challenge_summary

April 11, 2021

1 Challenge Summary

I trea cloud qubit as a blak box and we tried to simplify the problem as mutch as possible since we have acces onl;y to the input and output i mada not gata a gate that change state |0> in |1> ans |1> in |0> up to some scalr (-|1> and |1> and j|a> will give me the same output). But sign in front of the excited state cam be coreeste in the future with an unexpensive Z gate. For H i made a gate that change my state of qubit from |0> to 1/sqrt(2)(|0>+ |1>) idealy wold be to also ty to apply H on the state 1 that was create with the pulse not pulse put We mismanaged our time .

Firs We thought at the beggining about how to create a cost function. We decide that we will use proprity of a dot product : For X gate if we apply in an od number of time we will mouve from state |0> in state |1> wit probabiliy 100 so the desire outcome y_desire=[0,1,0].If we apply it an od number of time we XX=I so we remain in state |0> y_desire=[1,0,0]. For the H gate since we alweys start feom the state |0> for an od number of repetition y_desire=[0.5,0.5,0] (this is not a statevector is the main diagonal of density matrix) and for even we are in the same situation.

Next step was to creat some parametize pulse and here we have spent a lot of time figuring out how to get a pulse for X gate.

To simplify thinks evem more we ommited imaginary since X and H don't have imagginary part and we have time constrains with model training.

[1]:
```
import matplotlib.pyplot as plt
import numpy as np
import scipy.optimize

from qctrlvisualizer import get_qctrl_style, plot_controls
from qctrl import Qctrl

qctrl = Qctrl(email='', password='')
```

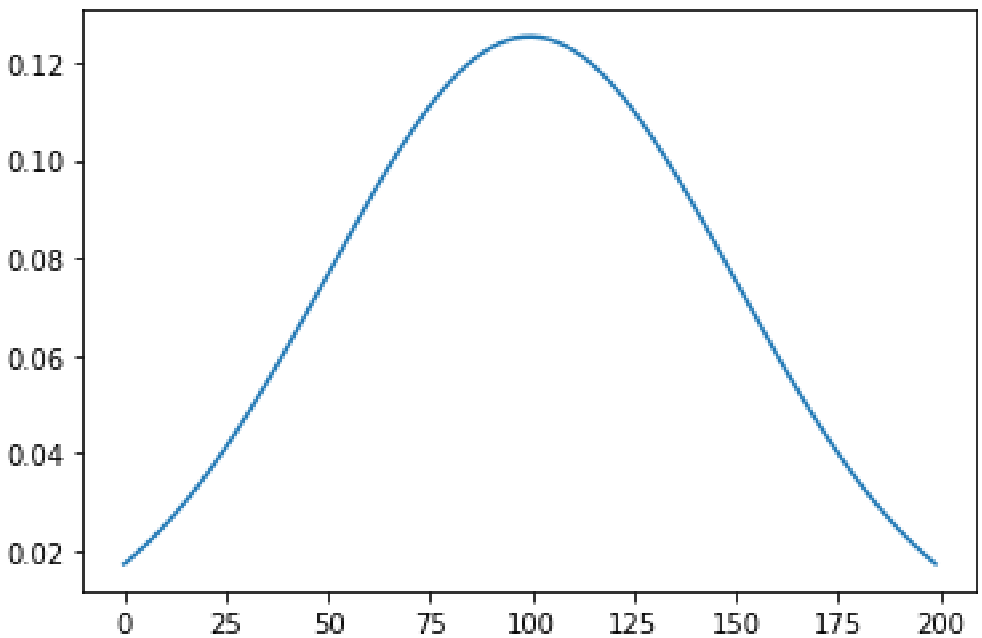
[39]:
```
# genrate data for a gaussian pulse
def gaussian_pulse(t, mean, width):
        return np.exp(-0.5 * ((t - mean) / width) ** 2.0) * np.sqrt(
            0.5 * np.pi / width ** 2.0)

def get_pulse(mean,width,segment_count):
    pulse=[]
    for i in range(0,segment_count):
```

```
        p=gaussian_pulse(t=i*segmentsize+segmentsize/2, mean=mean, width=width)
        pulse.append(p)
    return pulse
```

Here we have an example fro a pulse similar with the one used for best H

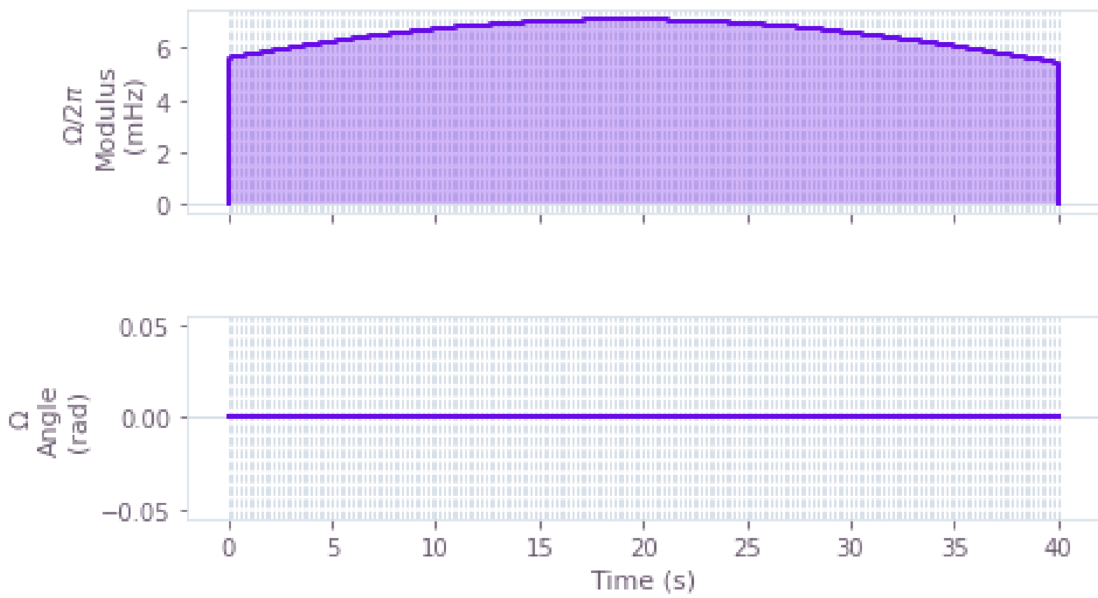
[32]:
```
#initial parameters

segment_count=200
duration=40
width=duration/4
mean=duration/2
segmentsize=duration/segment_count
amplitude=0.5

pulse=get_pulse(mean,width,segment_count)
plt.plot(pulse)
```

[32]:
```
[<matplotlib.lines.Line2D at 0x7fa84074fa10>]
```



[40]:
```
real_part = pulse#np.random.random(size=[segment_count])
imag_part = np.random.random(size=[segment_count])
values = amplitude * (real_part + 1j * imag_part*0)
control={"duration": duration, "values": values}
# Plot the last control as an example.
plot_controls(
```

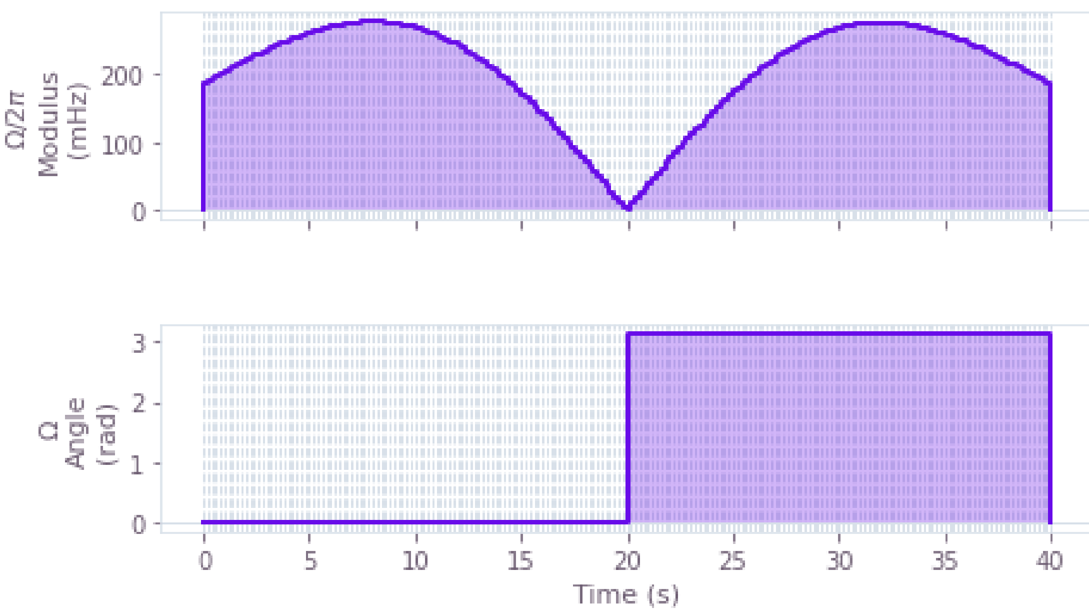
```
    figure=plt.figure(),
    controls={
        "$\Omega$": [
            {"duration": duration / segment_count, "value": value} for value in␣
↪values
        ]
    },
)
```



For X gate we observe that is hurd to put the qubit in |1> state. The think that excite your qubit is the energi and and ennery is proportional withe the are uner the graph so we decide to use two gaussian:

[49]:
```
segment_count=200
# values from a good pulse
amplitude1= 15.49724215#duration/4
amplitude2= -15.42531197#duration/4
width1=duration/4#25.56953712
width2=duration/4#26.86006445
mean1=duration/4
mean2=duration-mean1

segmentsize=duration/segment_count

pulse1=get_pulse(mean1,width1,segment_count)
pulse2=get_pulse(mean2,width2,segment_count)
pulse=pulse=[pulse2[i]-pulse1[i] for i in range (len(pulse1))]
```

```
values = np.array([amplitude1 * (pulse1[i] + 1j*0)+amplitude2 * (pulse2[i] + 1j␣
↪*0)for i in range (len(pulse1))])

control={"duration": duration, "values": values}
# Plot the last control as an example.
plot_controls(
    figure=plt.figure(),
    controls={
        "$\Omega$": [
            {"duration": duration / segment_count, "value": value} for value in␣
↪values
        ]
    },
)
```



Now even with such simplification we have some parameters that we can verry but we wil start to optimize just over amplitudes and width. We also made a lot of duration optimization by hand in pricipal we din't whant to have a long duration beacuse this will affect the nr of gates that we can ad in a qubit life time. Also wold be indicate to incees segment counts.

1.1 Building the cost function for H

1.1.1 !! to get the answers we started training first with a small number of repetitions=[1,2,3] and after eatch minimisation me add another ser of rpetition. In the var-H youu can follow the messy procedure that we followed.

Here we have just one amlitude and onw with over witch we will optimize.

[72]:
```
def cost_h(params):

    print('params:',params)
    amplitude=params[0]
    width=params[1]

    #
    duration=40
    mean=duration/2

    #

    segmentsize=duration/segment_count

    pulse_real=get_pulse(mean,width,segment_count)

    real_part = pulse_real
    imag_part = np.random.random(size=[segment_count])# if first experiments it␣
↪will be set to 0

    values = amplitude * (real_part + 1j * imag_part*0)

    repetitions=[1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19]
    controls=[]
    for repetition_count in repetitions:
        controls.append({"duration": duration, "values": values,␣
↪"repetition_count": repetition_count})
        experiment_results = qctrl.functions.
↪calculate_qchack_measurements(controls=controls,shot_count=shot_count,)


    cost=0
    for repetition_count, measurement_counts in zip(repetitions,␣
↪experiment_results.measurements):
        p0 = measurement_counts.count(0) / shot_count
        p1 = measurement_counts.count(1) / shot_count
        p2 = measurement_counts.count(2) / shot_count
        y_genrate=[p0,p1,p2]
        if  repetition_count%2==1:
```

```python
            y_desire=[0.5,0.5,0]
            c=np.array(y_desire) @ np.array(y_genrate)
            cost=cost-c
        else:
            y_desire=[1,0,0]
            c=np.array(y_desire) @ np.array(y_genrate)
            cost=cost-c

        print(f"With {repetition_count:2d} repetitions: P(|0>) = {p0:.2f},␣
↪P(|1>) = {p1:.2f}, P(|2>) = {p2:.2f} ,c={c:.3f} .")

    print('Cost:',cost)
    return cost
```

For cost_x check var-x.ipynb .

1.2 Optimization:

[ ]:
```python
# H gate:

shot_count = 250
params=[ 4.03658917 ,28.45216669]

cobyla_options = {'maxiter': 1, 'disp': True, 'catol': 0.002} # here we reduce␣
↪the nr of iterations because this is just for the sake of an exampl
res = scipy.optimize.minimize(cost_h, params,␣
↪method='COBYLA',options=cobyla_options)
params_h=res['x']
print(params_h)
```

```
params: [ 4.03658917 28.45216669]

100%|      | 100/100 [00:03<00:00, 31.81it/s]
  0%|          | 0/100 [00:00<?, ?it/s]
```

Obs: for reps%2==0 the value of c can be maximum 0.5 [0.5,0.5,0][0.5,0.5,0]=0.25+0.25=0.5 for reps%2==1 the value of c can be maximum 1

This method can be generalize to more complex gates if we change the cost function and we decide to use more complex pulse structure.

[ ]:
```python

```