

#32: Solving Master equation of quantum computing using Reinforcement Learning

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- The quantum open systems master equation has the Schrödinger portion of the equation plus the non-unitary thermal dissipation part. The objective here is to come up with an implementation where the Schrödinger part is solved by unitary operations, but the other piece is learnt through an agent acting in the open environment through reinforcement learning or RL.

Two-level system with unital dissipation

Atom Evolution: $H = -\frac{\hbar\omega\sigma_z}{2}$

Emission (Lindbladian Operator) : $\sqrt{\gamma}\sigma_-$

where γ is rate of spontaneous emission

Plugging above values in Master Equation, we get:

$$\frac{d\tilde{\rho}}{dt} = \gamma[2\sigma_- \tilde{\rho} \sigma_+ - \sigma_+ \sigma_- \tilde{\rho} - \tilde{\rho} \sigma_+ \sigma_-]$$

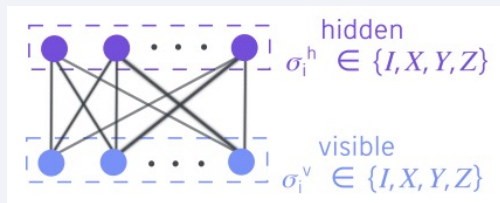
$$\tilde{\rho}(t) = \mathcal{E}(\tilde{\rho}(0))$$

\mathcal{E} has effect of amplitude dampening

Probability:

$$p_1(t) = \text{tr}(\pi_1 \rho(t))$$

Quantum Boltzmann Machine



input

$$H_{\text{eff}} = H_{\theta}^a + I^b$$

$$\tau = 1/2 (k_B T)$$

$$|\psi(\omega(0))\rangle = V(\omega(0))|0\rangle^{\otimes 2n} = |\phi^+\rangle^{\otimes n}$$

$$\text{with } |\phi^+\rangle = (|00\rangle + |11\rangle)/\sqrt{2}$$

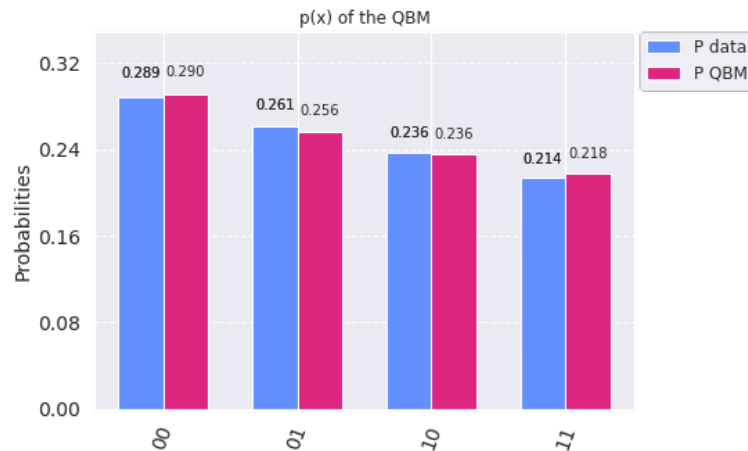
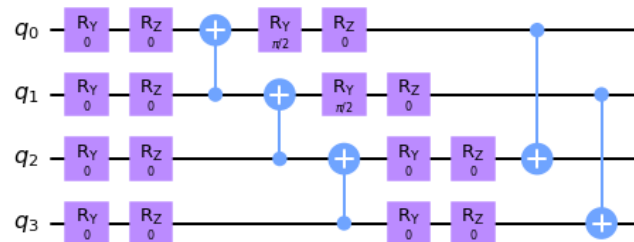
procedure

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for  $t \in \{\delta\tau, 2\delta\tau, \dots, \tau\}$  do
  Evaluate  $A(t)$  and  $C(t)$ 
  Solve  $A\dot{\omega}(t) = C$ 

  for  $i \in \{0, \dots, p-1\}$  do
    Evaluate  $\partial_{\theta_i} C$  and  $\partial_{\theta_i} A$ 
    Solve  $A(\partial_{\theta_i} \dot{\omega}(t)) = \partial_{\theta_i} C - (\partial_{\theta_i} A)\dot{\omega}(t)$ 
    Compute  $\partial_{\theta_i} \omega(t) = \partial_{\theta_i} \omega(t - \delta\tau) + \partial_{\theta_i} \dot{\omega}(t)\delta\tau$ 
  end for
  Compute  $\omega(t + \delta\tau) = \omega(t) + \dot{\omega}(t)\delta\tau$ 
end for
return  $\omega(\tau), \partial\omega(\tau)/\partial\theta$ 

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A close-up photograph of a computer keyboard. The central focus is a large, rectangular blue key with the words "Thank You!" printed in white, sans-serif font. The key is slightly raised and has a soft shadow. Surrounding it are several other white keys: to the left is a key with a hyphen and curly brace, above is a key with a comma and curly brace, and below is a key with the word "alt". The lighting is bright and even, highlighting the texture of the keys and the vibrant blue of the "Thank You!" key.

Thank You!