OPTIMIZING LABS

—

AN ANALYSIS OF HYBRID QUANTUM ALGORITHMS

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NVIDIA

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MEET THE SQUACKXIONS
(in their excited state)

The Problem & Our Plan

Low Autocorrelation Binary Sequences (LABS)

Find the binary sequence that:

$$\min\{E(s)\} = \min\left\{\sum_{k=1}^{N-1} C_k^2\right\} \quad \text{with} \quad C_k = \sum_{i=1}^{N-k} s_i s_{i(i+k)}$$

CLASSICAL

“Golden standard”

- Memetic Tabu Search (MTS)
- Global search, greedy local descent
- N <= 64
- ≈O(1.25^N) CPU
- ≈O(1.21^N) GPU

CLASSICAL + QUANTUM I

Phase 1

- QE: seeding initial population for MTS
- Measured improvement is shown only for 27 < N < 37
- ≈O(1.38^N)

CLASSICAL + QUANTUM II

Phase 2

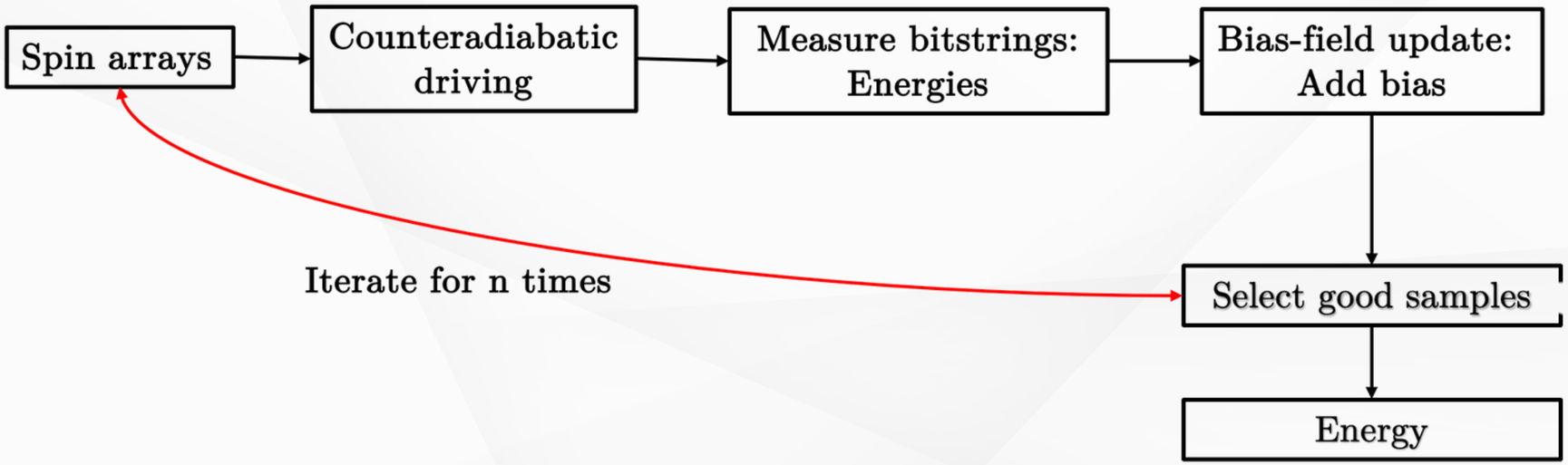
- QE improvement: Bias in magnetization (spins) learned
- ≈O(1.20^N)

BF-DCQO Algorithm

Bias-Field Counterdiabatic Quantum Optimization

WHY?

- Performs DCQO iteratively to use the solution from each to bias the next iteration
- Circumvent local minima & lead to faster convergence



The Plan: Acceleration

CLASSICAL

- From Zhang et al. paper : 26x speedup over 16-core CPU implementations
- How:
  - All in GPU
  - Two Level Parallelism
  - Shared Memory Data Structures

QUANTUM

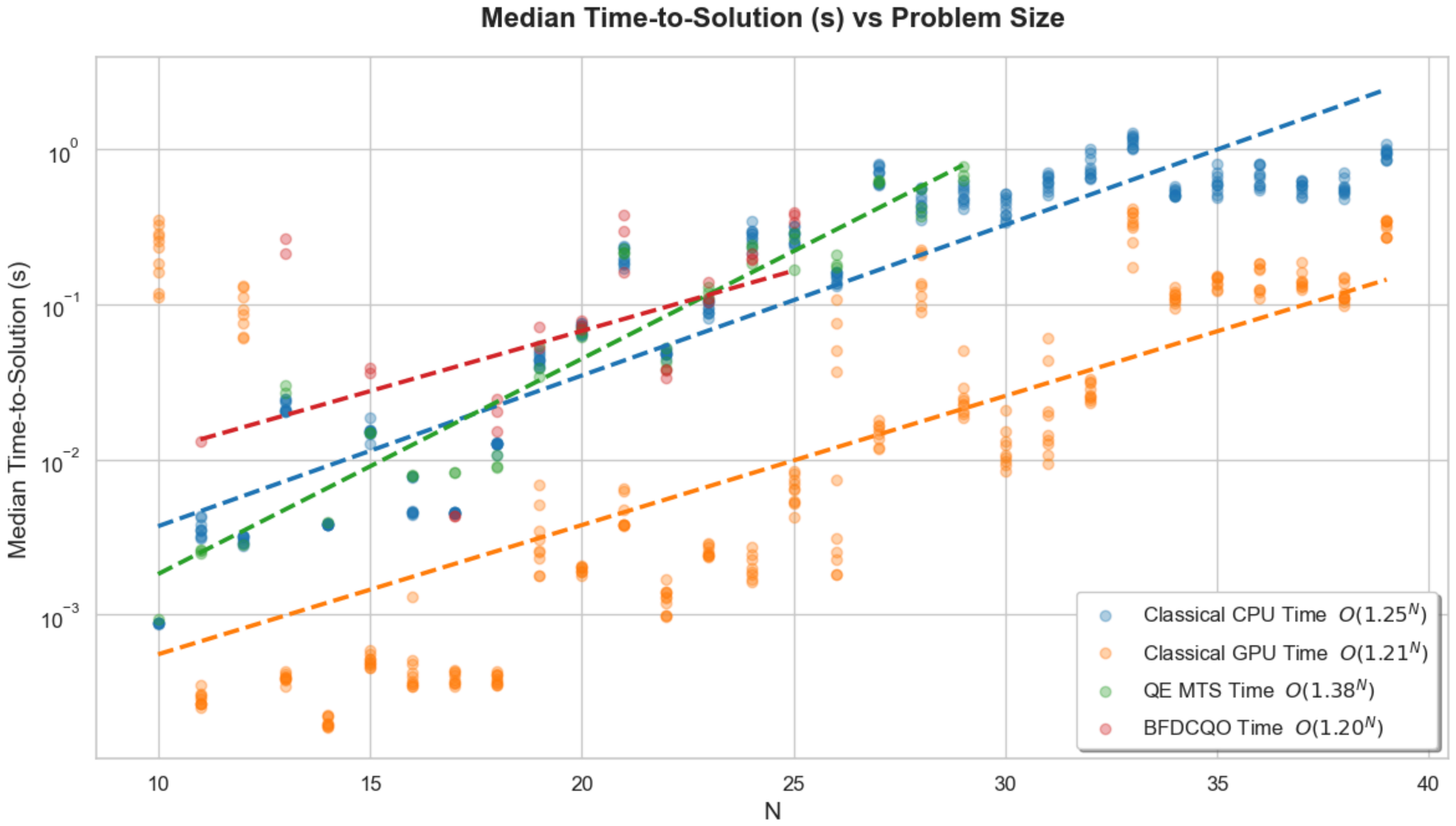
- Switch to NVIDIA GPUs as backends (A100 for dev/H100 for benchmark)
- MGPU/MQPU Backends
- Experimentation on superconducting quantum computers (QPU’s) from IQM Resonance

The Pivot

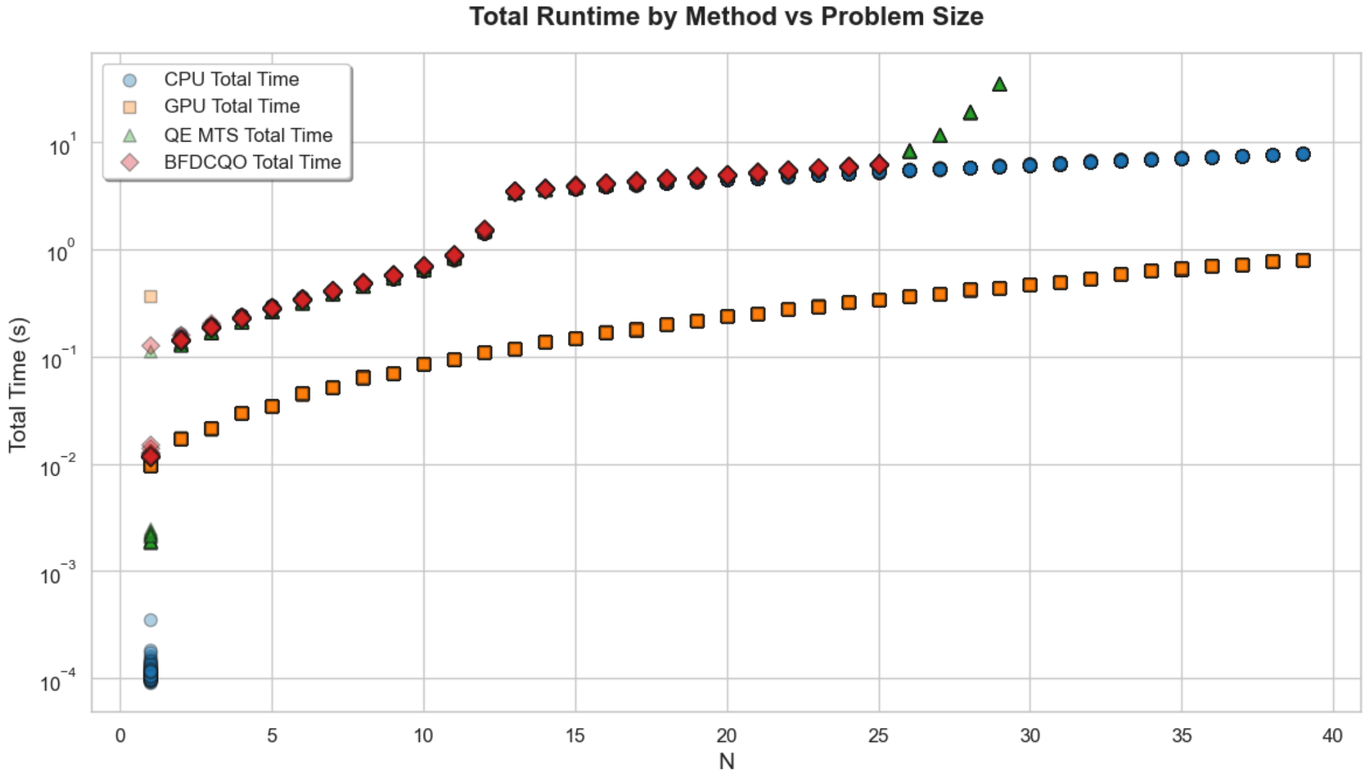
- Diversified Computing Platforms
  - qBraid for benchmarking, brev for dev
  - More compute power!

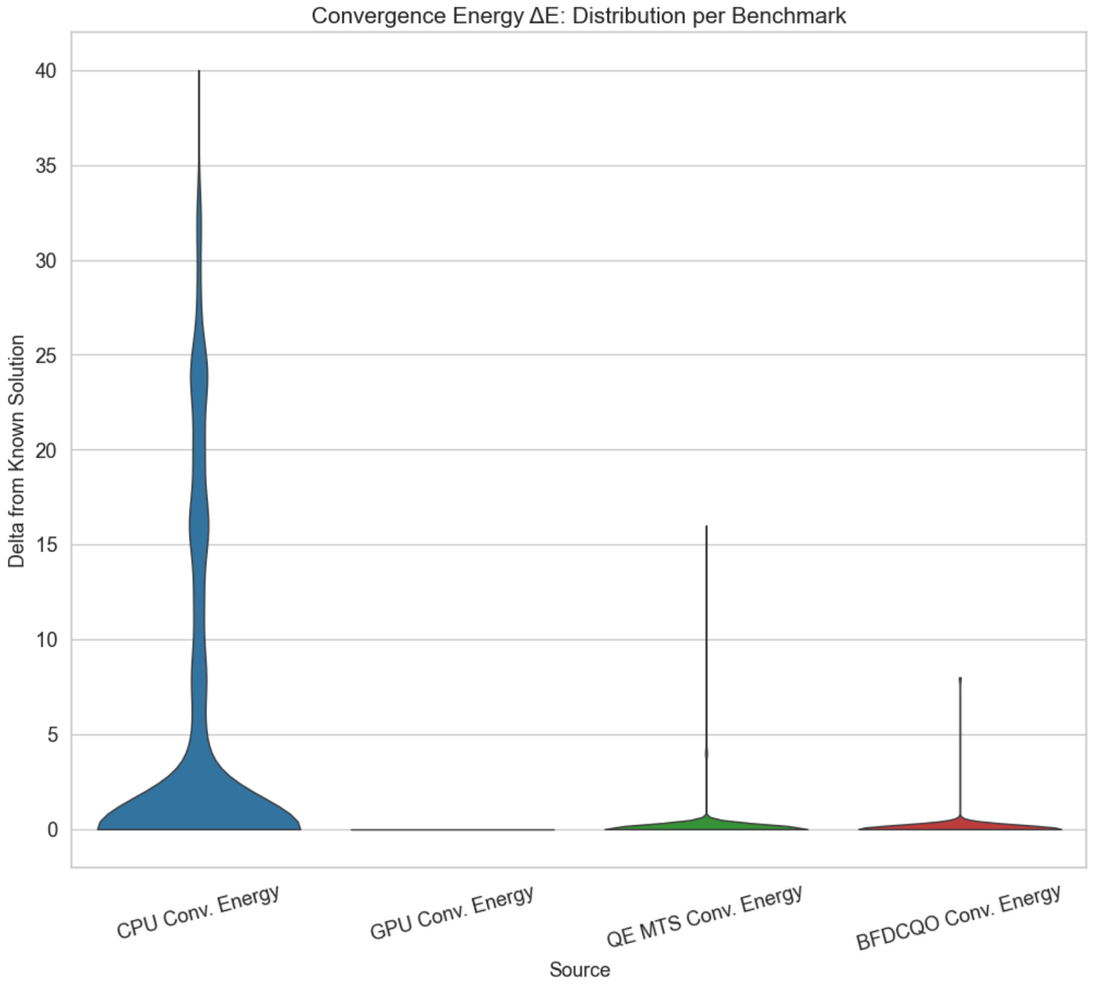
- Accelerating quantum algorithm by running on IQM’s Quantum Computers → future work

Results


Median Time-to-Solution (s) vs Problem Size
Median Time-to-Solution (s)
10^{0}
10^{-1}
10^{-2}
10^{-3}
10
15
20
25
30
35
40
N
Classical CPU Time $O(1.25^N)$
Classical GPU Time $O(1.21^N)$
QE MTS Time $O(1.38^N)$
BFDCQO Time $O(1.20^N)$

Results


Total Runtime by Method vs Problem Size
CPU Total Time
GPU Total Time
QE MTS Total Time
BFDCQO Total Time
Total Time (s)
N


Convergence Energy ΔE: Distribution per Benchmark
Delta from Known Solution
CPU Conv. Energy
GPU Conv. Energy
QE MTS Conv. Energy
BFDCQO Conv. Energy
Source

Team reflections

THANK YOU!