)^2}\\ &\geq \left(\frac{2}{\pi}\right)^2 \log\left(\tan^2(\varphi)\left(\frac{1-\epsilon}{\epsilon}\right)\right)(2\mu+1).\end{aligned}$$

and since φ is unknown, then assume $\varphi = \frac{\pi}{2}$ as an upper bound for the total number of steps j and so the scale of the measurement process is,

$$\begin{aligned}j_{proj} &\geq \frac{\pi}{2}(\Delta j)^2\\ &\geq \frac{2}{\pi}\left(\log\left(\tan^2\left(\frac{\pi}{2}\right)\left(\frac{1-\epsilon}{\epsilon}\right)\right)(2\mu+1)\right)^2\\ &\geq O(\mu^2).\end{aligned}$$

Correctness of Weak Measurement

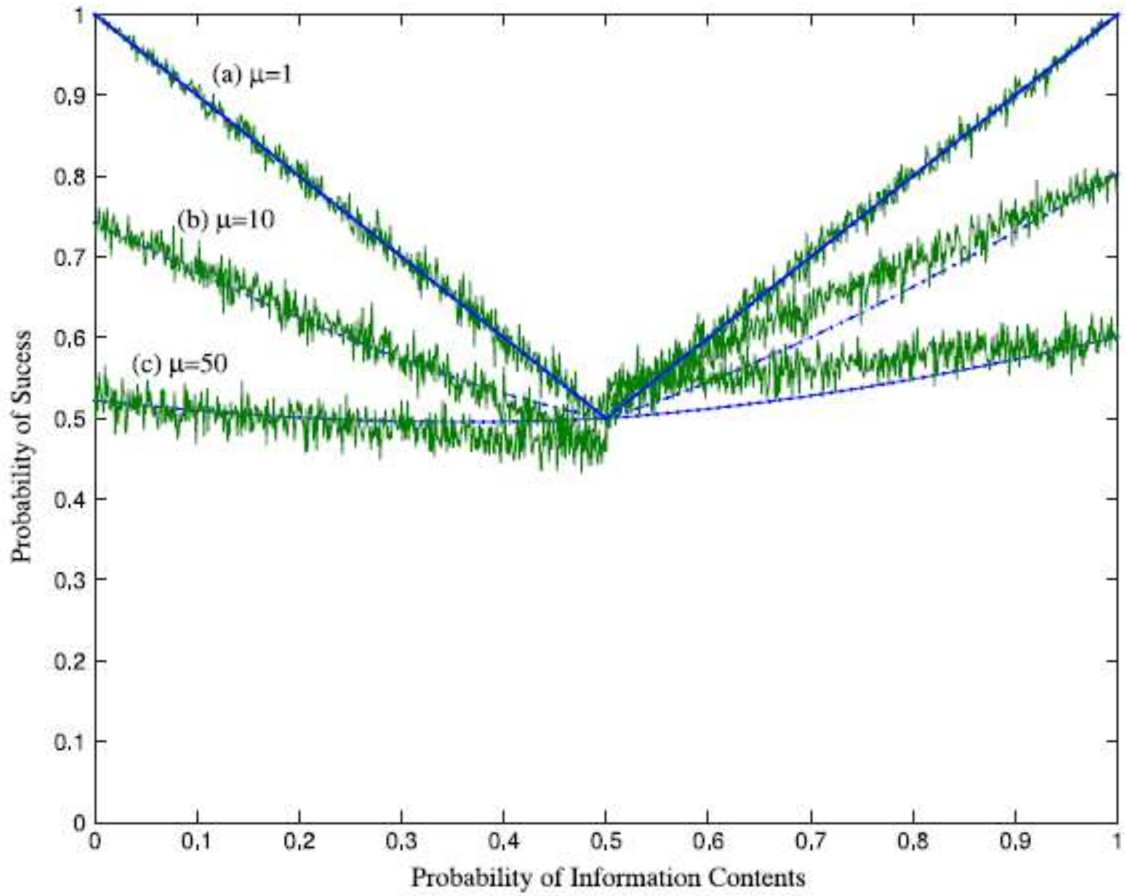


Fig. The probability of success for the measurement based quantum random walks with different values of μ, where the solid lines refer to the simulation results and the dotted lines are the probability of success

Quantum State Discrimination

Quantum Information Processing (2021) 20:307
https://doi.org/10.1007/s11128-021-03245-3

Quantum algorithm for quantum state discrimination via partial negation and weak measurement

Doha A. Rizk[1] · Ahmed Younes[1,2]

Received: 8 May 2021 / Accepted: 26 August 2021 / Published online: 13 September 2021

Abstract
The quantum state discrimination problem is to distinguish between non-orthogonal quantum states. This problem has many applications in quantum information theory, quantum communication and quantum cryptography. In this paper, a quantum algorithm using weak measurement and partial negation will be proposed to solve the quantum state discrimination problem using a single copy of an unknown qubit. The usage of weak measurement makes it possible to reconstruct the qubit after measurement since the superposition will not be destroyed due to measurement. The proposed algorithm will be able to determine, with high probability of success, the state of the unknown qubit and whether it is encoded in the Hadamard or the computational basis by counting the outcome of the successive measurements on an auxiliary qubit.

Keywords Quantum state discrimination · Quantum algorithm · Weak measurement · Partial negation · Computational basis · Hadamard basis

Quantum State Discrimination

Problem Statement

Given a qubit $|\psi\rangle$ which is promised to be in one of the following four states $|0\rangle$, $|1\rangle$, $|+\rangle$ and $|-\rangle$ where, $|\pm\rangle = \frac{1}{\sqrt{2}}(|0\rangle \pm |1\rangle)$. It is required to determine the state of $|\psi\rangle$ using a single copy and whether it is encoded in the Hadamard or the computational basis. The probabilities that the unknown qubit $|\psi\rangle$ is in one of the previously mentioned four states when measured in the computational or the Hadamard basis is shown in Table (1).

$\lvert\psi\rangle$	Measurement using computational basis	Measurement using Hadamard basis
$\lvert 0\rangle$	100%	50%
$\lvert 1\rangle$	100%	50%
$\lvert +\rangle$	50%	100%
$\lvert -\rangle$	50%	100%

Table 1: Probailities that an unknown qubit $|\psi\rangle$ is in state $|0\rangle$, $|1\rangle$, $|+\rangle$ or $|-\rangle$ when measured in the computational or the Hadamard basis.

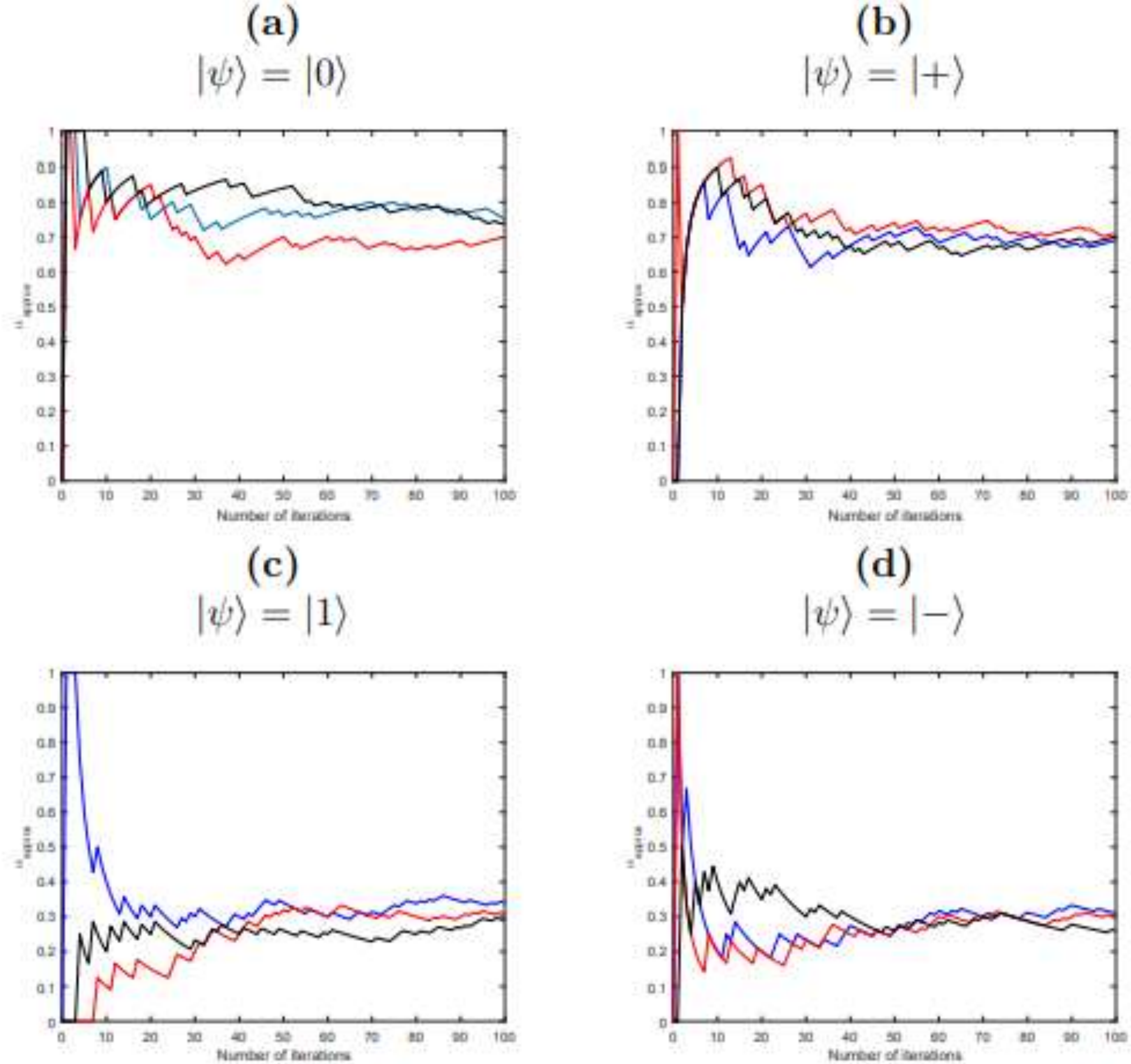


Figure : Three sample runs for the random walks for each of the considered cases, $|\psi\rangle = |0\rangle$, $|\psi\rangle = |+\rangle$, $|\psi\rangle = |1\rangle$ and $|\psi\rangle = |-\rangle$.

Table The percentages of success and failure after 10^3 trials for determining the state of $|\psi\rangle$, when it is assumed to be in the Hadamard or the computational basis, in addition to the total percentage of success for determining $|\psi\rangle$ when $|\psi\rangle = |0\rangle$, $|\psi\rangle = |+\rangle$ represented in Table (a) and $|\psi\rangle = |1\rangle$, $|\psi\rangle = |+\rangle$ represented in Table (b)

	$\|\psi\rangle = \|0\rangle$				$\|\psi\rangle = \|+\rangle$			
(*a*)								
Actual basis	Computational basis				Hadamard basis			
Assumed basis	Hadamard basis		Computational basis		Hadamard basis		Computational basis	
Transformation applied	$H\|\psi\rangle$		No transformation		$H\|\psi\rangle$		No transformation	
% of trials transformation is applied based on α_{approx}	$\simeq$ 44.953%		$\simeq$ 55.047%		$\simeq$ 45.498%		$\simeq$ 54.502%	
Correctness for determining $\|\psi\rangle$	Success: $\simeq$ 22.645%	Failure: $\simeq$ 22.226%	Success: $\simeq$ 55.047%	Failure: $\simeq$ 0.029%	Success: $\simeq$ 45.498%	Failure: $\simeq$ 0.026%	Success: $\simeq$ 27.192%	Failure: $\simeq$ 27.24%
Total % of success	$\simeq$ 77.656%				$\simeq$ 72.320%			
	$\|\psi\rangle = \|1\rangle$				$\|\psi\rangle = \|-\rangle$			
(*b*)								
Actual basis	Computational basis				Hadamard basis			
Assumed basis	Hadamard basis		Computational basis		Hadamard basis		Computational basis	
Transformation applied	$H\|\psi\rangle$		No transformation		$H\|\psi\rangle$		No transformation	
% of trials transformation is applied based on α_{approx}	$\simeq$ 45.060%		$\simeq$ 54.940%		$\simeq$ 45.200%		$\simeq$ 54.801%	
Correctness for determining $\|\psi\rangle$	Success: $\simeq$ 22.526%	Failure: $\simeq$ 22.464%	Success: $\simeq$ 54.936%	Failure: $\simeq$ 0.021%	Success: $\simeq$ 45.199%	Failure: $\simeq$ 0.03%	Success: $\simeq$ 27.408%	Failure: $\simeq$ 27.324%
Total % of success	$\simeq$ 77.462%				$\simeq$ 72.607%			

Thank You

Ahmed Younes
Professor of Quantum Computing,
Alexandria University

ayounes@alexu.edu.eg
ayounes@aiu.edu.eg
dr.a.younes@gmail.com