QUANTUM INSPIRED FINGERPRINTING

Tensor Networks Approach

Group Name: Quantum Ninjas

Singular value decomposition (SVD)

$$M = \begin{bmatrix} 0.435839 & 0.223707 & 0.10 \\ 0.435839 & 0.223707 & -0.10 \\ 0.223707 & 0.435839 & 0.10 \\ 0.223707 & 0.435839 & -0.10 \end{bmatrix}$$

Can factorize as

$$\begin{bmatrix} 1/2 & -1/2 & 1/2 \\ 1/2 & -1/2 & -1/2 \\ 1/2 & 1/2 & 1/2 \\ 1/2 & 1/2 & -1/2 \end{bmatrix} \begin{bmatrix} 0.933 & 0 & 0 \\ 0 & 0.300 & 0 \\ 0 & 0 & 0.200 \end{bmatrix} \begin{bmatrix} 0.707107 & 0.707107 & 0 \\ -0.707107 & 0.707107 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

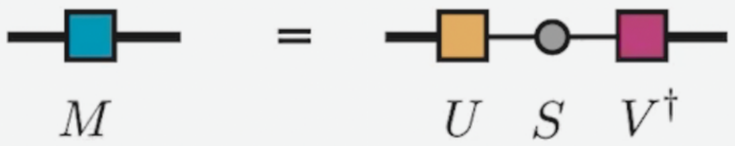
U S V^T

$$\begin{bmatrix} 1/2 \\ 1/2 \\ 1/2 \\ 1/2 \end{bmatrix} \quad \begin{bmatrix} 0.933 \end{bmatrix} \quad \begin{bmatrix} 0.707107 & 0.707107 & 0 \end{bmatrix}$$

$$M_3 = \begin{bmatrix} 0.329773 & 0.329773 & 0 \\ 0.329773 & 0.329773 & 0 \\ 0.329773 & 0.329773 & 0 \\ 0.329773 & 0.329773 & 0 \end{bmatrix}$$

Truncating SVD =

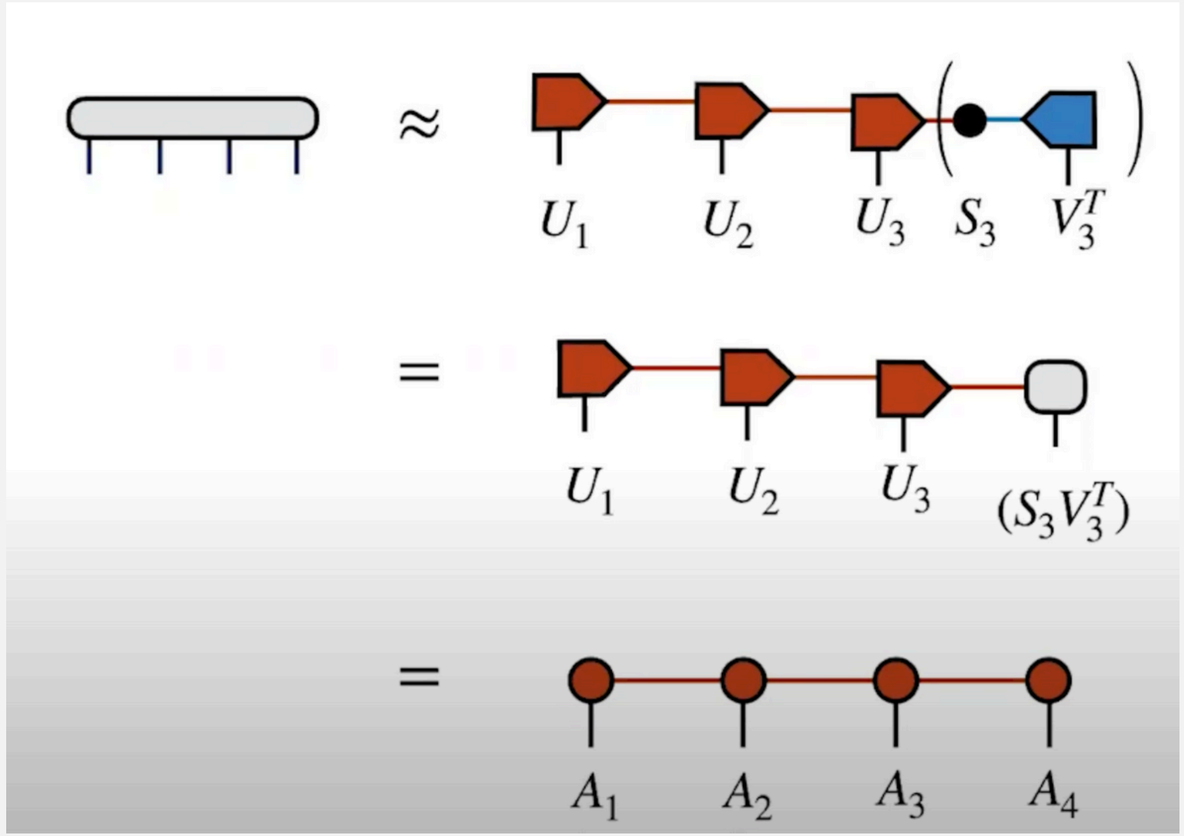
Controlled approximation for M



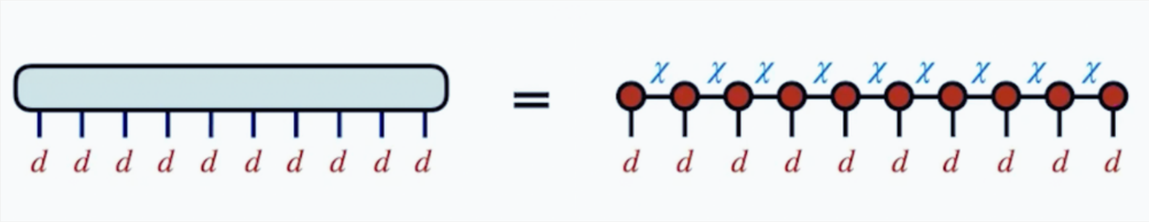
$$||M_3 - M||^2 = 0.13 = (0.3)^2 + (0.2)^2$$

Error

We put a cutoff limit and throw away some values



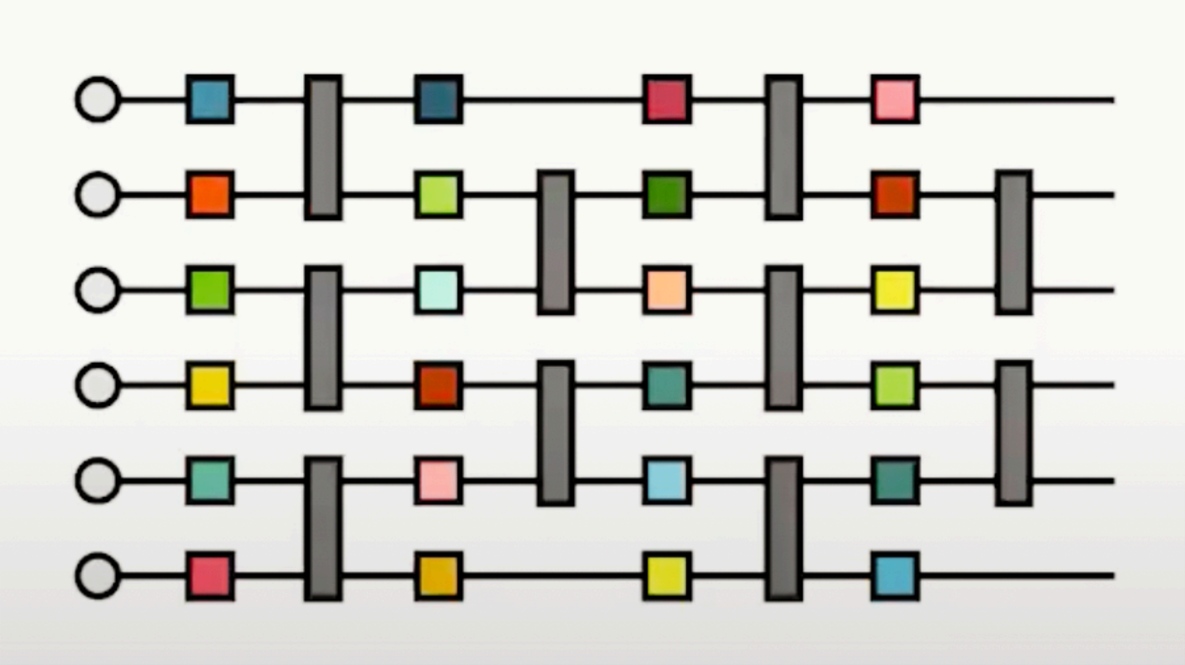
We keep repeating SVD till we get this result



$$d^N \longrightarrow N d \chi^2$$

The new state is called ‘Matrix Product State’ (MPS)

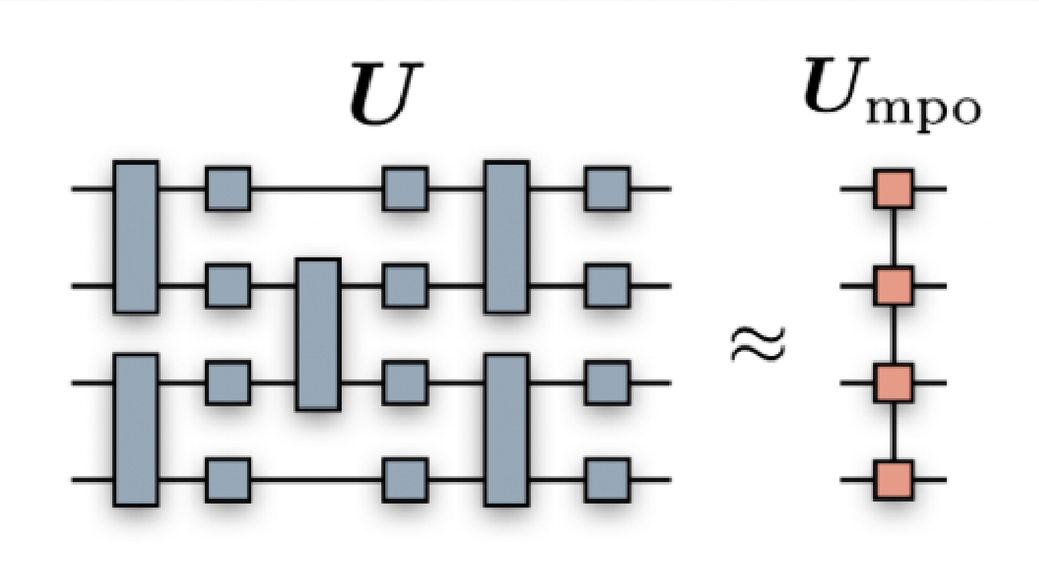
Quantum Circuit

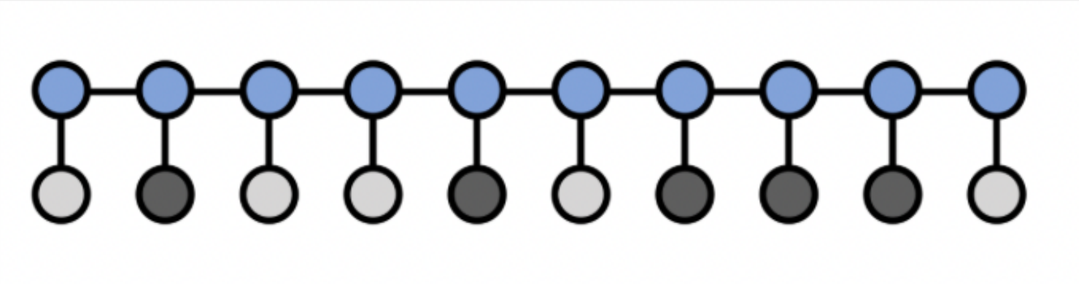


Now we don’t need to store the whole matrix and multiply, we can apply indivudual gates (small matrices) directly to the required qubit.

MATRIX PRODUCT OPERATOR (MPO)

- The full circuit can be stores in a MPO format and then directly multiplied to the MPS after taking the input. This reduces time by a lot as we don’t need to apply gates anymore.





Directly multiply MPO and MPS

Low entanglement -> Low bond order

EXECUTION METHOD

Convert the array data into MPS

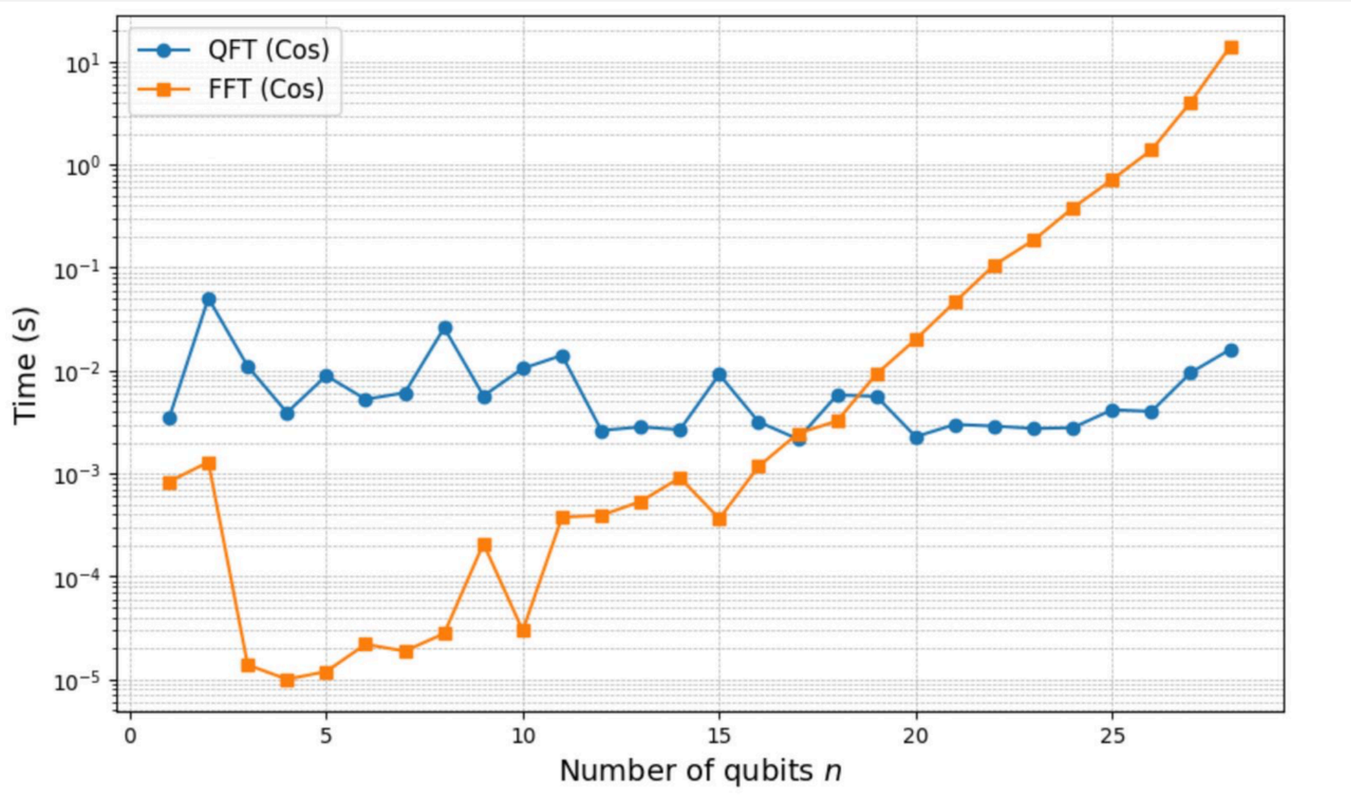
Multiply the MPS with pre-calculated MPO

Convert MPS back to array

MPO is already calculated and stored in a file. it is directly read and multiplied for maximum speed

The FFT part in the code is now replaced with QFT using this method

COMPARISION WITH FFT



Time to convert the array to MPS is not included in this graph

QFT time = time to multiplying MPO and MPS

As the number of qubits increase, we can see the advantage

FINGERPRINTING

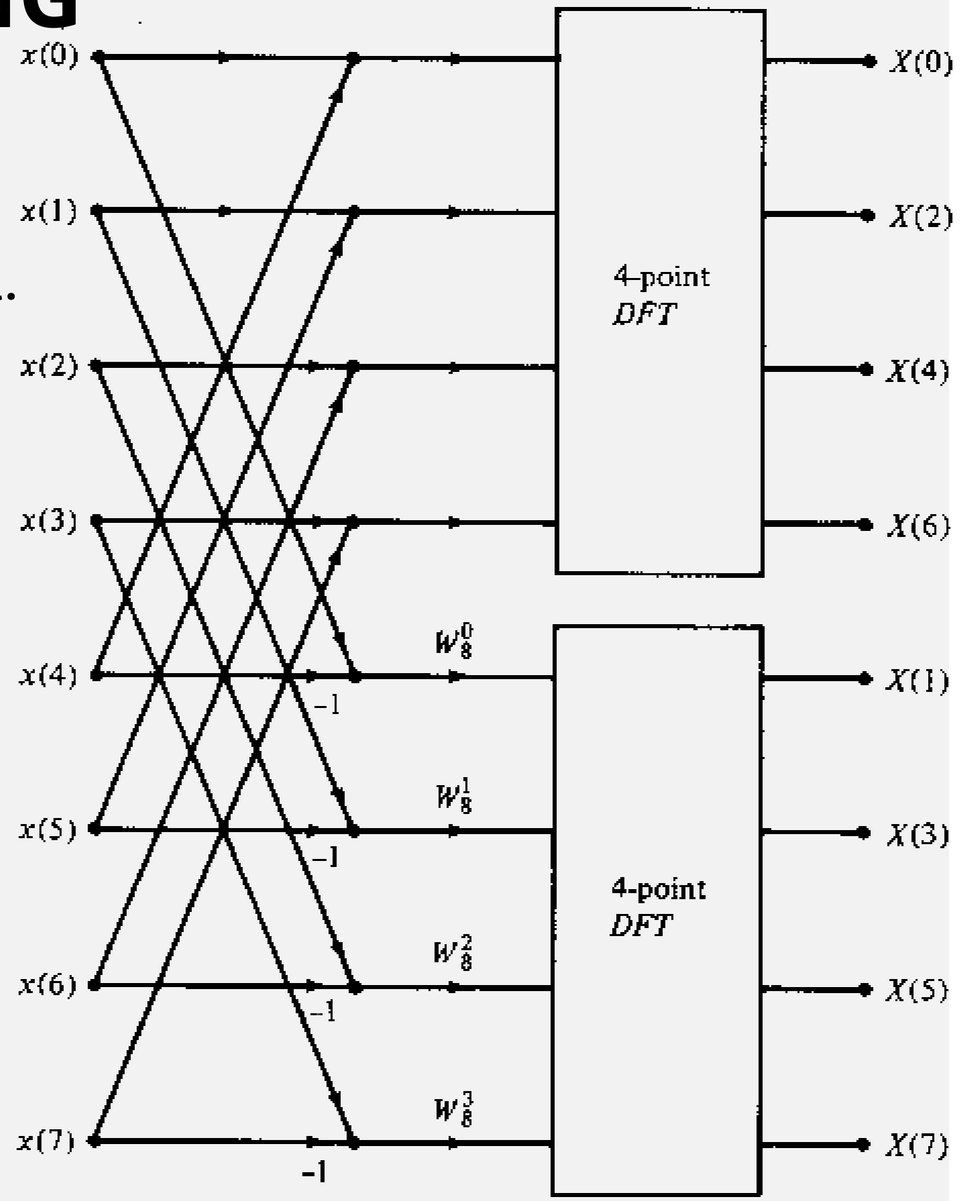
Technique used to generate a compact and unique digital summary (or "fingerprint") of an audio signal.

WHY FFT IS USED

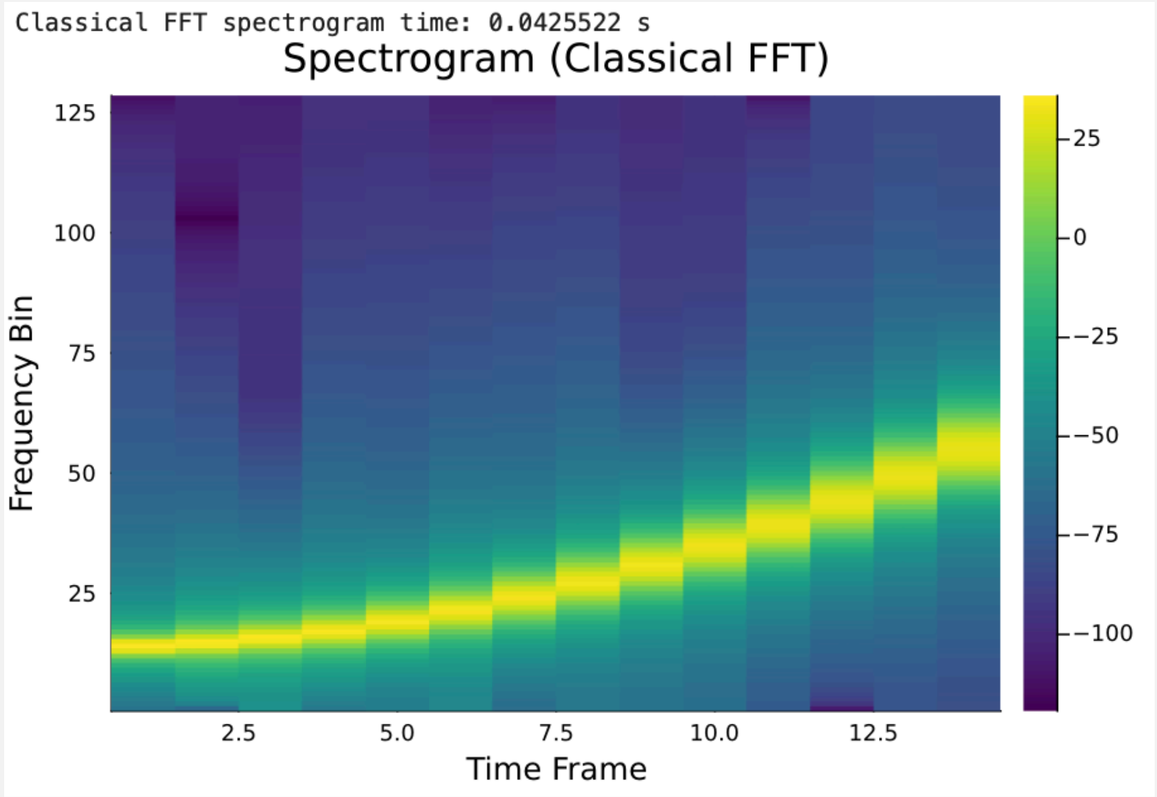
Reveals the intensity of different frequencies at that time slice.

Each peak is encoded into a compact hash.

These hashes form the fingerprint of the audio.



Classical Results



Time Taken

0.0425522 S

Quantum Inspired Results

```
Loading QFT MPO from Basis states Final/MPO_8.h5…
Preloading 256 basis MPS for inner products…
QFT–MPO spectrogram time: 0.00151367 s
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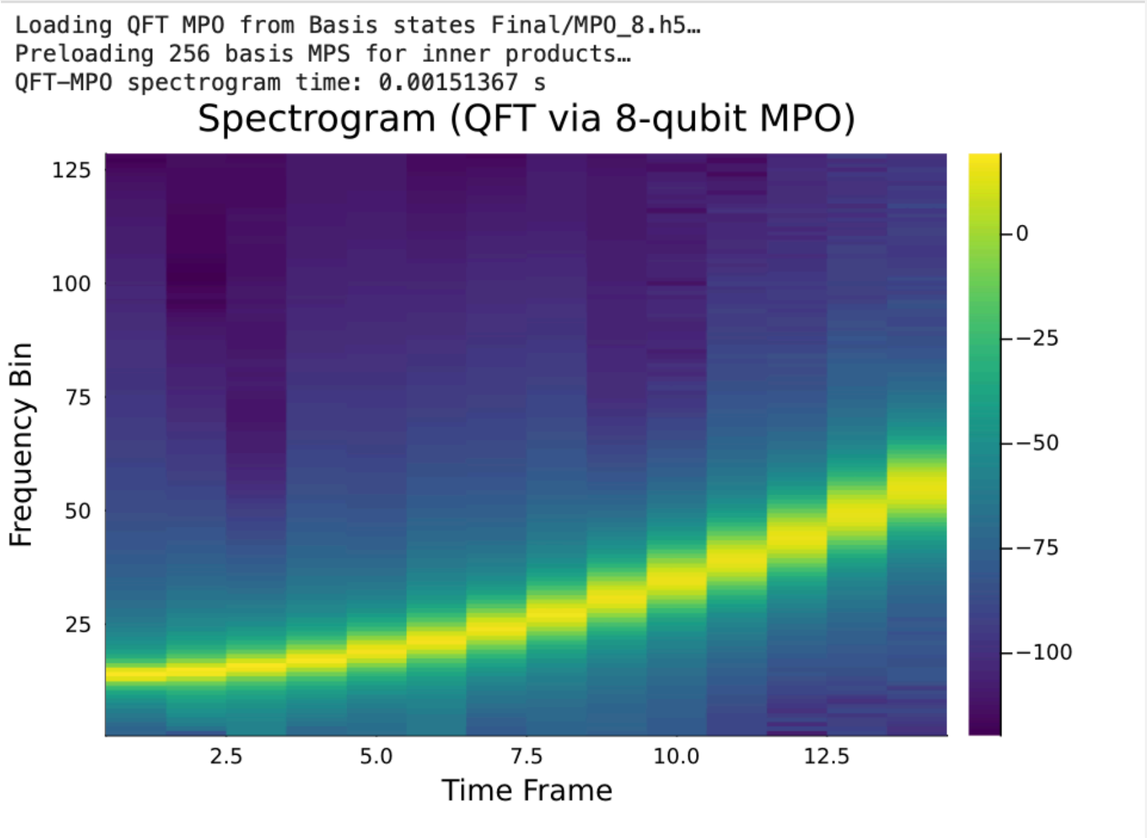


Time Taken

0.00151367 S

What we were able to achieve

A quantum based fingerprinting advantage in time
(approximately **28 times faster**!)

Too good to be true??

Unfortunately yes :(

LIMITATIONS

The overall runtime is still slower than FFT :(

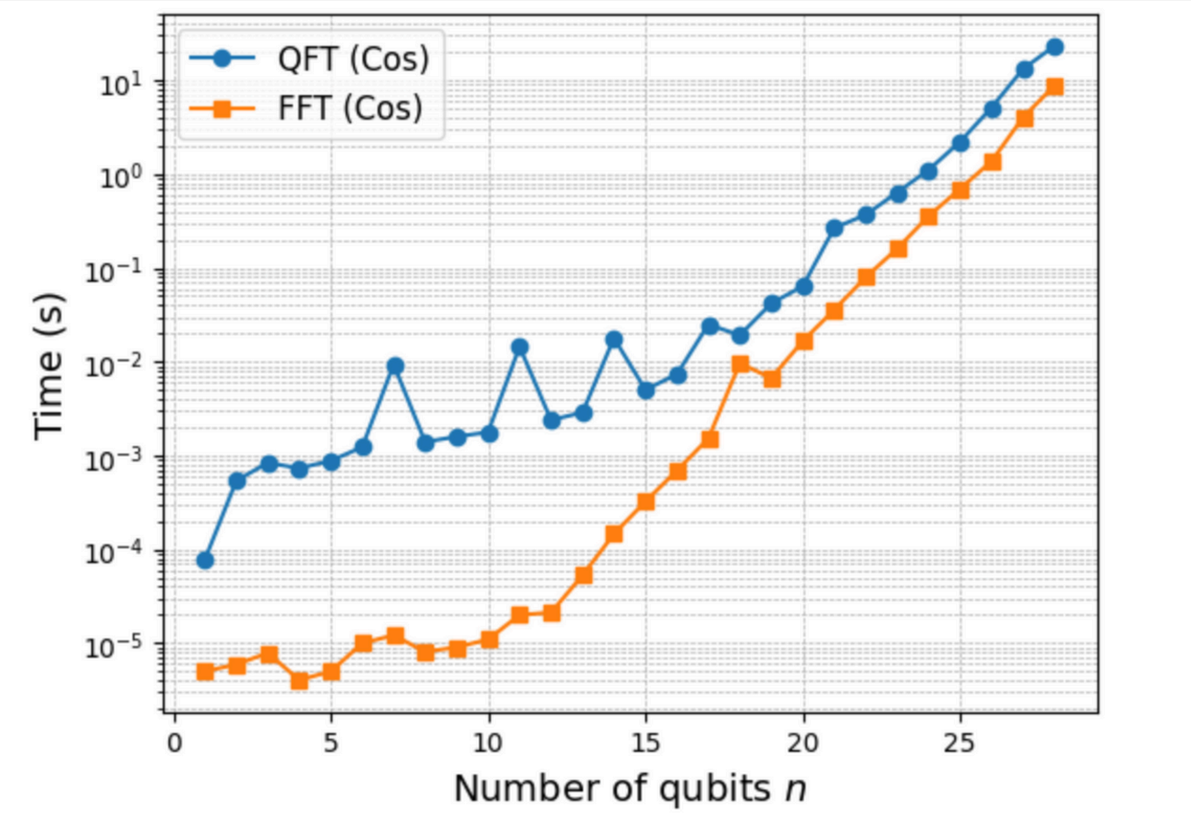
- We couldn’t find the most optimal way to convert data from array to MPS and back efficiently. This when considered is slower than FFT.

Solution:

- Look for a better optimal way to convert
- Re-write the whole algorithm with data in MPS instead of array :/

We belive future work can be done in this field to make it useful practically

GRAPH



Time to convert the array to MPS is included in this graph

Cutoff Value set : 10^(-18)

FUTURE WORK

- Coming up with a faster way to convert input data into MPS

- Using this algorithm instead of FFT and gaining significant time advantage in many applications such as
  - signal processing
  - physics simulations

Real world Applications

SHAZAM

(for audio recognition)

YouTube

(detect copyrighted music)

(Speaker Verification)

Thank You