Introduction to Quantum Computing Pennylane: Grover searching

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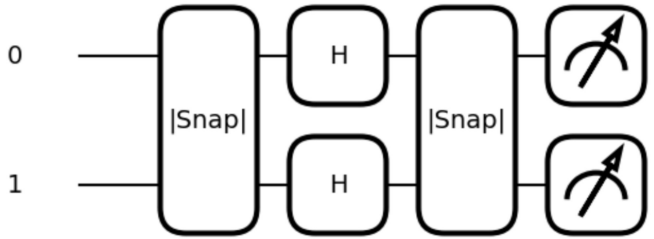
Last week:

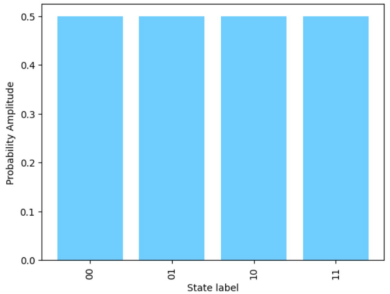
- Broke locks (provided by oracles) by testing in pairs
- Deutsch-Josza determines whether solution is present, not what it is
- Use last, auxiliary, qubit catalytically

This week:

- Grover goal: figure out what solution is
- Amplitude amplification: start in uniform superposition
  ‘pump’ amplitude from other states into the solution state.

Exercise 1: Uniform superposition



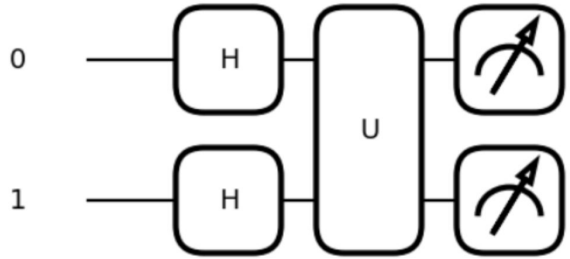



```
n_bits = 4
dev = pl.device("default.qubit", wires=n_bits)

@pl.qnode(dev)
def uniformsuperposition():
   """Build a circuit that creates an n-qubit uniform superposition. Use pl.Snapshot, inspect the results"""
   return pl

pl.drawer.use_style("black_white")
pl.draw_mpl(uniformsuperposition)();
pl.snapshots(uniformsuperposition)()
```

Exercise 2: Oracle




```
[[-1.  0.  0.  0.]
 [ 0. -1.  0.  0.]
 [ 0.  0.  1.  0.]
 [ 0.  0.  0.  1.]]
```

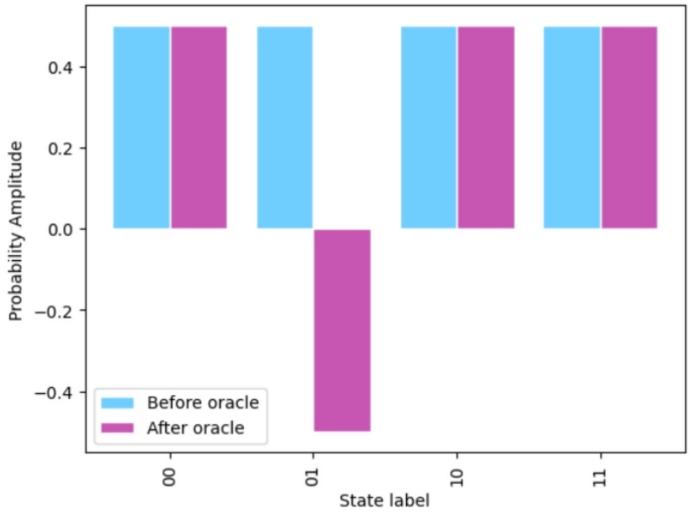
```
def oracle(keys):
   # return a diagonal matrix with entries 1 and -1 for the oracle
   return matrix

@pl.qnode(dev)
def circuit(keys):
   # build a uniform superposition
   # perform the oracle as a unitary gate
   return pl.probs(wires=wires)
```

Exercise 3: Amplitude amplification

```
keys = [[0,1]]
dev = pl.device("default.qubit", wires=n_bits)

@pl.qnode(dev)
def circuit():
    pl.broadcast(pl.Hadamard, wires=wires,
pattern="single")
    pl.Snapshot("Before oracle")
    pl.QubitUnitary(oracle(keys), wires=wires)
    pl.Snapshot("After oracle")
    return pl.probs(wires=wires)
# inspect the results before and after applying the oracle
# plot them in a bar chart using plt
```

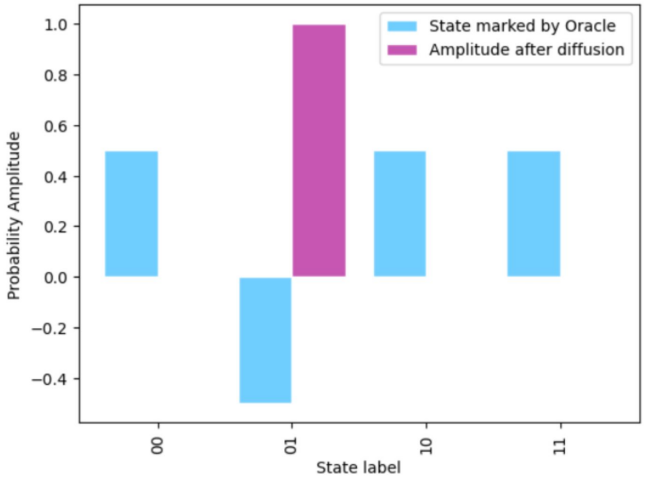


Exercise 4: Diffusion operator

```
def diffusion_operator(wires):
    """Build diffusion operator circuit"""

def circuit():
   pl.broadcast(pl.Hadamard, wires=wires, pattern="single")
   pl.Snapshot("Uniform superposition")
   pl.QubitUnitary(oracle(keys), wires=wires)
   pl.Snapshot("State marked by Oracle")
   diffusion_operator(wires)
   pl.Snapshot("Amplitude after diffusion")
   return pl.probs(wires=wires)

results = pl.snapshots(circuit)()
```



Exercise 5: Grover search, multiple keys

```
n_bits = 4
dev = pl.device("default.qubit", wires=n_bits)
wires = list(range(n_bits))
keys = [[0,1,0,1],[1,1,1,1]]
M = 2
N = 2**n_bits

@pl.qnode(dev)
def circuit():
    # build the grover circuit, and iterate it sqrt(n/m)*pi/4
times
    # hint: you can use pl.templates.GroverOperator
    return pl.probs(wires=wires)

results = pl.snapshots(circuit)()
# check the results
```