Quantum Generative Adversarial Network with Noise

Project Name: Quantum Generative Adversarial Network with Noise

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Contents

1 Experiment

In oreder to reproduce the article adversarial quantum circuit learning for pure state approximation [1],I write some code to simulate quantum circuits. The author only use a layout as a building block for generator and discriminator by two-qubits unitaries.In this layout every two-qubits unitaries can be efficiently implemented with three CNOT gate and fifteen parametrized single-qubit rotations.

when I use single-qubit gate and two-qubits gate,I had some trouble in how to build a quantum circuit by two-qubits gate [2].A quantum circuit only use single-qubit gate $R_n(\theta)$ and two-qubits gate $CNOT$.Every single-qubit gate is one-parametrized gate which have a formula like $R_n(\theta) = e^{-i\sigma_n\theta/2}$ .Each single-qubit gate place in a line of qubit and have a parameter θ.But $CNOT$ gate don't need a parameter.In my mind,to complete a quantum circuit,I need a list to save every single-qubit gate's paramter.And the sequence of paramter should be a fixed sequence.$CNOT$ gate don't need a paramter.So I don't know how to code $CNOT$ gate into quantum circuit.Because $CNOT$ gate don't have a paramter in paramter's list when I need a matrix representation by paramter's list.In this context,I choose a way to compromise.I fixed the generator and discriminator's quantum circuit in only one condition that the system number was fixed.

By using section A's method,the minimax game can be written as minmax $V(\theta, \phi)$ with loss function

$$V(\theta, \phi) = tr[E_0 D(|\psi_t >< \psi_t| \otimes |0 >< 0|)]P(t) - tr[E_0 D(G|0 >< 0|G^\dagger \otimes |0 >< 0|)]P(g)$$

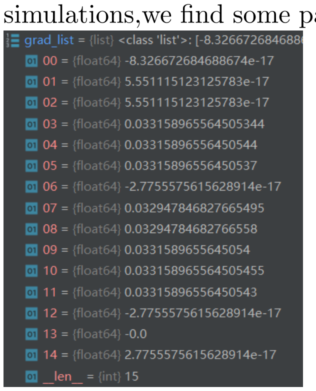
and the partial derivatives and $\frac{\partial V}{\partial \theta_l}$ and $\frac{\partial V}{\partial \phi_k}$.

The result is not good.

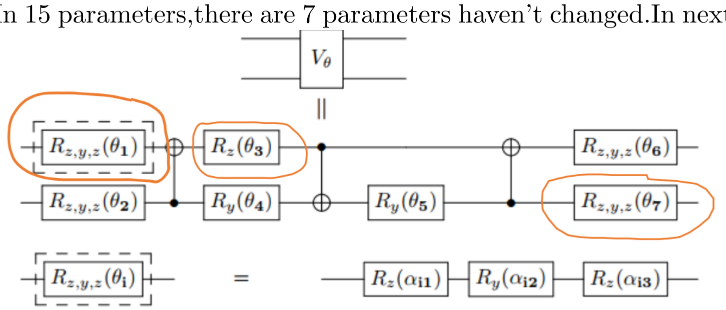
Because of the bad result of last experiment,I want to find some possible reasons.

First,E0 is a project measurement.So we will get a real number when we execute E0 on final state.In general the final state is represented by a complex vector ,so we will get a complex number when we execute E0 on a complex vector.This is contradictory. At the same time,I find this complex number has a big real and a very small image.So the first way is just use the real part.The second way is use a modulu of complex number.Two ways have the same effect when we compute $tr[E_0 D(|\psi_t >< \psi_t| \otimes |0 >< 0|D^\dagger)] - tr[E_0 D(G|0 >< 0|G^\dagger \otimes |0 >< 0|D^\dagger)]$

Second,$\frac{\partial V}{\partial \theta_l}$ and $\frac{\partial V}{\partial \phi_k}$ is too small when G and D just transform only one gate by change one of all parameters in quantum circuits. Ref.[1] use a universal two-qubit circuit[2] as general two-qubit unitary.But in numerical simulations,we find some paramiter in paramiterised unitary haven't changed after several gradient descent.

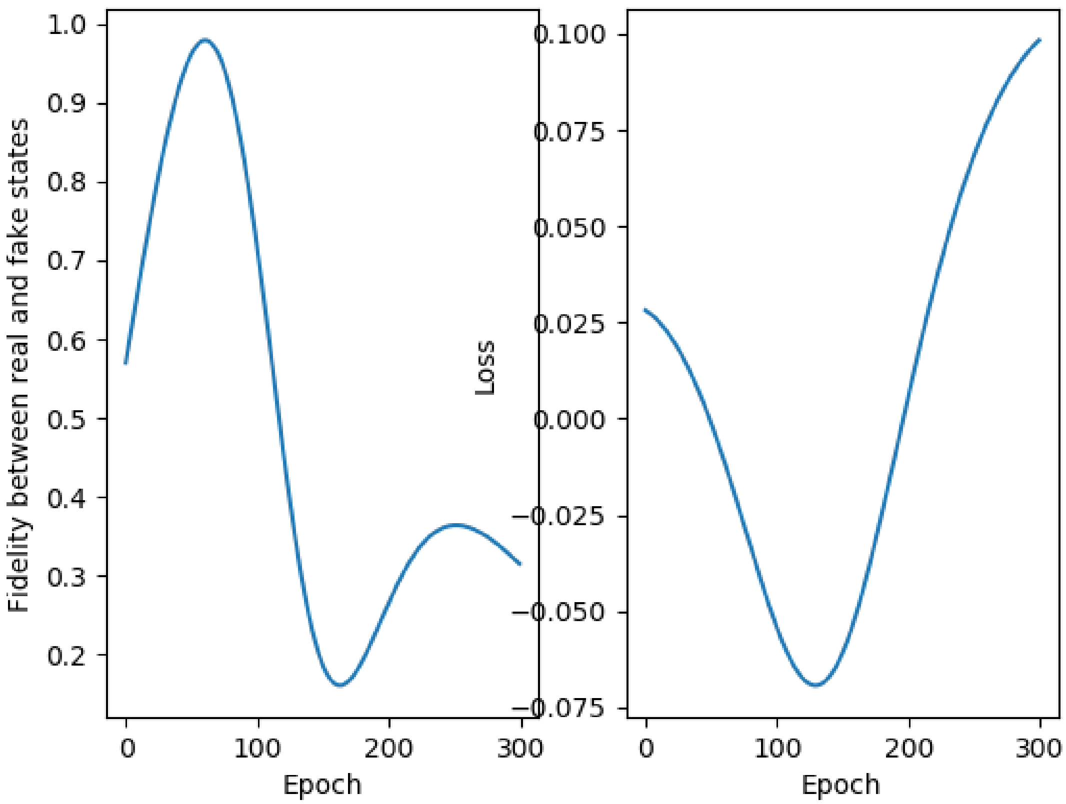

grad_list = {list} <class 'list'>: [-8.326672684688
00 = {float64} -8.326672684688674e-17
01 = {float64} 5.551115123125783e-17
02 = {float64} 5.551115123125783e-17
03 = {float64} 0.033158965564505344
04 = {float64} 0.03315896556450544
05 = {float64} 0.03315896556450537
06 = {float64} -2.7755575615628914e-17
07 = {float64} 0.032947846827665495
08 = {float64} 0.03294784682766558
09 = {float64} 0.0331589655645054
10 = {float64} 0.033158965564505455
11 = {float64} 0.03315896556450543
12 = {float64} -2.7755575615628914e-17
13 = {float64} -0.0
14 = {float64} 2.7755575615628914e-17
__len__ = {int} 15

In 15 parameters,there are 7 parameters haven't changed.In next figure,we can see them in two-qubit unitary.



so,parameter in this parameter gate remains the same.Can we think it is Identity gate or line in circuits? If we think it is the line or Identity gate,this result and Ref.[2] are contradictory. If we don't think that,we need all parameterized gate update parameter instead of this no-changed-parameter cricuit.
Next,I want to get some inspiration in Ref.[3]quantum circuit learning.

2 Results



This figure is a wrong experiment.

3 Next Plan

P: 1 finished quantum circuit code(finished)

2 checking gate gradient descent

3 find the reason why some parameter haven't changed.

4 Reference

References

[1] Benedetti, M., Grant, E., Wossnig, L., and Severini, S. Adversarial quantum circuit learning for pure state approximation. *New Journal of Physics 21*, 4 (2019), 043023.

[2] Shende, V. V., Markov, I. L., and Bullock, S. S. Minimal universal two-qubit controlled-not-based circuits. *Physical Review A 69*, 6 (2004), 062321.

5 Appendix

A Source Code

just add core codes