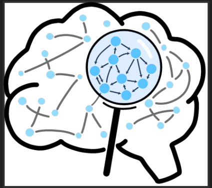
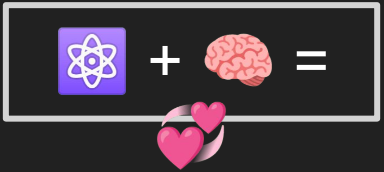
Quantum Hybrid Neural Decoding

QHack 2023

Introduction

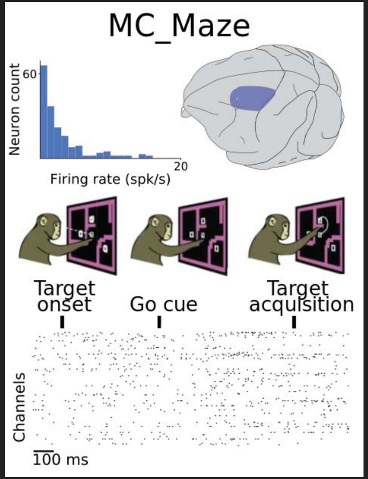


Inspired by advances in neuroscience and related recording technology, the Neural Latents Benchmark Challenges (NLB) was a Machine Learning Competition in 2021. The Challenge was won by my colleagues on the Brain-Computer-Interface team at AE Studio (see here).



In this project, I continue work on the NLB dataset by exploring the intersection between Hybrid Quantum ML and Neural Decoding.

Data Overview



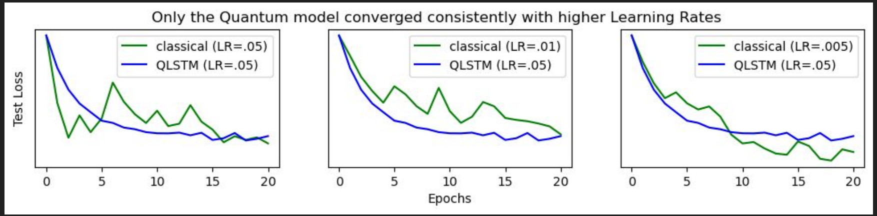
The NLB MC_Maze dataset is a set of neural activity recordings from Macaque Monkeys. A monkey with a brain implant views a screen, and is instructed to move a digital cursor through a simple maze. Each electrode on the monkey's implant records neural activity, measured by proximate spikes in voltage. These spikes in activity can be used to predict the actual movement that the monkey performed.

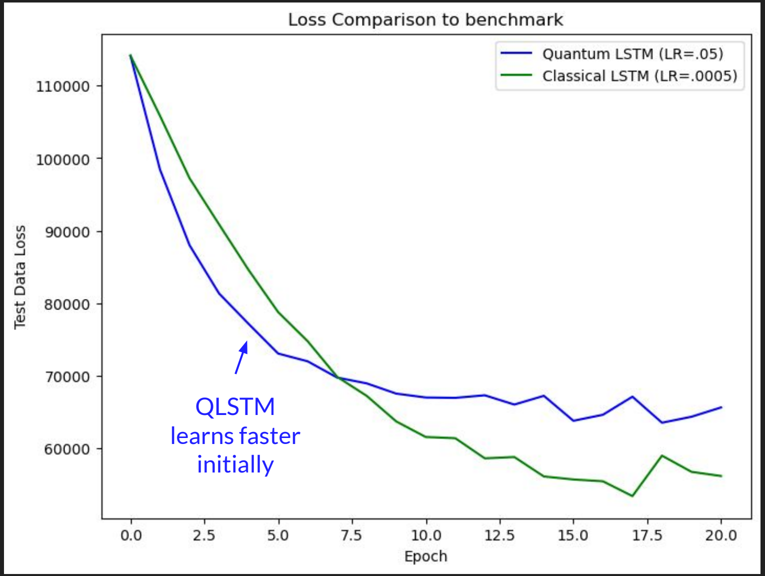
Credit -- The dataset was provided by Krishna Shenoy, Mark Churchland, and Matt Kaufman from Stanford University, and you can learn more about the task design, data collection, and their analyses of the data in a number of papers, including Churchland et al. 2010.

Process & Key Results

- Both Classical and Quantum-Hybrid Time Series models were trained to decode the monkey's neural signals and predict the X-dimension hand velocity.

- Notably, the QLSTM model is able to afford a higher learning rate, and therefore can learn faster over the initial epochs
  - SEE 'Future work' for more - this may be valuable for Brain-Computer Interfaces Research
  - The faster learning can be attributed to a higher learning rate. When the Classical Model was trained with a comparably high learning rate, the loss was erratic and the model did not consistently converge - examples below:





- The classical benchmark achieved overall better results vs. the small & shallow Quantum-Hybrid LSTM (QLSTM) architecture
  - QLSTM used only 4 qubits for each VQC. As Quantum Computing Scales, this performance gap may be overcome with wider quantum layers.

Predicting X-dim velocity	Classic LSTM	QLSTM
R^2	.53	.41

Future Work (and Speculation)

- Some humans have brain implants already, but the fluidity of the human brain means that the implant shifts over time. The implanted electrodes may not be sensing the same neurons it did previously, and re-calibration is required.

- This is an open research problem in BCI called 'stabilization', and most current solutions require retraining of a decoder, normally at least daily.

- In many clinical applications, this retraining happens while the user is sitting there waiting. Methods that learn faster, even over short epochs, could be valuable to BCI researchers

Anthony Copeland became one of the first humans to receive brain implants 7 years ago

Possible Future Research:

- *Applying VQCs in architectures besides LSTMs for Neural Decoding*
- *Wider Quantum layers on real hardware instead of simulators*