PAPER LINK

Neural networks and deep learning have proven to be very successful and therefore offer a further source of inspiration for circuit design. Both variational circuits and neural networks can be thought of as layers of connected computational units controlled by adjustable parameters. This has led some authors to refer to variational circuits as‘quantum neural networks’.

Here we shall briefly discuss the key differences that make this approach to circuit design rather difficult. **First, quantum circuit operations are unitary and therefore linear;** this is in contrast with the nonlinear activation functions used in neural networks, which are key to their success and universality. There are several ways to construct nonlinear operations in quantum circuits, both coherently (i.e. exploiting entanglement) or non-coherently (e.g. exploiting the natural coupling of the system to the environment). These can in turn be used to implement classical artificial neurons in quantum circuits.

Wikipedia Link

A lot of proposals attempt to find a quantum equivalent for the perceptron unit from which neural nets are constructed. **A problem is that nonlinear activation functions do not immediately correspond to the mathematical structure of quantum theory, since a quantum evolution is described by linear operations** and leads to probabilistic observation. Ideas to imitate the perceptron activation function with a quantum mechanical formalism reach from special measurements to postulating non-linear quantum operators (a mathematical framework that is disputed)

Paper Link

Also, it is worth pointing out a key difference between classical and quantum neural networks: the former, in fact, are usually highly non linear models, **while in quantum mechanics operators that act on states are always linear. Implementing a non-linear activation function in a quantum neural network is a major problem**, and several attempts have been made to overcome it, e.g. by using specific measurements. To this day, though, there are no proposals for the implementation of a non-linear quantum operator, and most quantum neural networks offload nonlinearities to classical computers, or make use of quantum kernels.