ETH zürich

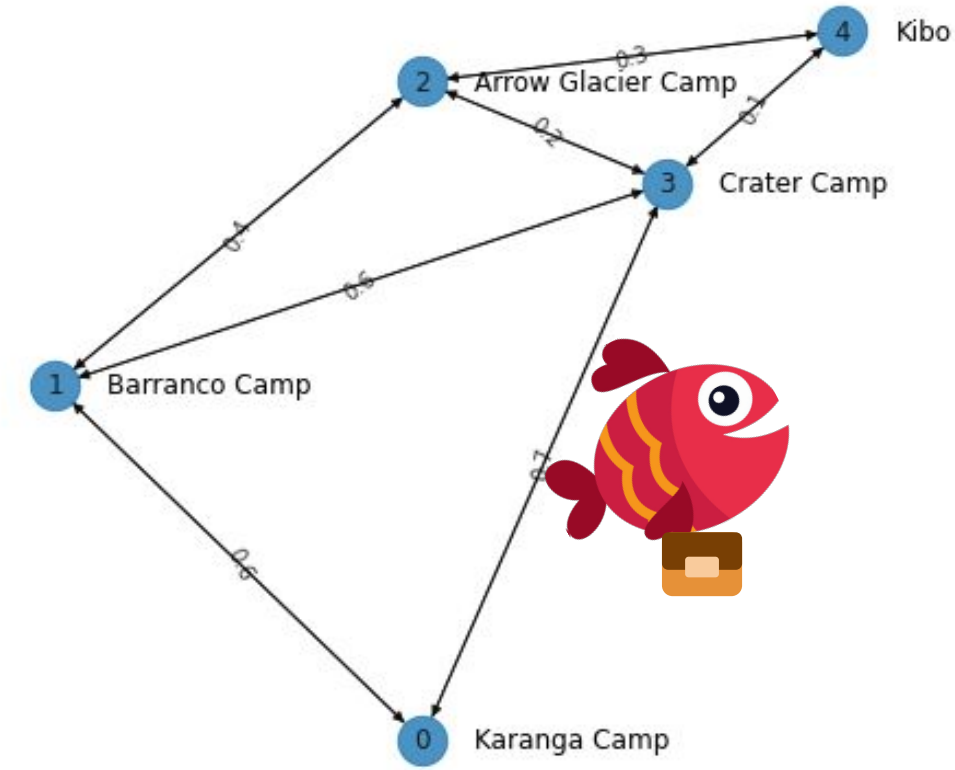
ETH Quantum Hackathon

Travelling Salesman Problem

An improved QAOA expedition to Kilimanjaro

Team Red Squishy Fishy 🐟

Fish from pngegg.com


4
Kibo
2
Arrow Glacier Camp
0.3
0.2
0.7
3
Crater Camp
0.1
0.5
1
Barranco Camp
0.6
0.7
0
Karanga Camp

NP - Hard

Attempt 1 - Encoding in $O(N^2)$

A QAOA solution to the traveling salesman problem using *pyQuil*

Matthew Radzihovsky, Joey Murphy, Mason Swofford

May 2019

Unfortunately that did not work very well...

```
number of qubits needed to solve the problem:  9
best energy:  37.169586810927754
```

We tried to do better than that

in $O(N \log N)$

Attempt 2 - Encoding location in O(N log(N))

log(n) bits
("camp label/index in binary")

| A ⟩ (Id 0)
00

| C ⟩ (Id 2)
10

| B ⟩ (Id 1)
01

n timesteps to
visit n cities

	ENC
A	00
B	01
C	10

Attempt 2 - Encoding in O(N log(N))

e.g. N^2 vs N log(N) , for $Q = 10^3$

N = # nodes
Q = # qubits

$Q = N^2$
$N \cong 31$

Q = N log(N)
$N \cong 140$

Attempt 2 - Hamiltonians

Cost Hamiltonian

$$\hat{H}_4 = \sum_{j=0}^{n-2} \lambda_{A,B}(|A\rangle_i|B\rangle_j\langle A|_i\langle B|_j + |B\rangle_i|A\rangle_j\langle B|_i\langle A|_j)$$

Mixing Hamiltonian

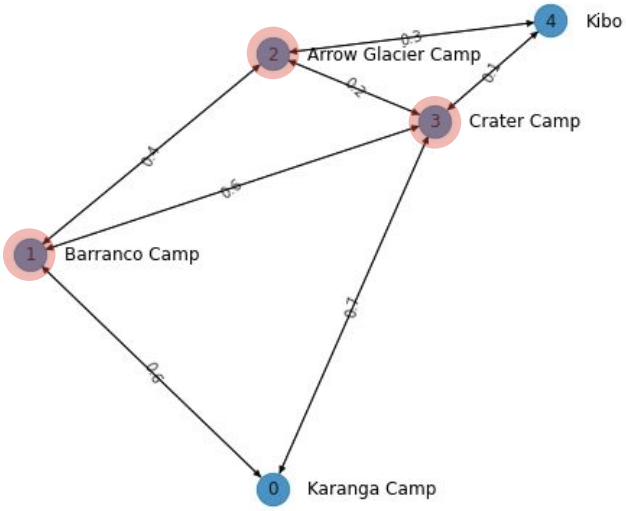
$$\hat{H}_{enc\,\{i,j\},\{A,B\}} = |A\rangle_j|B\rangle_i\langle B|_j\langle A|_i$$

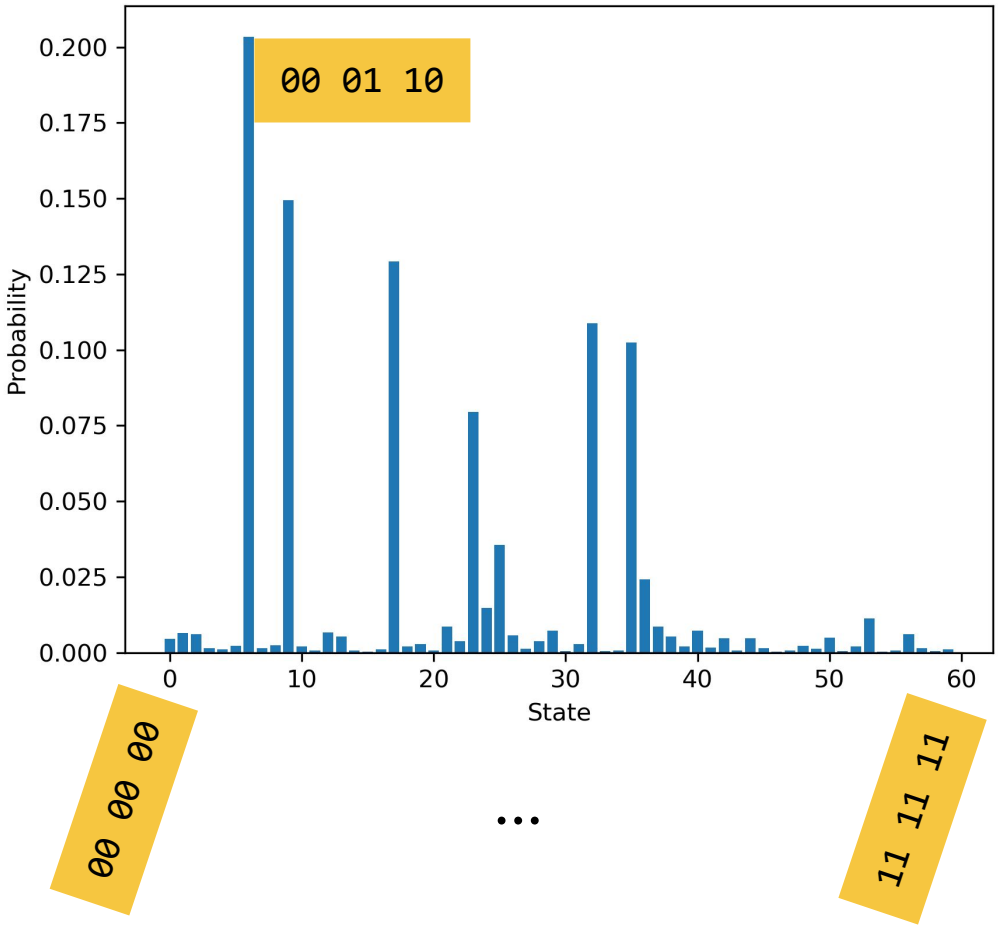
Initial state

$$|s\rangle = H^{\otimes N}|0\rangle^N$$

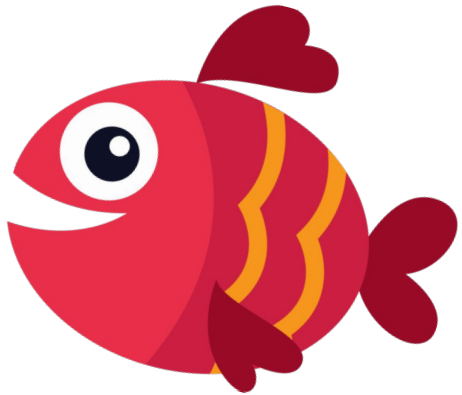
Attempt 2 - QAOA probabilities

For a 3-City TSP problem





Thank you for your attention!



The Team:

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