Preprocessing Optimization for SAS/R* Classification and Detection

2024 Quantum Machine Learning REU Program

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RESEARCH BACKGROUND/DESCRIPTION

- Preprocessing data is crucial for the performance of many statistical techniques including machine learning algorithms.
- With improvements in quantum fidelity in recent years, we investigate a hybrid preprocessing architecture for increased efficiency and accuracy* in SAS/R* classification and detection tasks.

RESEARCH OBJECTIVES/PLAN

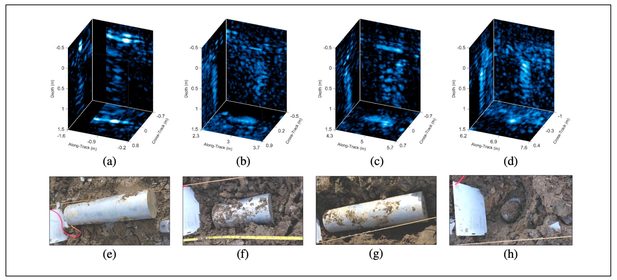


Fig 1 3D SAS cubes and respective targets

- Machine Learning is one of the most effective tools in classifying and detecting targets from non-targets, when data often contains many clutter objects or when data is produced by weak acoustic signals. [2]
- We investigate applications of a VHN preprocessing layer [1] with quantum convolutional kernels in CNN-based architectures.

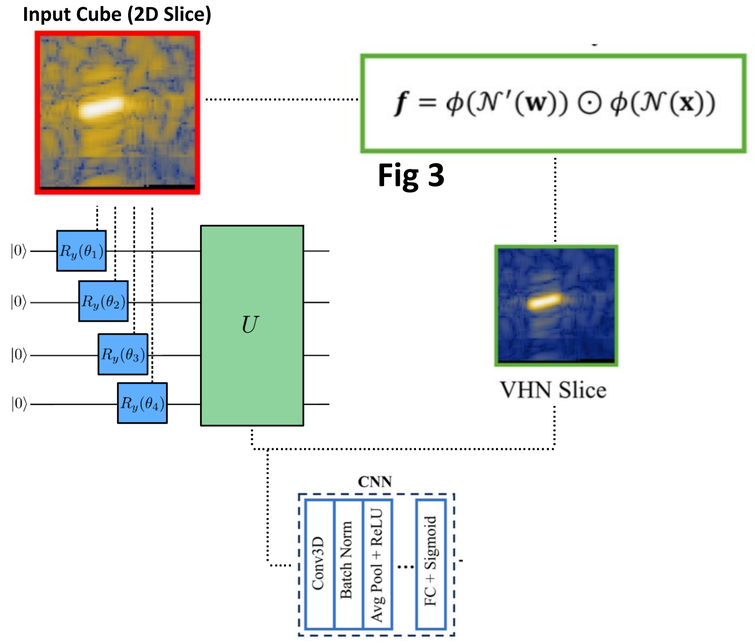
Fig 2 Regularization for VHN layer

$$\mathcal{L}_{\mathrm{r}} = \left\| \mathcal{N}'(\mathbf{w}) - \mathcal{N}\left(\frac{1}{N_T}\sum_{i=1}^{N_T}\mathbf{x}_i\right) \right\|_2^2$$

Template-Matching Regularization

PROPOSED ARCHITECTURE

- A 3D SAS cube is fed into a quantum convolutional circuit with k*k*k kernel size to produce f filtered data cubes. Together, with the **V**olumetric **H**adamard **N**ormalized, (eq pictured in **Fig 3**) the CNN classifies targets and non targets.



EXPERIMENTAL RESULTS

- **Fig 4** shows preliminary testing with a small subset of the MNIST dataset for a purely quantum preprocessing layer. The accuracy is graphed as a function of number of filters *3f*.
- **Fig 5** is the baseline results for a purely classical algorithm with and without the VHN preprocessing layer on a small subset of the SVSS dataset (3D SAS Cubes).

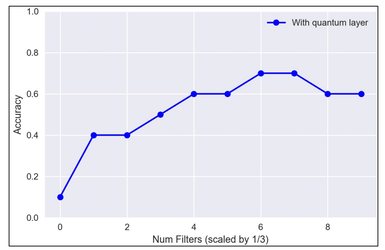


Fig 4

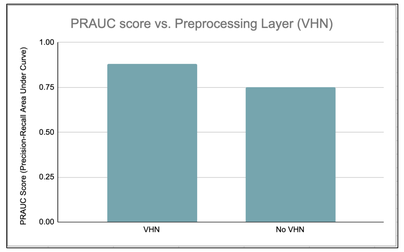
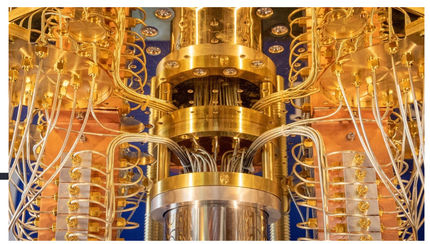


Fig 5

CHALLENGES / CONCLUSIONS

- Current quantum simulations take a tedious amount of time to run.
- Our models that implement hybrid architecture have been limited to testing on smaller datasets, but future works will begin testing / simulating with larger datasets soon
- Future research will look into preprocessing layers for 2D SAR detection



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SAS/R: Synethetic Aperture Sonar / Radar; accuracy refers to a general metric on model performance, i.e: for classification tasks, we refer to AUC-PR score

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