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

Mentor: Abhijit Mitra
Vaibhaw Kumar

Mentees: Alberto Maldonado
Shivam Sawarn
Hirmay Sandesara

Description

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

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

where γ is rate of spontaneous emission

Plugging above values in Master Equation, we get:

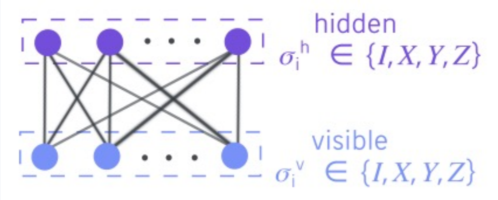
$$\frac{d\tilde{\rho}}{dt} = \gamma[2\sigma_-\tilde{\rho}\sigma_+ - \sigma_+\sigma_-\tilde{\rho} - \tilde{\rho}\sigma_+\sigma_-]$$

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

$\mathcal{E}$ has effect of amplitude dampening

Probability: $p_1(t) = \mathrm{tr}\big(\pi_1\rho(t)\big)$

Quantum Boltzmann Machine



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input
$H_{\text{eff}} = H_\theta^a + I^b$
$\tau = 1/2\,(k_B T)$
$|\psi(\omega(0))\rangle = V(\omega(0))|0\rangle^{\otimes 2n} = |\phi^+\rangle^{\otimes n}$
 with $|\phi^+\rangle = (|00\rangle + |11\rangle)/\sqrt{2}$

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

    for $i \in \{0, \ldots, p-1\}$ do
        Evaluate $\partial_{\theta_i} C$ and $\partial_{\theta_i} A$
        Solve $A\left(\partial_{\theta_i}\dot{\omega}(t)\right) = \partial_{\theta_i} C - \left(\partial_{\theta_i} A\right)\dot{\omega}(t)$
        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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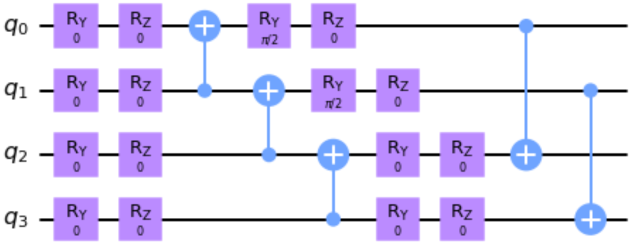

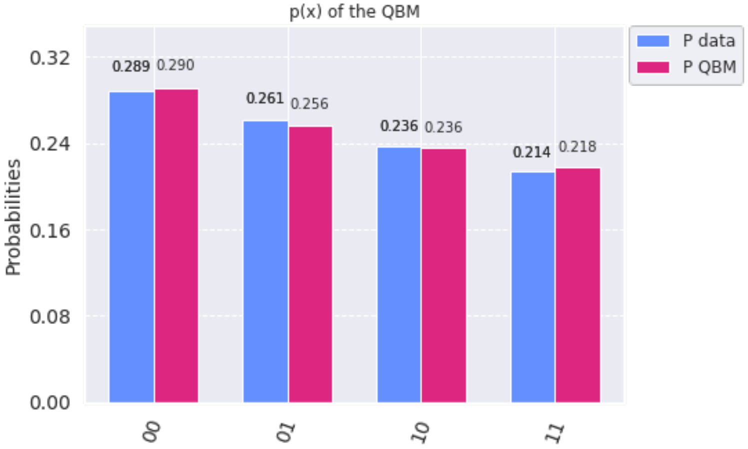


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