A QCNN for Quantum State Preparation

Carnegie Vacation Scholarship

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Week 6
(05/08/2024 - 14/08/2024)

Erratum

The slides for the previous weeks showed the wrong placement of the absolute signs in the definition of SAM. The definition should read:

$$\mathsf{SAM}(|x\rangle, |y\rangle) = 1 - \sum_k |x_k||y_k|. \quad (1)$$

This has now been corrected. Equivalently for WIM.

Aims for the Week

The following aims were set at the last meeting (05/08/2024):

Generalise Input States

When training in superposition, feed in a wider range of input states to ensure the network learns as intended.

Work on Code and Documentation

Continue re-structuring and re-documenting the code to ensure a smooth handover.

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Generalised Input States

- When training in superposition, the QCNN now takes the input state

$$|\psi\rangle_{\text{in}} = \sum_{j=0}^{2^n-1} c_j |j\rangle \tag{2}$$

  where the coefficients $c_j \sim \frac{1}{\sqrt{2^n}}$ are randomly sampled each epoch
- The range of the random sampling is controlled by a hyper-parameter δ, $0 \leq \delta \leq 1$
- For instance, $\delta = 0$ gives $c_j = \frac{1}{\sqrt{2^n}}$ while $\delta = 1$ gives $c_j \in (0, 1)$
- This generalisation should ensure that the network learns the operation $|j\rangle |0\rangle \mapsto |j\rangle |\Psi'(j)\rangle$ as opposed to just learning how to produce a particular fixed state

Amplitudes after applying $\tilde{Q}$ with $\Psi(f) \sim f^2$ and the input register in initial state $\hat{H}\,|0\rangle$ ($L = \mathbf{9}$, $m = 3$, SAM, 600 epochs):

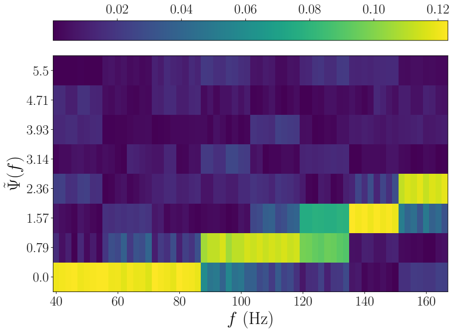

Figure 1: $\delta = 0$

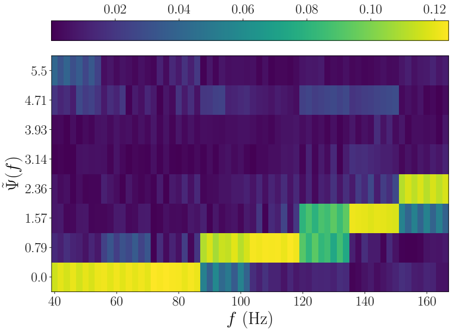

Figure 2: $\delta = 0.2$

Results

Amplitudes after applying $\tilde{Q}$ with $\Psi(f) \sim f^2$ and the input register in initial state $\hat{H}\,|0\rangle$ ($L = \mathbf{9}$, $m = 3$, SAM, 600 epochs):

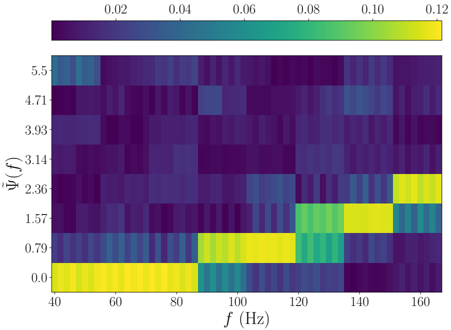

Figure 3: $\delta = 0.4$

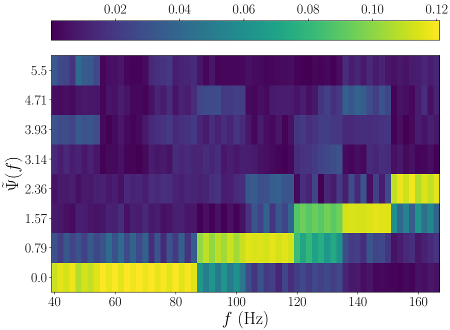

Figure 4: $\delta = 0.6$

Results

Amplitudes after applying $\tilde{Q}$ with $\Psi(f) \sim f^2$ and the input register in initial state $\hat{H}\,|0\rangle$ ($L = \mathbf{9}$, $m = 3$, SAM, 600 epochs):

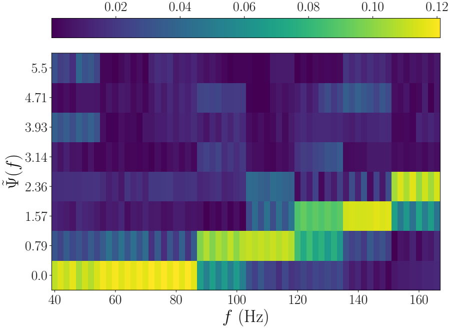

Figure 5: $\delta = 0.8$

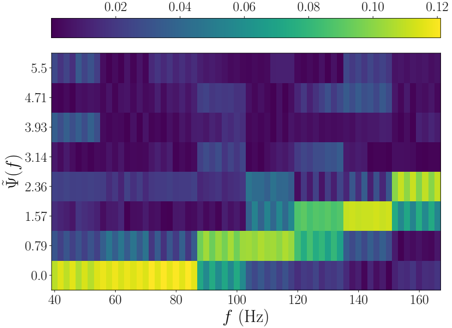

Figure 6: $\delta = 1.0$

Results

- Slightly randomised input states ($\delta = 0.2$) have a positive effect on performance
- More significantly randomised input states ($\delta \geq 0.6$) have an adverse effect
- Notably, no positive effect of non-zero δ is apparent for $L = 6$
- Also notable are the appearance of thin 'stripes' with increasing δ which could be linked to input layer structure
- Equivalent effects are observed for $\Psi(f) \sim f$ and Ψ_{H23}

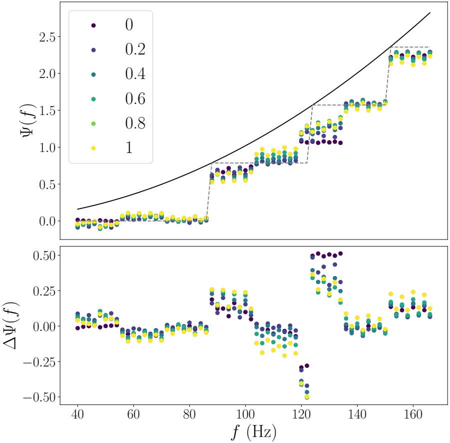

Figure 7: Comparing the effect of δ values for $\Psi(f) \sim f^2$ ($L = 9$, $m = 3$, SAM, 600 epochs)

RUN THINGS FOR L=12 TO COMPARE !! (nearly done with plots .. running delta=1.0 right now)... do plots !!
then do more complex pltos
TRY AND DO SOME BARREN PLATEAU ???
document resource tools

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Code and Documentation

- Continued work on code documentation: now hosted online here

TO DO:

a. integrate encode.py into plotting
b. update doc files on github
c. publish to pypi

add some info here ...

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Next Steps

- Start work on poster for Carnegie