

Task 3 - A Simple Quantum Compiler

```
In [11]: import numpy as np  
import math  
import functools
```

Task Description:

Input assumptions: A circuit consisting of gates to be simplified, this is represented by a list of lists of gates. The possible gates are H,X,Y,Z.

Output assumptions: A circuit consisting of only CZ,RX,RZ

Description of most naive approach: The most naive approach would be to simply take every single gate in the original circuit and replace them with their decomposition.

Description of main ideas for this construction:
-Palindromic circuits of even length may be removed - it is important to note here that RX(theta),RZ(theta),RY(theta) are not self inverse, but (-theta) or (2pi-theta) of the same gate is. Also, to include multi qubit gates in a palindromic circuit, between them on all qubits they act on must be palindromic.
-All identity gates can be disregarded -consecutive RX gates may be turned into RY gates and the same is true for rz gates

Creating a gate representation

- This design of gates is working off of the assumption that all angles of rotation are limited between -pi and pi, thus any input angles to parameterized gates will give an error of out of bounds
- The superclass gate is the parent to both singlequbitgate and twoqubitgate from which all of the gates that match that are descended from

-A circuit is expected here to be a list of lists, a list of lists of gates for each qubit index. So a circuit of n qubits is a list of length n.

-This assumes that the two qubit gates are given an indication in both the lists of gates for the qubits that they act on.

-Gates need the attributes: matrix, id (for checking type), angles (x,y,z), basisrepresentation (list of gates that represent the gate in terms of rx, ry and rz)

Jupyter Screening tasks (containing an error)

```
In [173]: class Gate:
    def __init__(self, name):
        self.name = name
        self.id = None
        self.gate_type = None
        self.gate_matrix = None
        self.qubit_id = None
        self.basis_representation = None

    def __str__(self):
        return f'{self.name} ({self.id})'

    def __eq__(self, other):
        if self.name == other.name and self.id == other.id:
            return True
        else:
            return False

    def __hash__(self):
        return hash(self.name + str(self.id))

    def get_gate_matrix(self):
        if self.gate_matrix is None:
            raise Exception("Gate matrix has not been defined")
        return self.gate_matrix

    def get_qubit_id(self):
        if self.qubit_id is None:
            raise Exception("Qubit ID has not been defined")
        return self.qubit_id

    def get_gate_type(self):
        if self.gate_type is None:
            raise Exception("Gate type has not been defined")
        return self.gate_type

    def get_basis_representation(self):
        if self.basis_representation is None:
            raise Exception("Basis representation has not been defined")
        return self.basis_representation
```

```
In [174]: class Singlequbitgate(Gate):
    def __init__(self, name, theta):
        super().__init__(name)
        self.theta = theta
        self.gate_matrix = np.array([[np.cos(theta), -np.sin(theta)], [np.sin(theta), np.cos(theta)]])

    def get_xyrotationangles(self):
        return self.angles(self)

    def is_palindromic(self,g):
        if super().is_palindromic():
            return True
        else:
            raise Exception("A single qubit gate cannot be represented as just one or no gates. Please define the class definition this is by so that they can be removed during conversion")

    def __eq__(self, other):
        if self.name == other.name and self.theta == other.theta:
            return True
        else:
            return False
```

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else:
    self.basisrepresentation = [self]

def is_palindromic(g):
    if g.get_xyzrotationangles()[2] == -self.angles[2] & g.get_xyzrotationangles()[0] == 0 & g.get_xyzrotationangles()[1] ==
        return True
    return False

class RY(singlequbitgate):
    def __init__(self,theta):
        if theta > math.pi | theta < -math.pi:
            raise Exception()
        self.matrix = np.array([[np.cos(theta/2)-(np.sin(theta/2))*1j,0],[0,np.cos(theta/2)+(np.sin(theta/2))*1j]])
        self.angles = (0,theta,0)
        self.id = ('RY')
        self.basisrepresentation = [RX(-math.pi/2),RZ(theta),RX(math.pi/2)]
        if g.get_xyzrotationangles()[1] == -self.angles[1] & g.get_xyzrotationangles()[0] == 0 & g.get_xyzrotationangles()[2] ==
            return True

    class H(singlequbitgate):
        def __init__(self,theta):
            self.matrix = np.array([[np.cos(theta/2),-(np.sin(theta/2))*1j],[-(np.sin(theta/2))*1j,np.cos(theta/2)]])
            self.angles = (math.pi/2,0,math.pi/2)
            self.id = ('H')
            self.basisrepresentation = [RZ(math.pi/2),RX(math.pi/2),RZ(math.pi/2)]

    class X(singlequbitgate):
        def __init__(self,theta):
            self.matrix = np.array([[np.cos(theta/2)-(np.sin(theta/2))*1j,0],[0,np.cos(theta/2)+(np.sin(theta/2))*1j]])
            self.angles = (math.pi,0,math.pi)
            self.id = ('X')
            self.basisrepresentation = [RX(-math.pi/2),RZ(math.pi),RX(math.pi/2),RZ(math.pi)]

    class V(singlequbitgate):
        def __init__(self,theta):
            self.matrix = np.array([[np.cos(theta/2),-(np.sin(theta/2))*1j],[-(np.sin(theta/2))*1j,np.cos(theta/2)]])
            self.angles = (math.pi,math.pi/2,math.pi/2)
            self.id = ('V')
```

```
self.basisrepresentation = [self]
#For parametric gates, if theta for the comparison gate = -theta for this
def is_palindromic(self,g):
    if g.get_xyzrotationangles()[0] == -self.angles[0] & g.get_xyzrotation
        return True
    return False

class RZ(singlequbitgate):
    def __init__(self,theta):
        if theta > math.pi | theta < -math.pi:
            raise Exception()
        self.matrix = np.array([[np.cos(theta/2)-(np.sin(theta/2))**2j,0],[0,np.cos(theta/2)+(np.sin(theta/2))**2j]])
        self.angles = (0,0,theta)
        self.id = ('RZ')
        if theta == 0:
            self.basisrepresentation = []
        else:
            self.basisrepresentation = [self]

    def is_palindromic(g):
        if g.get_xyzrotationangles()[2] == -self.angles[2] & g.get_xyzrotationangles()[0]
            return True
        return False

class RY(singlequbitgate):
    def __init__(self,theta):
        if theta > math.pi | theta < -math.pi:
            raise Exception()
        self.matrix = np.array([[np.cos(theta/2),(np.sin(theta/2))**2j],[0,np.cos(theta/2)-(np.sin(theta/2))**2j]])
        self.angles = (0,theta,0)
        self.id = ('RY')
        self.basisrepresentation = [RX,-RZ,RY,RX]
        if g.get_xyrotationangles() == self.angles & g.get_xyrotationangles() == self.angles
```





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```
def __init__(self,theta):
    self.matrix = np.array([[np.cos(theta/2)-(np.sin(theta/2))*1j,0],[0,np.cos(theta/2)+(np.sin(theta/2))*1j]])
    self.angles = (math.pi,0,math.pi)
    self.id = ('X')
    self.basisrepresentation = [RX(-math.pi/2),RZ(math.pi),RX(math.pi/2),RZ(math.pi)]


class Y(singlequbitgate):
    def __init__(self,theta):
        self.matrix = np.array([[np.cos(theta/2),-(np.sin(theta/2))*1j],[-(np.sin(theta/2))*1j,np.cos(theta/2)]])
        self.angles = (math.pi,math.pi/2,math.pi/2)
        self.id = ('Y')
        self.basisrepresentation = [RZ(math.pi/2),RX(-math.pi/2),RZ(math.pi),RX(math.pi/2),RZ(math.pi/2)]


class Z(singlequbitgate):
    def __init__(self,theta):
        self.matrix = np.array([[np.cos(theta/2)-(np.sin(theta/2))*1j,0],[0,np.cos(theta/2)+(np.sin(theta/2))*1j]])
        self.angles = (0,0,math.pi)
        self.id = ('Z')
        self.basisrepresentation = [RZ(math.pi)]

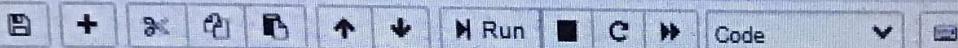

class I(singlequbitgate):
    def __init__(self,theta):
        self.matrix = np.array([[1,0],[0,1]])
        self.angles = (0,0,0)
        self.id = 'I'
        self.basisrepresentation = []

    def is_palindromic(self,g):
        if g.get_xyrotationangles() == (0,0,0):
            return True
        return super().is_palindromic(g)
```

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Description of palindrome finding protocol

The process of moving palindromes shall be called remove_palindromes(self).

The steps of this function are defined as such: -for each qubit in the circuit, call removepalindromesfromqubit(index)

removepalindromesfromqubit is defined as: -while removelargestpalindrome() > 1: #this is when there is no palindrome left -call removelargestevenpalindrome()

removelargestevenpalindrome is defined as: -find start and end indices of largest palindrome in qubit line -set that line of

In [172]: #defining the two qubit gates

```
class twoqubitgate(gate):
    def __init__(self,controlindex,actindex):
        self.controlindex = controlindex
        self.actindex = actindex

    def get_actindex(self):
        return self.actindex

    def get_controlindex(self):
        return self.controlindex

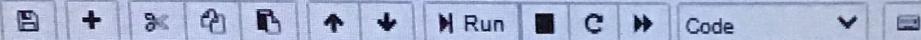
    def is_palindromic(self,g,qubitindexon,circuit,dist):
        if g.id == self.id & g.get_controlindex() == self.controlindex & g.get_actindex == self.actindex:
            if qubitindexon > min(self.actindex,self.controlindex): #if the index passed to it is larger than one of them
                return False
            if circuit[max(self.actindex,self.controlindex)].index(g) - circuit[min(self.actindex,self.controlindex)].index(g) < dist:
                return False
        return False #todo

class CX(twoqubitgate):
    def __init__(self,controlindex,actindex):
        if controlindex == actindex:
            raise Exception
        self.controlindex = controlindex
        self.actindex = actindex
```

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```
self.basisrepresentation = [H.getmatrix(),CZ(controlindex,actindex),H.getmatrix]

class CZ(twoqubitgate):
    def __init__(self,controlindex,actindex):
        if controlindex == actindex:
            raise Exception
        self.controlindex = controlindex
        self.actindex = actindex
        self.id = ('CZ')
        #if self.actindex > self.controlindex:
        #    self.matrix = np.array([[1.+0.j 0.+0.j 0.+0.j 0.+0.j],[0.+0.j 1.+0.j 0.+0.j 0.+0.j],[0.+0.j 0.+0.j 0.+0.j 1.+0.j],[0.+0.j 0.+0.j 1.+0.j 0.+0.j]])
        #else:
        #    self.matrix = np.array([[1.+0.j 0.+0.j 0.+0.j 0.+0.j],[0.+0.j 0.+0.j 0.+0.j 1.+0.j],[0.+0.j 0.+0.j 1.+0.j 0.+0.j],[0.+0.j 1.+0.j 0.+0.j 0.+0.j]])

        self.basisrepresentation = [self]
```

```
In [ ]: class Circuit():
    def __init__(self,numqubits):
        self.circuit = []
        for i in range(numqubits):
            self.circuit.append([])
        self.reducedcircuit = []

    def add_gate(self,qubitindex,g):
        self.circuit[qubitindex].append(g)
        #If a controlled gate, put reference in both qubits
        if g.get_id() == 'CX' | g.get_id() == 'CZ':
            if qubitindex == g.get_controlindex():
                self.circuit[g.get_actindex()].append(g)
            else:
                self.circuit[g.get_controlindex()].append(g)

    def get_compiledcircuit():
        #This step replaces all of the gates with their basis representations, if they are not already
        for index in len(self.circuit):
            for g in self.circuit[index]:
                self.reducedcircuit[index].append(g.get_basisrepresentation())

    def removealiquotnames(self):
```

