VQE and QAOA to solve MAXCUT

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1 Coding graphs

1.1 Cuts in graphs

We need to cut every links from a vertex in V_0 to a vertex in V_1

```python
def costOfCut(g,s):
    r = 0
    l = len(s) - 1
    for n, e in g.items():
        for d in e:
            if s[l - d] != s[l - n]:
                r += 1
    return r
```

Listing 1: Code that computes the cost of a cut s in a graph g

1.2 Scalar product

```python
def scalprod(g,d):
    r = 0
    for k, p in d.items():
        r += costOfCut(g, k) * p
    return -r
```

Listing 2: Code that computes the scalar product who whant to optimize

2 MAXCUT with VQE

```python
def probDistVQE(a):
    q = QuantumRegister(4)
    c = ClassicalRegister(4)
    qc = QuantumCircuit(q,c)

    assert(len(a) % 12 == 0)

    for i in range(len(a) // 12):
        for qi in range(4):
            j = qi * 3 + i * 12
            qc.u(a[j], a[j + 1], a[j + 2], q[qi])
        for qi in range(4):
            qc.cnot(q[qi], q[(qi+1) % 4])
    qc.measure(q, c)

    backend = BasicAer.get_backend('qasm_simulator')
    job = execute(qc, backend, shots=1000)
    res = dict(job.result().get_counts(qc))

    for i in res:
        res[i] = res[i] / 1000
    return res
```

Listing 3: code that creates and simulates the VQE circuit

- What are the various proposed cuts (V_0, V_1) ?

cuts	probabilities
1001	0.699
0110	0.292
1010	0.003
0011	0.005
1100	0.001

- Change the graph and check that it does not work "just by chance" (for instance, use g_2, g_3, or your own).

  It also work for g_2 and g_3.

- Are all possible cuts there ?

- The problem is symmetric, in the sense that if '0110' is an answer, so is '1001'. Is this reflected in the resulting probabilities ?

  There's symmetry, but you don't get it every time

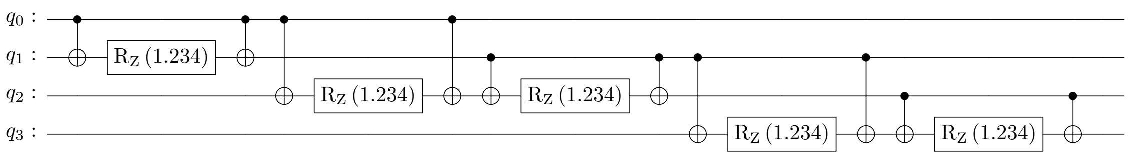
- If we had access to a real quantum co-processor, how would the code change ?

3 MAXCUT with QAOA

```python
def V(qc,q,angle,g):
    for s in g:
        for e in g[s]:
            qc.cnot(q[s], q[e])
            qc.rz(angle, q[e])
            qc.cnot(q[s], q[e])
    return
```

Listing 4: code that add V gate in a quantum circuit

If we exectue V on an empty circuit with graph g_1 and angle = 1.234 we have this circuit :



```python
def probDistQAOA(a,g):
    p = int(len(a)/2)
    beta = a[:p]
    gamma = a[p:]

    q = QuantumRegister(4)
    c = ClassicalRegister(4)
    qc = QuantumCircuit(q,c)


    qc.h(q)


    for i in range(p):
        V(qc,q,gamma[i],g)
        for qb in q:
            qc.rx(beta[i], qb)
    qc.measure(q, c)

    backend = BasicAer.get_backend('qasm_simulator')
    job = execute(qc, backend, shots=1000)
    res = dict(job.result().get_counts(qc))

    for i in res:
        res[i] = res[i] / 1000
    return res
```

Listing 5: code that creates and simulates the QAOA circuit

- Does it still work with other graphs ?

  Yes, it still work.

- Does it find all of the possibilities ? How about the symmetry of the results ?

  The symmetry is much more common than VQE.

- Play with the length of the array a ($p = 2, 4, ...$ – make sure to keep it even). Do you see any loss/increase in precision ?

  Yes if we increase the length of the array a we can an improvement of the precision but the exectution is slower.

- Remark how the number of necessary parameters is way smaller than for VQE.