HNCDI Explain: Grover Tutorial 2

This is tutorial 3 on Grover's Algorithm. This is a 3-qubit example, with 1-Grover iteration.

Task. Run through the provided notebook, which steps through the stages of Grover's algorithm. Notice that the good item $x_m=111$ still occurs with high probability, but the other strings now have non-zero probability.

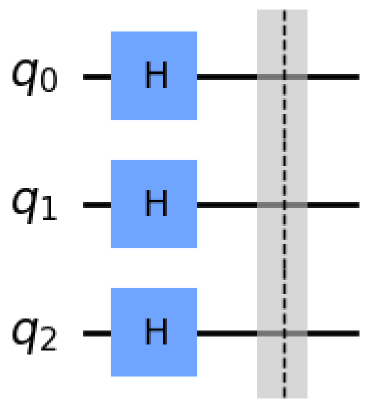
In [1]:
```
# Import standard Qiskit libraries
import numpy as np
from qiskit import QuantumRegister, ClassicalRegister, QuantumCircuit, tr
from qiskit.compiler import transpile
from qiskit.tools.jupyter import *
from qiskit.visualization import *
from ibm_quantum_widgets import *

from qiskit import execute
from qiskit.providers.ibmq import least_busy
```

As in tutorial 1, we will now step through Grover's algorithm but for 3-qubits.

Step 1: Create the superposition state $|s \rangle$.

In [2]:
```
# Define no. of qubits to be n = 3 and create a quantum circuit called "c
n = 3
circ = QuantumCircuit(n)

#Apply a Hadamard gate to each qubit in the circuit.
for i in range(n):
    circ.h(i)

circ.barrier()
circ.draw('mpl')
```

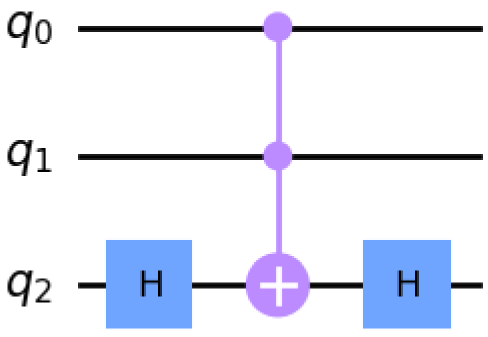
Out[2]:



Step 2. Here we create the circuit that implements the oracle that marks the good item 111. The circuit that implements this is the CCZ gate.

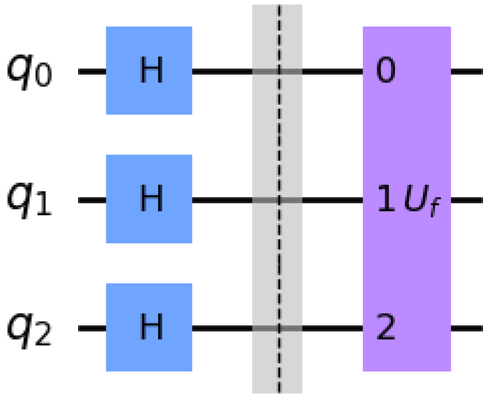
In [3]:
```
qc = QuantumCircuit(3)

## mark item 111
qc.h([2])
qc.ccx(0,1,2)
qc.h([2])
qc.draw('mpl')
```

Out[3]:



In [4]:
```
oracle = qc.to_gate()
oracle.name = "$U_f$"
circ.append(oracle, [0,1,2])
circ.draw('mpl')
```

Out[4]:



Step 3. Apply the Grover Diffusion operator.

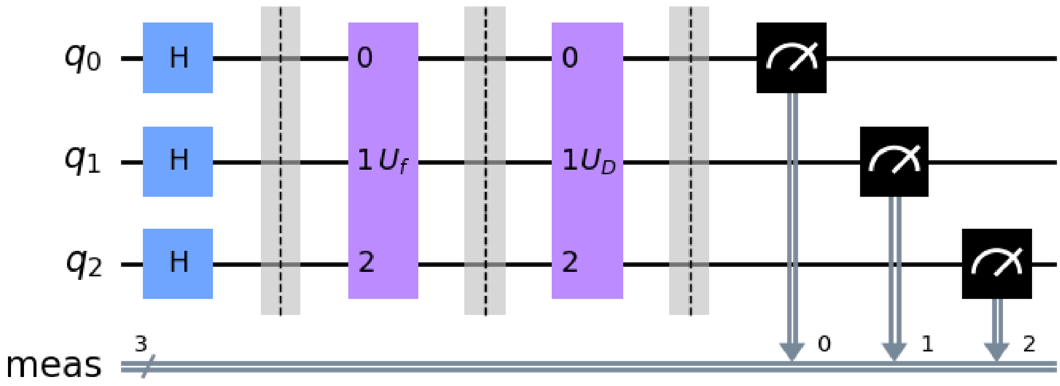
In [5]:
```
# This is code provides a general implementation of Grover's Diffusion op
def diffuser(nqubits):
    qc = QuantumCircuit(nqubits)
    # Apply transformation |s> -> |00..0> (H-gates)
    for qubit in range(nqubits):
        qc.h(qubit)
    # Apply transformation |00..0> -> |11..1> (X-gates)
    for qubit in range(nqubits):
        qc.x(qubit)
    # Do multi-controlled-Z gate
    qc.h(nqubits-1)
    qc.mct(list(range(nqubits-1)), nqubits-1)  # multi-controlled-toffoli
    qc.h(nqubits-1)
    # Apply transformation |11..1> -> |00..0>
```

```
    for qubit in range(nqubits):
        qc.x(qubit)
    # Apply transformation |00..0> -> |s>
    for qubit in range(nqubits):
        qc.h(qubit)
    # We will return the diffuser as a gate
    U_s = qc.to_gate()
    U_s.name = "$U_D$"
    return U_s
```

In [6]:
```
circ.barrier()
circ.append(diffuser(n), [0,1,2])
circ.draw()
circ.measure_all()
print({'This is the final Grover Circuit with 1-iteration.'})
circ.draw('mpl')
```

```
{'This is the final Grover Circuit with 1-iteration.'}
```

Out[6]:

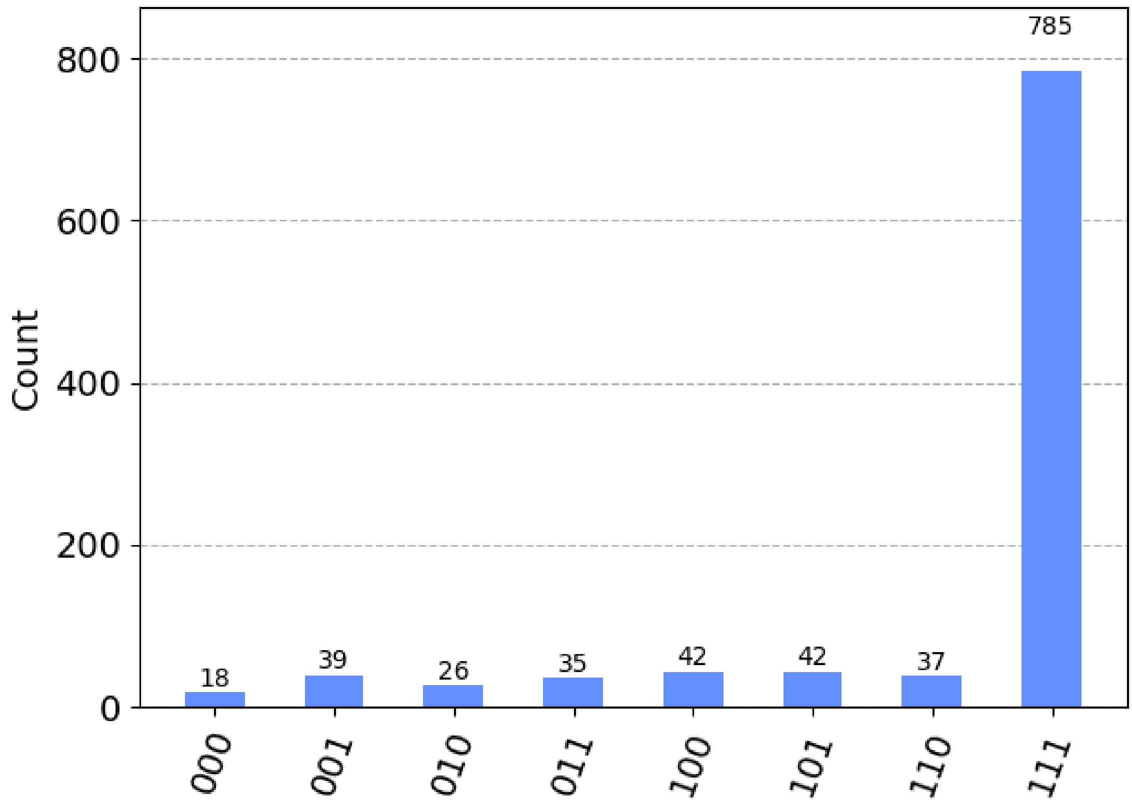


Step 4: We will now submit the quantum circuit to A) a simulator and B) a real quantum computer.

Notice that the marked item $x_m = 111$ was identified with high probability with only one Grover-iteration, however unlike tutorial 1 the other strings now have non-zero probability.

In [7]:
```
# OPTION 1: RUN ON QUANTUM SIMULATOR
backend = Aer.get_backend('qasm_simulator')
results = execute(circ, backend=backend, shots=1024).result()
answer = results.get_counts()
plot_histogram(answer)
```

Out[7]:



In [8]:

```
# OPTION 2: RUN ON QUANTUM HARDWARE


#provider = IBMQ.load_account()
#device = least_busy(provider.backends(filters=lambda x: x.configuration(

##transpile
#t_circuit = transpile(circ, device, optimization_level=3)
#job = execute(t_circuit, backend = device, shots =1024, optimization_lev
#from qiskit.tools.monitor import job_monitor
#job_monitor(job, interval = 2)
#results = job.result()
#answer = results.get_counts(grover_circuit)
#plot_histogram(answer)
```

In [ ]: