QML SoC
Evaluation for QML

Siddhant Midha & Vedang Asgaonkar

Note You are supposed to submit only `.ipynb` files, answer the questions as markdown boxes in these files. Submit one file for each question, with appropriate file names.

1 Learning decomposition of a unitary

In this question, we shall dive into two things you have already seen before. One, is the fact that an arbitrary single qubit unitary can be decomposed into three rotations with a global phase (Refer `QCQI`). We shall ignore the global phase here. The other is the `Quantum SWAP Test` that we did in the QC evaluation.
The problem is as follows, you have some known single qubit unitary U, and prepare the state $|\psi\rangle = U|0\rangle$. You have to come up with an (decompositional) ansatz to learn this state variationally, and equivalently learn the unitary U.

1. Code up the above situation in `Pennylane`.
2. How many qubits do you need?
3. How many parameters do you need to learn?
4. What is the loss function?
5. Explicitly compute the learned unitary and compute the following distance between the learned and the target unitary.

$$D(A,B) = \sqrt{\sum_{i=1}^{n}\sum_{j=1}^{n}(a_{ij}-b_{ij})^2}$$

   for $A = [a_{ij}]$ and $B = [b_{ij}]$.
6. *Bonus*: Draw the trajectory of the state vector along the bloch sphere as your parameters evolve through the optimization procedure.

You can use any non-trivial single qubit unitary as the target in your code. Explicitly state what you used.

2 Hyperparameters in Quantum Machine Learning

Parametrized Quantum Circuits (PQCs) are a key ingredient of Variational Quantum Algorithms. This necessitates for a deeper analysis of PQCs. For different purposes, different quality of a particular PQC can be relevant. We shall treat these quantities as hyperparameters.
We shall explore the effect of varying hyperparameters of QML circuits on the accuracy (or other metrics relevant to the model). You can analyse the impact of change in values of hyperparameters on the QML model you have chosen to implement. Alternatively, you can choose to perform the analysis on a simpler QML circuit. You can plot graphs, or choose any other mode of analysis. You should pick up a subset of hyperparameters mentioned in section 3.1 of this paper. You can also use any other hyperparameter you find suitable for your circuit like number of qubits in the encoding.