Four strategies for the early quantum jungle

Will Zeng
will@unitary.fund

Unitary Fund

“The process of technological development is like building a **cathedral**. Over the course of several hundred years new people come along and each lays down a block on top of the old foundations, each saying, ‘I built a cathedral.’ Next month another block is placed atop the previous one. Then comes along an historian who asks, ‘Well, who built the cathedral?’ Peter added some stones here, and Paul added a few more. If you are not careful, you can con yourself into believing that you did the most important part. But the reality is that each contribution has to follow onto previous work. Everything is tied to everything else.”

- Paul Baran co-inventor of packet switching as quoted in Where Wizards Stay up Late by Katie Hafner

Unitary Fund

But cathedrals aren’t quite right. They are static and monolithic.

Technological development is like planting a **jungle**

Unitary Fund

Creating a quantum technology ecosystem that benefits the most people.

https://unitary.fund/

Creating a quantum technology ecosystem that benefits the most people.

How: A robust open ecology makes this happen faster and for more people.

https://unitary.fund/

Four strategies

1. Healthy soil: build bottoms up community
2. Niches: target open niches
3. Specialization: choose modular design with small footprint
4. Symbiosis: choose reciprocal altruism

Unitary Fund

Case study on healthy ecology: Unitary Fund

Unitary Fund

Developing the open quantum tech ecosystem

Microgrant Program

$4k grants to open quantum tech projects

Compilers, simulators, educational tools, visualizers, and more!

Unitary Labs: open source research team

- Building **Mitiq**, an open source error-mitigating compiler
- Supporting **QuTiP**, >30k annual downloads, >2500 citations

Supporters

IBM
Microsoft
rigetti
XANADU
ZAPATA
Unitary Fund
EeroQ
PLOS

Collaborators

Stanford University
Lawrence Livermore National Laboratory
APL The Johns Hopkins University Applied Physics Laboratory
DARTMOUTH
University of Maryland 1856
The University of Chicago

Small microgrants => big impact

Unitary Fund

30 projects

14 countries, 4 continents
7 publications
1 venture funded startup
> 12 open source libraries
7 new folks FT in the field

Open source **metrics**:
> 950 stars
> 150 forks

$90k

“Unitary Fund was a very important achievement on our first steps of starting the Gate42 QC initiative in Armenia. Armenia, via Unitary Fund was first time marked on the QC world map!”

— Hakob Avetisyan (now teaching the first quantum computing course in Armenia)

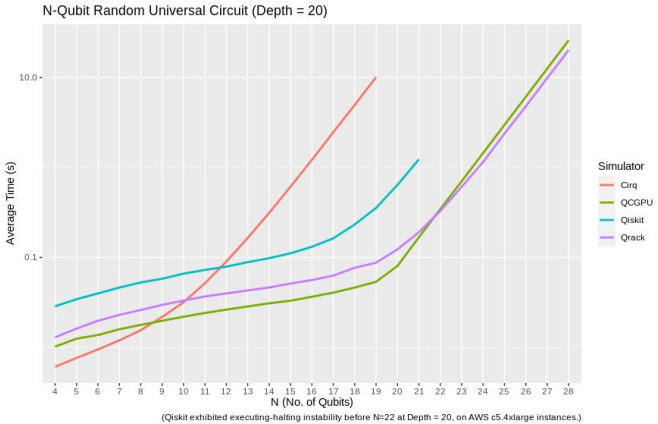
Unitary Fund

Building state of the art open software

QRack

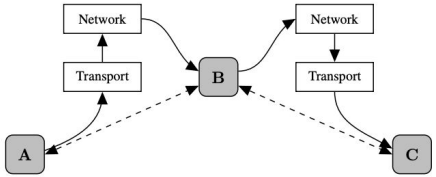
an open source, comprehensive, GPU-accelerated framework for simulating universal quantum processors.

Better performance that industry options.



QuNetSim

To Stephen DiAdamo to develop the first full featured software stack for quantum network protocols.



OLSQ

To Daniel Tan to develop and open source the Optimal Layout Synthesizer for Quantum Computing, OLSQ. This compiler beats other benchmarks on optimal layout of computational qubits onto physical qubits.

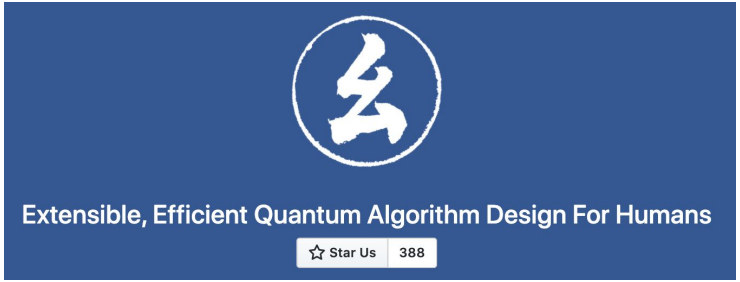
Table 4. Evaluation of QAOA-OLSQ

	t|ket⟩		TB-OLSQ		Depth	SWAP	QAOA-OLSQ		Depth	SWAP
M	Depth	SWAP	Depth	SWAP	Reduction	Reduction	Depth	SWAP	Reduction	Reduction
10	16	7.3	6.9	7.3	56.7%	0	6.5	5.5	59.3%	23.6%
12	17.8	11.7	8.5	9.3	52.3%	20.4%	5.6	5.8	67.3%	46.2%
14	19.0	13.2	9.0	12.3	52.6%	6.8%	6.0	6.6	68.3%	48.0%
16	21.7	20.2	9.1	13.6	58.2%	32.7%	6.4	6.9	70.2%	62.6%
18	25.5	26.7	8.9	14.5	64.9%	45.7%	6.0	8.3	75.5%	65.7%
20	30.6	37.5	9.3	16.3	68.9%	57.7%	7.2	10.8	75.7%	68.8%
22	29.8	38.4	10.3	17.8	65.4%	53.6%	7.8	14.2	73.7%	61.8%
Geometric Mean					59.5%	29.4%			70.2%	53.8%

Unitary Fund

Connecting the quantum ecosystem

Case Study: Yao.jl + pyZX



+

To Aleks Kissinger and John van de Wetering to support the development of **pyZX**, an optimizing quantum circuit compiler based on a diagrammatic semantics from monoidal categories.

SUPPORTED BY UNITARY FUND

Two publications: (i) an overview of the pyZX library and (ii) benchmarks showing that pyZX outperforms the state of the art in reducing T-Count.

=

Summer 2020: YaoLang released support for its first circuit optimization pass based on ZX calculus.

Unitary Fund

Growing an inclusive global quantum workforce

QWORLD

Open educational workshops across 7 countries in Eastern Europe

Gate42

> Led to the first courses on quantum tech in Armenia

> Now starting the first quantum technologies research division under their national lab

FS QC **Full-Stack Quantum Computation**
Community-driven, open-source education resources

> Worldwide community developing educational content

> Meta-community that reaches into new channels, i.e. Discord

Unitary Fund

We are a central node in quantum open source

Advisory Board

15 experts in quantum systems and software

From organizations:

+

Community

43 grant winners

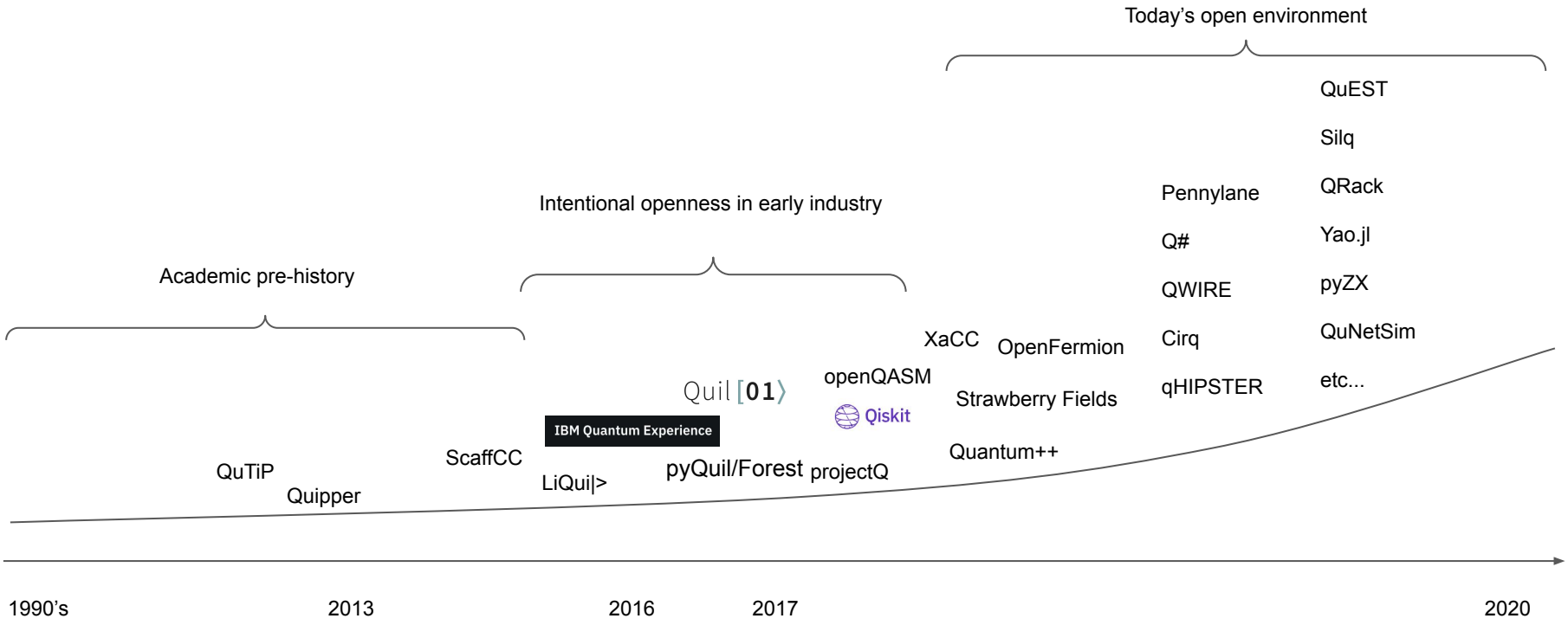
Mentors and volunteers

Unitary Fund

Why does this work so effectively?

Unitary Fund

Today’s environment is intentional



* This is a gestural timeline and not meant to be exact or exhaustive

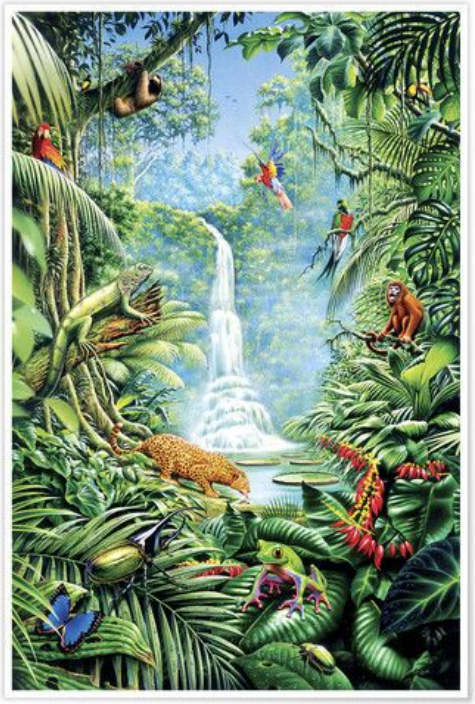
We should stay intentional going forward

Unitary Fund

From silos to jungles

Today: open source vertical stacks

Tomorrow: a rich interlocking ecology in shared soil

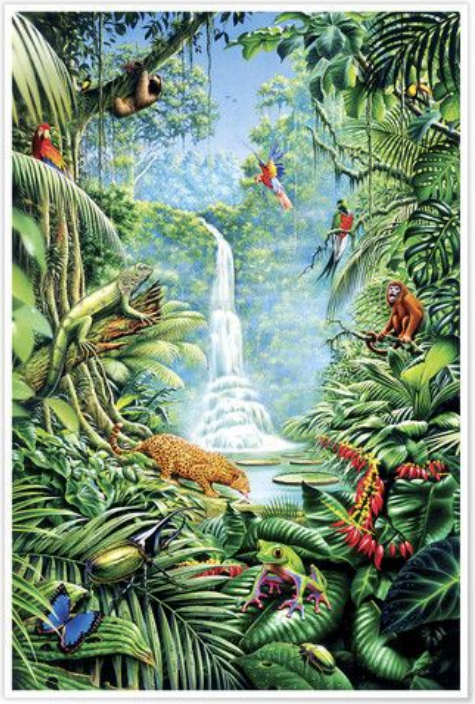


Unitary Fund

From silos to jungles

Today: open source vertical stacks

Tomorrow: a rich interlocking ecology in shared soil



This is **not premature standardization**

Unitary Fund

There’s a long way to go to large valuable markets for quantum computing

Vertical exclusive stacks are too fragile to go the distance

Unitary Fund

Four strategies to get there

1. Healthy soil: build bottoms up community
2. Niches: target open niches
3. Specialization: choose modular design with small footprint
4. Symbiosis: choose reciprocal altruism

Unitary Fund

1. Healthy soil: bottoms-up community building

Qiskit Global summer school w/ > 6k participants

Unitary Fund

Q2WORK

qosf

Quantum Computing

QWORLD

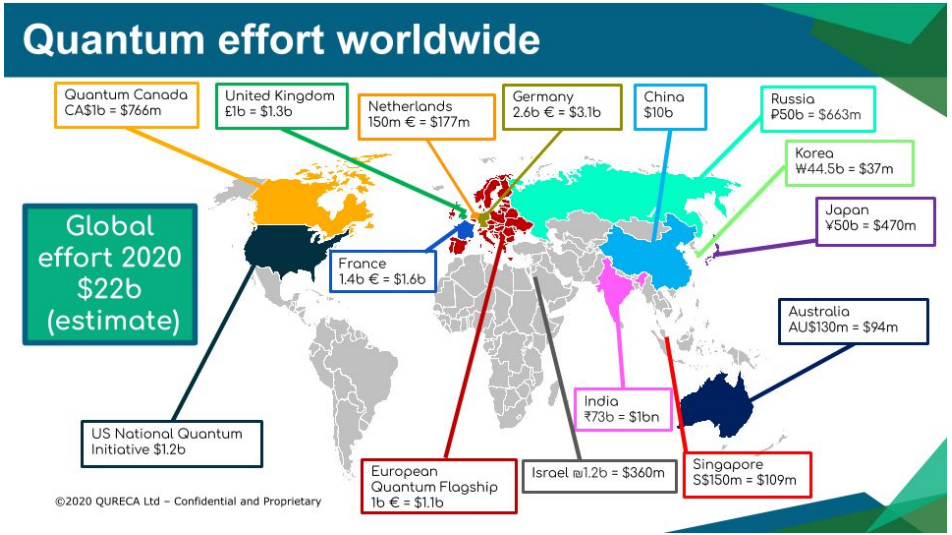
FS QC **Full-Stack Quantum Computation**
Community-driven, open-source education resources

WIQCA

Sydney Quantum Academy

THE QUANTUM DAILY
QUANTUM COMPUTING AND BEYOND

QHACK
TORONTO CANADA



Unitary Fund

1. Healthy soil: recognizing contributions

Wittek Quantum Prize for Open Source Software

wittekprize.com

$4k cash prize for an otherwise unnoticed individual for their outstanding high-impact contribution to the field of quantum open-source software.

Nominations will be accepted until November 30th, 2020 @ 11:59 PM EST

2. Niches: target open niches

Unitary Fund

Error mitigation is key for noisy quantum computing

No overhead → **Lots of overhead**

Today

Cross-your-fingers method

Tomorrow

Error mitigation

- Probabilistic Error Cancellation [1,2]
- Randomized Compiling [3]
- Dynamical Decoupling [4-7]
- Quantum optimal control [8]
- **Zero-noise extrapolation [1, 9, 10]**

The Future

Error correction

- Uses additional qubits
- Requires fast classical control

[1] K. Temme, S. Bravyi, and J. M. Gambetta, “Error Mitigation for Short Depth Quantum Circuits,” Physical Review Letters, vol. 119, p. 180509, 11 2017.
[2] S. Endo, S. C. Benjamin, and Y. Li, “Practical quantum error mitigation for near-future applications,” Physical Review X, vol. 8, no. 3, p. 031027, 2018.
[3] J. J. Wallman and J. Emerson, “Noise tailoring for scalable quantum computation via randomized compiling,” Physical Review A, vol. 94, no. 5, p. 052325, 2016.
[4]] E. Knill, “Quantum computing with realistically noisy devices,” Nature, vol. 434, no. 7029, pp. 39–44, 2005.
[5] L. Viola and E. Knill, “Random decoupling schemes for quantum dynamical control and error suppression,” Physical review letters, vol. 94, no. 6, p. 060502, 2005.
[6] B. Pokharel, N. Anand, B. Fortman, and D. A. Lidar, “Demonstration of fidelity improvement using dynamical decoupling with superconducting qubits,” Physical review letters, vol. 121, no. 22, p. 220502, 2018.
[7] P. Sekatski, M. Skotiniotis, and W. Dur, “Dynamical decoupling leads to ¨ improved scaling in noisy quantum metrology,” New Journal of Physics, vol. 18, no. 7, p. 073034, 2016.
[8] T. J. Green, J. Sastrawan, H. Uys, and M. J. Biercuk, “Arbitrary quantum control of qubits in the presence of universal noise,” New Journal of Physics, vol. 15, no. 9, p. 095004, 2013.
[9] Y. Li & S.C. Benjamin, "Efficient Variational Quantum Simulator Incorporating Active Error Minimization", Phys. Rev. X 7, 021050 (2017), https://journals.aps.org/prx/abstract/10.1103/PhysRevX.7.021050
[10] T. Giurgica-Tiron, Y. Hindy, R. LaRose, A. Mari, and W. J. Zeng, “Digital zero noise extrapolation for quantum error mitigation,” arXiv:2005.10921 [quant-ph], May 2020.

Unitary Fund

Error mitigation will critically affect benchmarking for years to come

There needs to be an open solution to have

Standard benchmarks

Reduced time to state of the art

Snowball effect of techniques

Unitary Fund

Mitiq: Mitigate errors with one line

Qiskit

```
from qiskit import QuantumCircuit
from mitiq import mitigate_executor
qskt_noisy_sim = mitigate_executor(qsk)
circ = QuantumCircuit(1, 1)
for __ in range(120): circ.x(0)
circ.measure(0, 0)

expectation = qskt_noisy_sim(circ)
print(f"Error is {1 - expectation:.{3}}")
```

```
Error is 0.0582
```

Cirq

```
from cirq import Circuit, LineQubit, X
from mitiq import mitigate_executor
noisy_simulation = mi

qbit = LineQubit(0)
circ = Circuit(X(qb
expectation = noisy

print(f"Error is {1 - expectation:.{3}}")
```

min
mitigate_executor
mitiq_basic-Copy1.ipynb
mitiq_basic.ipynb
mitiq

```
Error is 0.0625
```

R. LaRose, A. Mari, P.J. Karalekas, N. Shammah, W.J. Zeng, Mitiq: A software package for error mitigation on noisy quantum computers, 2020.
T. Giurgica-Tiron, Y. Hindy, R. LaRose, A. Mari, W.J. Zeng, Digital zero-noise extrapolation for quantum error mitigation, 2020.
Mitiq GitHub: https://github.com/unitaryfund/mitiq.

Unitary Fund

Some open niches

- Benchmarking
- Transpiling
- Debuggers/IDEs
- Integrations with the broader open source ecosystem (e.g. a verified randomness source in numpy)

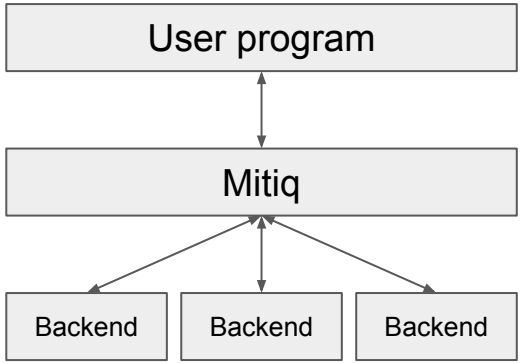
All would make great Unitary Fund projects

Unitary Fund

3. Specialization: choose modular design with small footprint

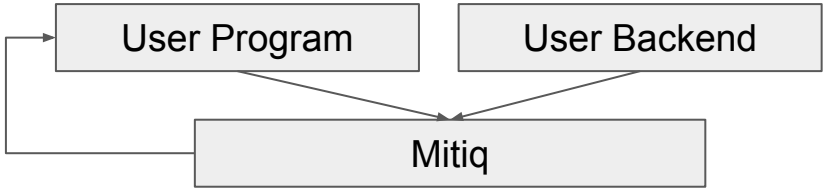
Build tools not just platforms

~~Mitiq~~: platform-style



- Limited support
- High maintenance burden
- User lock-in

Mitiq: tool-style




```
from mitiq import mitigate_executor

run_mitigated = mitigate_executor(noisy_simulation)
mitigated = run_mitigated(circ)
```

```
def executor(circ: Circuit) -> float:
```

- General support
- Low maintenance burden
- Flexible use

Unitary Fund

4. Symbiosis: choose reciprocal altruism

- Upstream!
  - (Quil import and export in cirq came from mitiq)

- Contribute to open roadmaps and open issues in your major dependencies

Unitary Fund

Four strategies

1. Healthy soil: build bottoms up community
2. Niches: target open niches
3. Specialization: choose modular design with small footprint
4. Symbiosis: choose reciprocal altruism

Unitary Fund

Can we get open source closer to the metal?

E.g. in control systems firmware

Why?

- quantum error correction (and mitigation/detection)
- variational programming
- new architectures beyond the circuit model

Let’s grow a vibrant and fertile quantum jungle

Unitary Fund

Let’s grow a vibrant and fertile quantum jungle

Unitary Fund

Creating a quantum technology ecosystem that benefits the most people.

Can you help?

Become a Supporter

Spread the word | **Mentor** | **Contribute Code**

will@unitary.fund