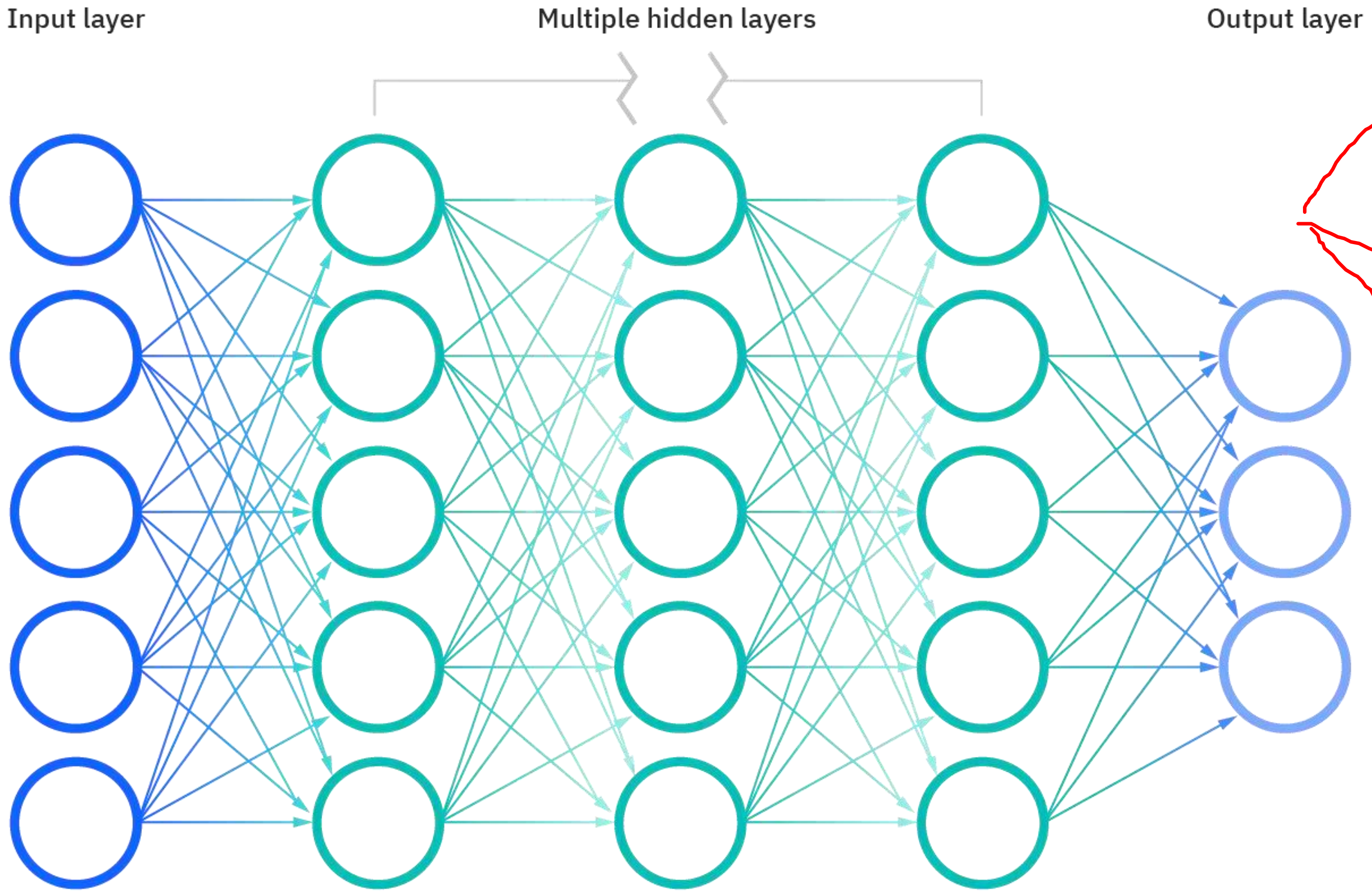
Quanvolutional neural network

20/5/2022

https://arxiv.org/abs/1904.04767

https://arxiv.org/abs/2108.00661.pdf

Neural network

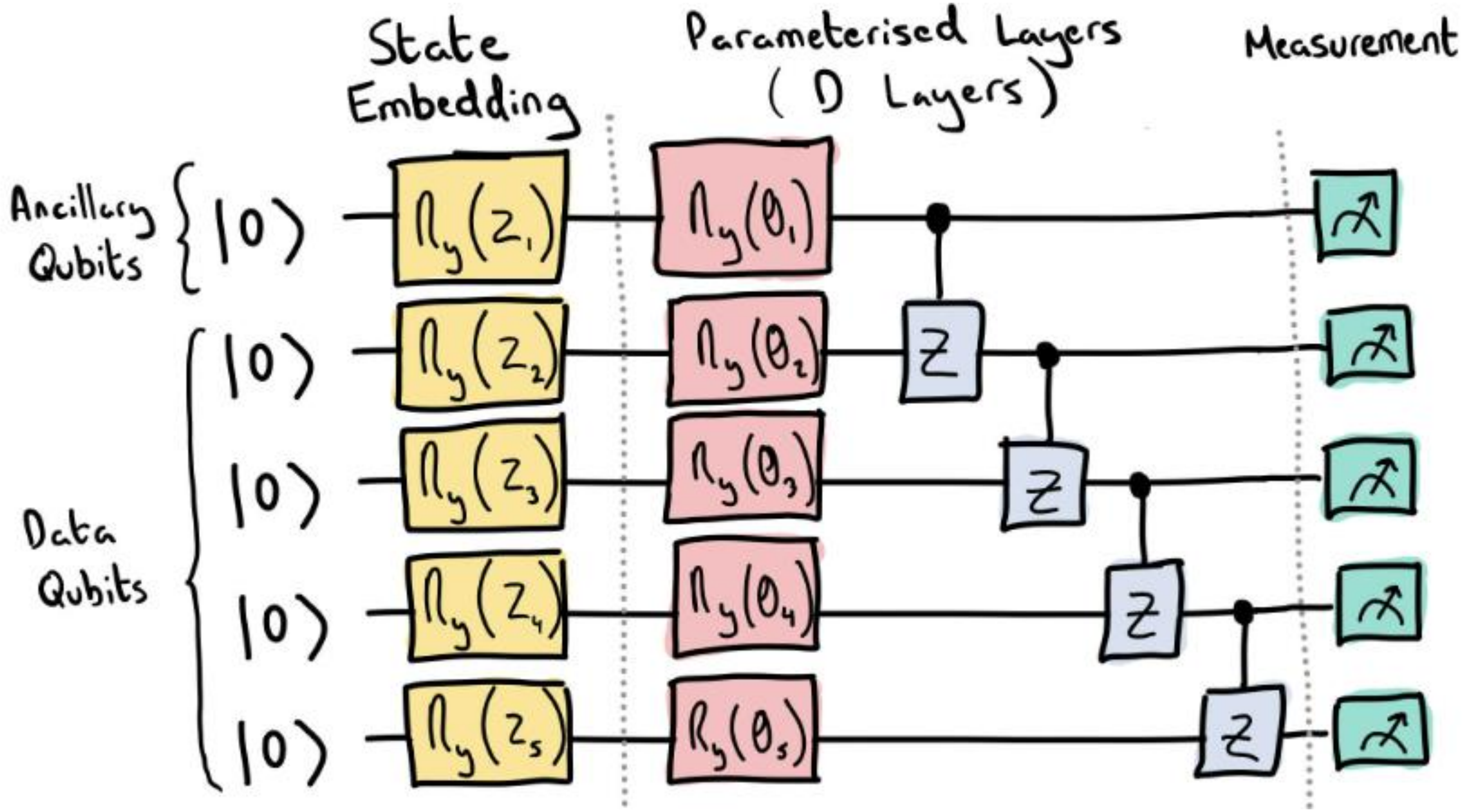


Time series
LSTM

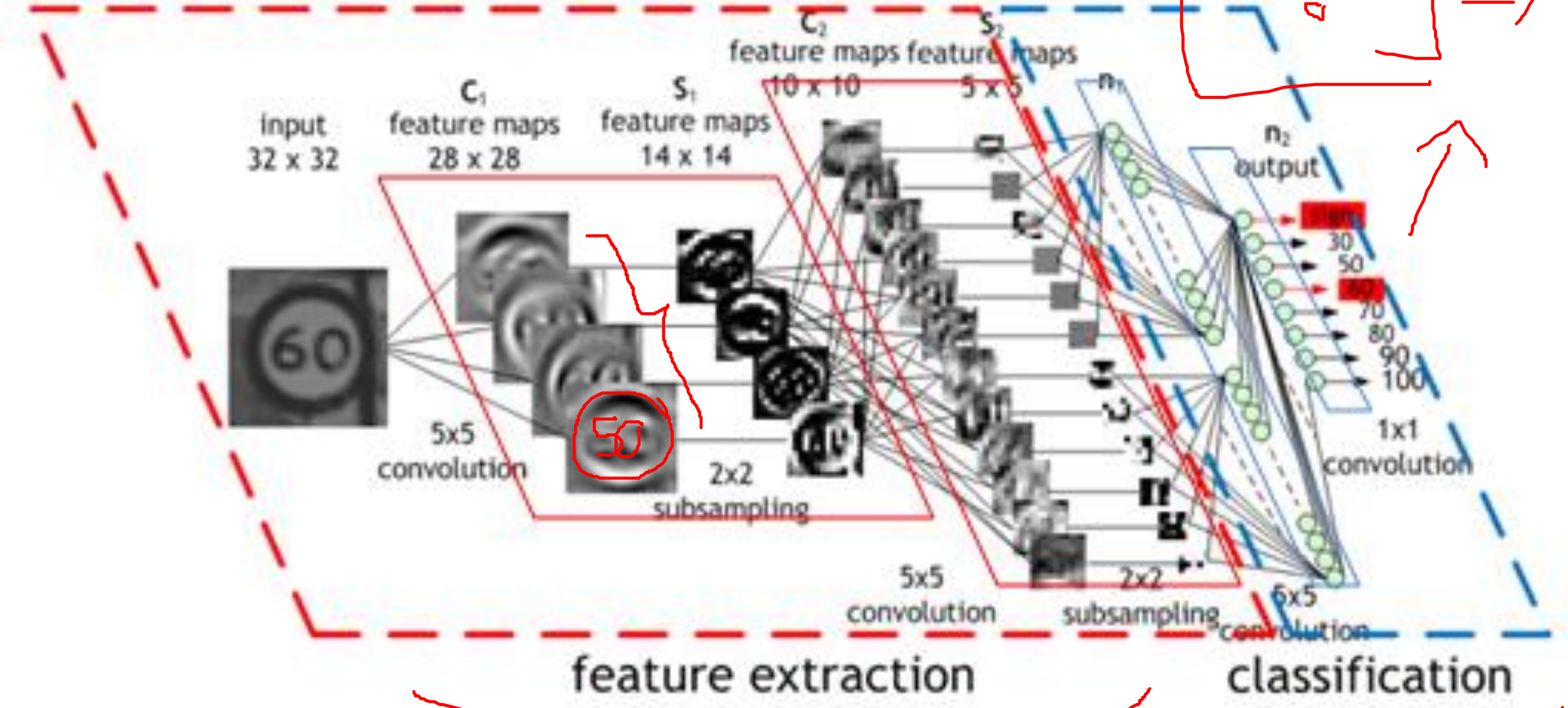
UNET

Convolutional

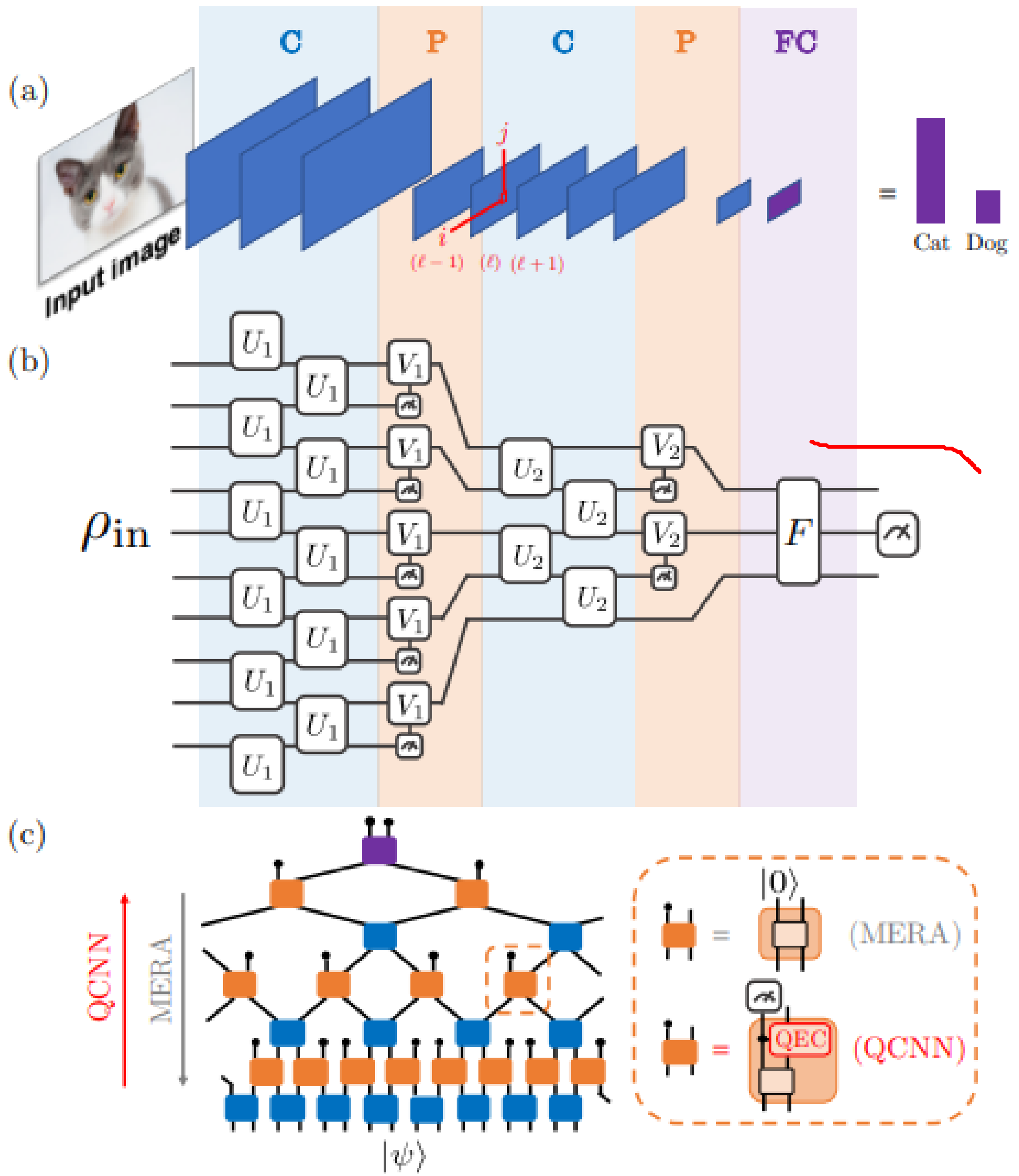
Quantum neural network



Convolutional neural network



Quantum convolutional neural network



Absence of Barren Plateaus in Quantum Convolutional Neural Networks, PRX, 11,041011 (2021)

Overall structural

classical

quantum

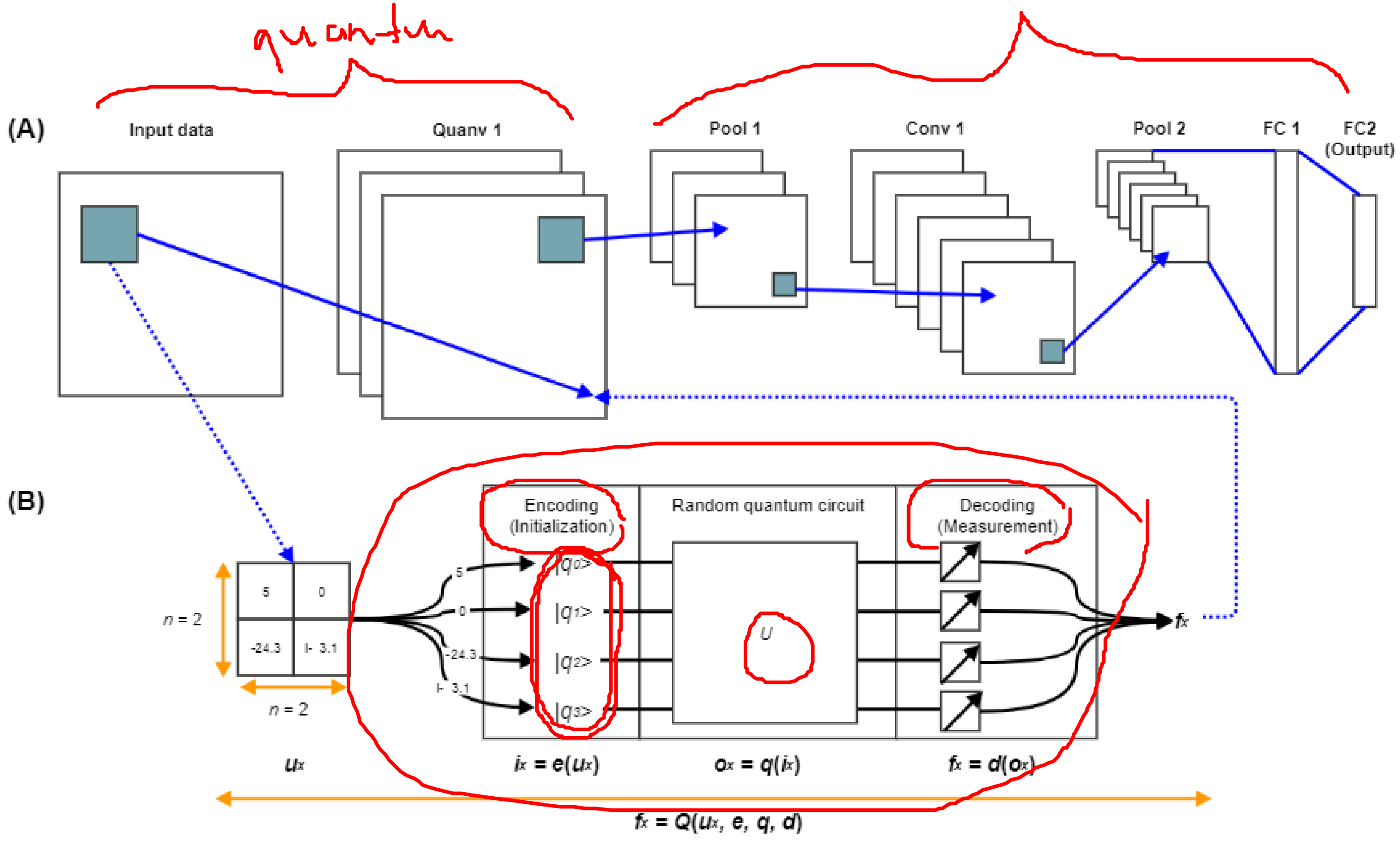
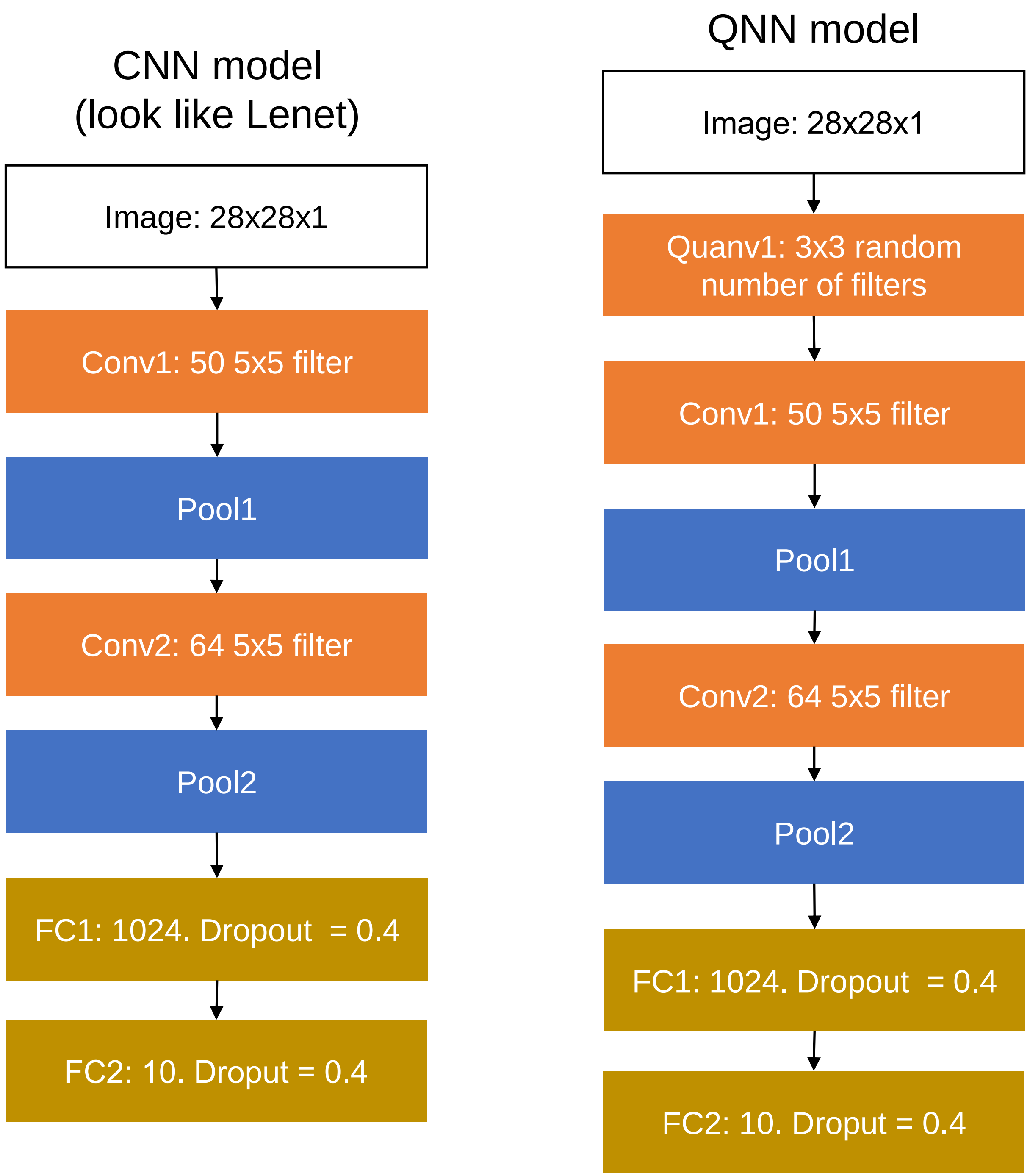
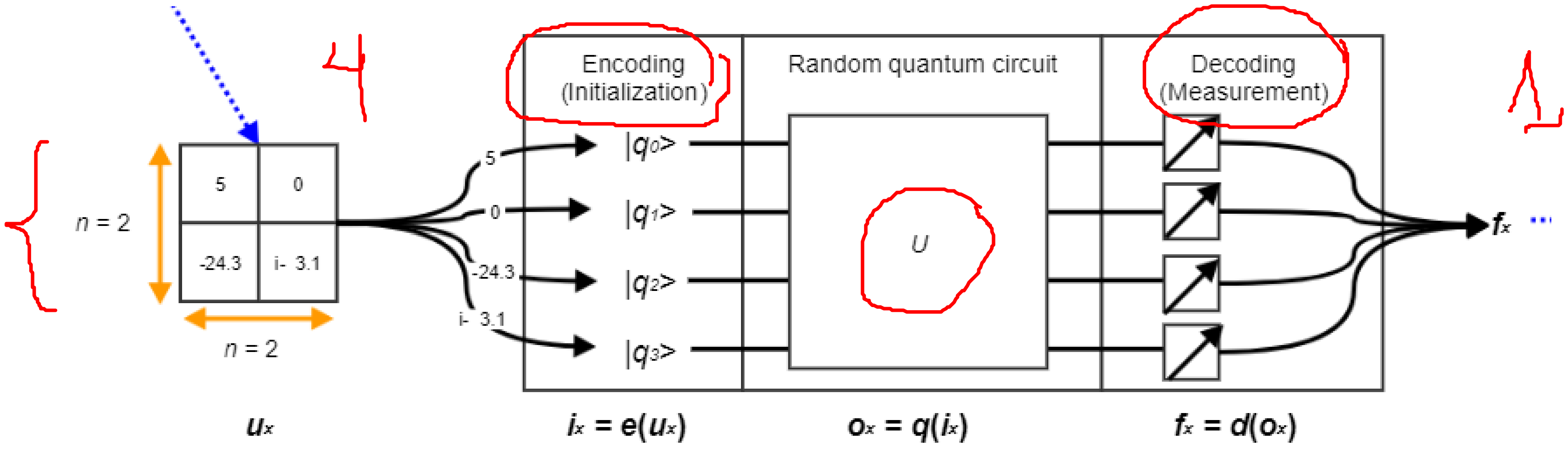


Fig. 1.: A. Simple example of a quanvolutional layer in a full network stack. The quanvolutional layer contains several quanvolutional filters (three in this example) that transform the input data into different output feature maps. B. An in-depth look at the processing of classical data into and out of the random quantum circuit in the quanvolutional filter.

Models


CNN model
(look like Lenet)
Image: 28x28x1
Conv1: 50 5x5 filter
Pool1
Conv2: 64 5x5 filter
Pool2
FC1: 1024. Dropout = 0.4
FC2: 10. Droput = 0.4
QNN model
Image: 28x28x1
Quanv1: 3x3 random number of filters
Conv1: 50 5x5 filter
Pool1
Conv2: 64 5x5 filter
Pool2
FC1: 1024. Dropout = 0.4
FC2: 10. Droput = 0.4

Quanvolutional layer



Quanvolutional layer = $f(u_x, \boldsymbol{e}, \boldsymbol{q}, \boldsymbol{d})$: $\mathbb{R}^{nxn} \rightarrow \mathbb{R}$ where:

- u_x: patch
- e: encoder
- q: random quantum circuit
- d: decoder

Encoding & Decoding

$e: \mathbb{R}^{nxn} \rightarrow |\psi\rangle$

Amplitude encoding

- $\log N$ qubits but exponentially number of gates
- N qubit, linear number of gate

Threshold encoding: if pixel value is less than threshold t, the according qubits will be $|0\rangle$ and vice versa.

$d: |\psi\rangle \rightarrow \mathbb{R}$

$0.8 > 0.5$

$|0\rangle$

$|1\rangle$

Quantum circuit

The number of qubits is 9.

Chose $(0 \rightarrow 2n^2$) random 1 qubit gate.

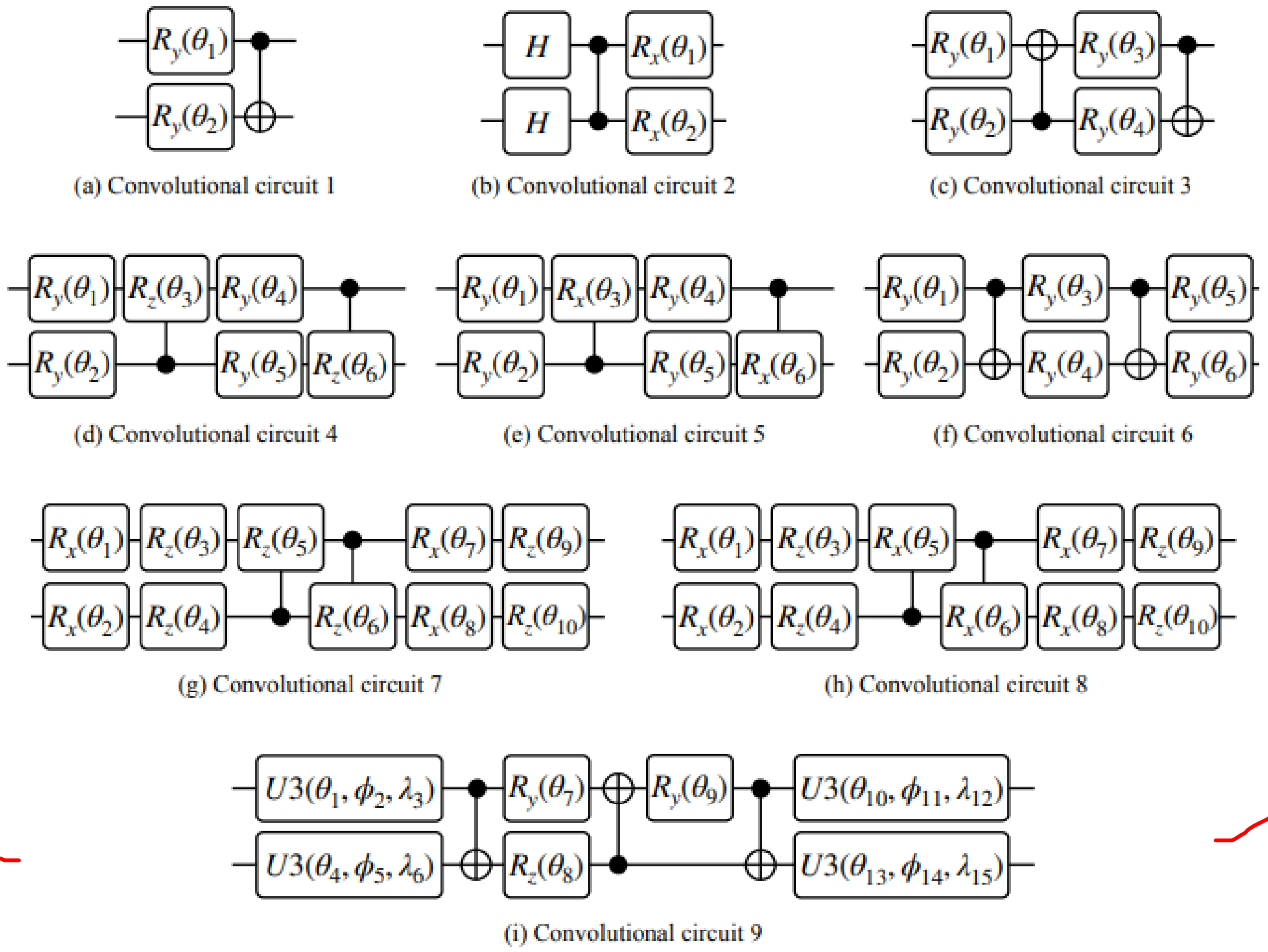
$$\underbrace{X(\theta), Y(\theta), Z(\theta), U(\theta), P, T, H}$$

θ is random in $[0,2\pi]$

And random 2 qubits gate (to make entanglement)

$\rightarrow$ The set of gates is suffled => One quanvolutional layer

Quantum circuit: Example



Quantum advantages

Quantum computers can access kernel functions in highdimensional Hilbert spaces much more efficiently than classical computers.

→ Coverage faster

Disadvatanges

- Number of measurements
- Number of quanvolutional filters

Dataset

- 70k 28x28 gray MNIST samples (60k train, 10k test)

Results

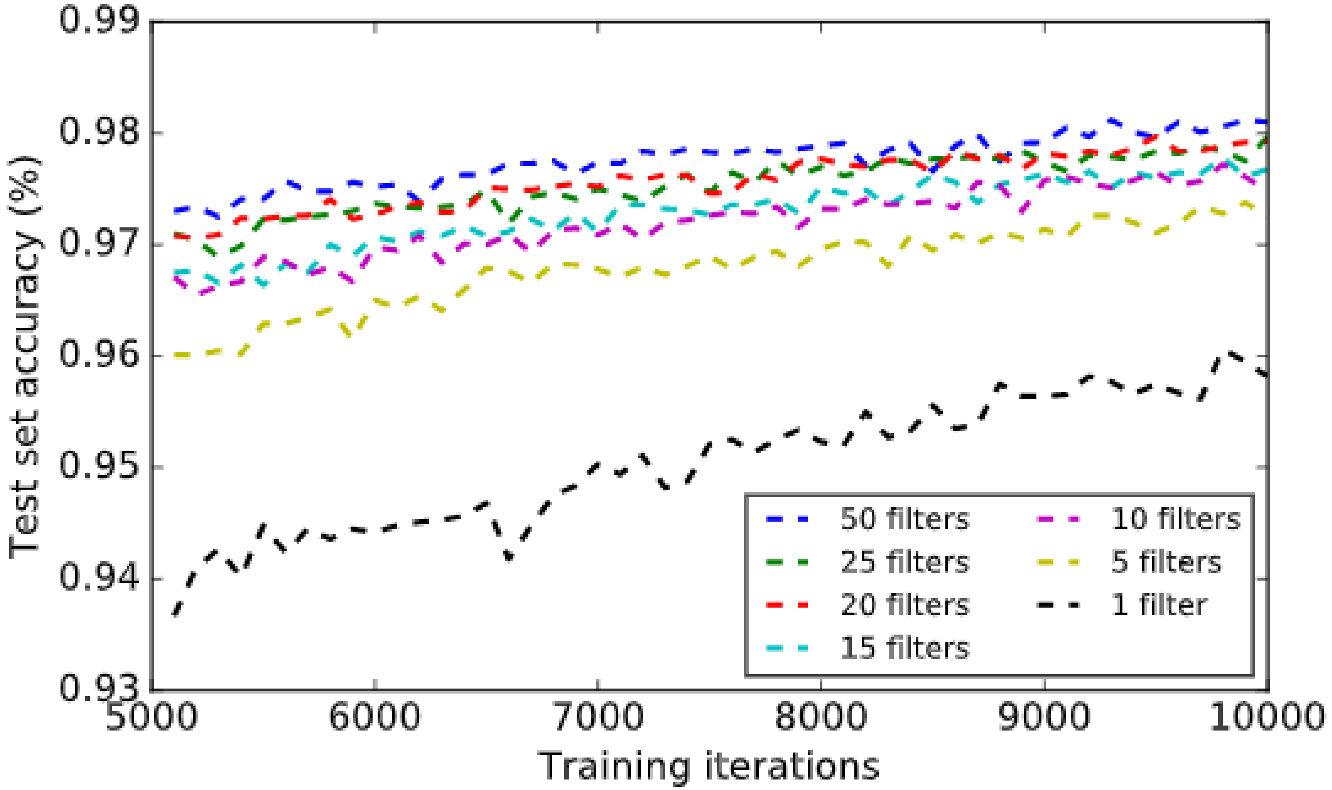
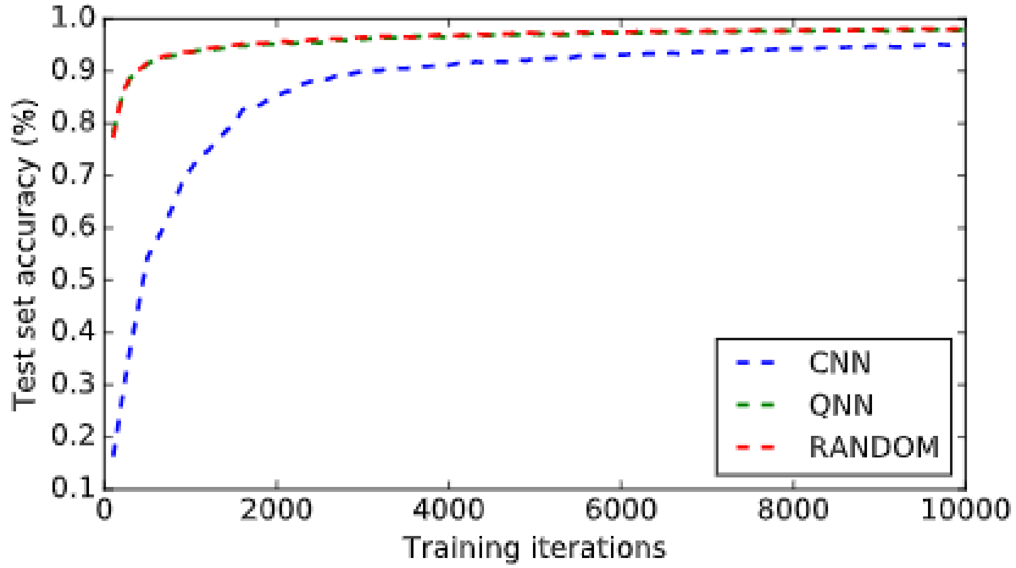


***Fig. 2.**: QNN MODEL test set accuracy results using a variable number of quanvolutional filters.*

Results



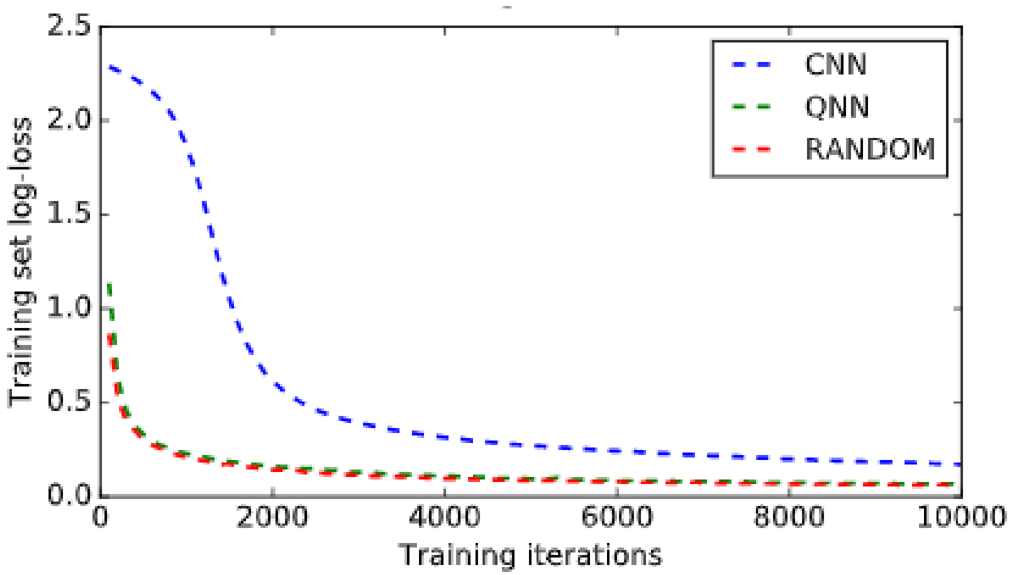


***Fig. 3.**: QNN MODEL performance, in terms of (A) test set accuracy and (B) training log-loss, compared to both CNN MODEL and RANDOM MODEL.*

Future works

- Test on another dataset and deeper QNN.
- Make quanvolutional layer trainable or change by time by the evolutional / genetic algorithm. => Use QNG in quanvolutional layer

Thanks for listening!