Tensor Networks for (Quantum) Machine Learning

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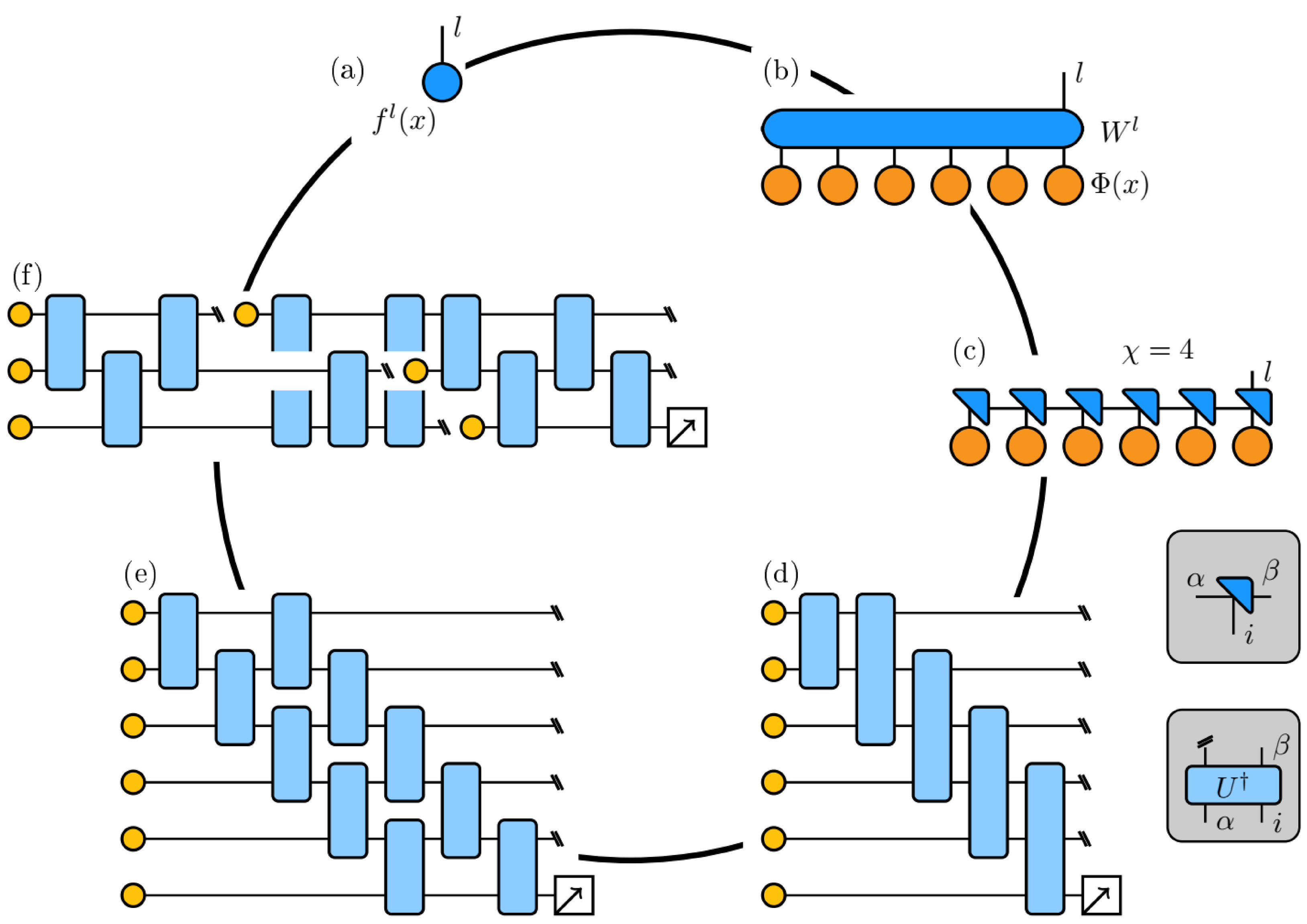
From classical to quantum tensor network machine learning

a) Machine learning is a data driven approach where a model function f is trained to map a datum x to a desired result l
b) The model f(x) consists of a data mapping $\Phi(x)$ and a weight tensor W
c) Tensor networks are an ansatz for W
d) Mapping isometric tensor nodes to quantum gates provides a quantum ansatz
e) For NISQ devices a 2-qubit ansatz is required
f) Mid-circuit measurements and resets provide a qubit efficient ordering



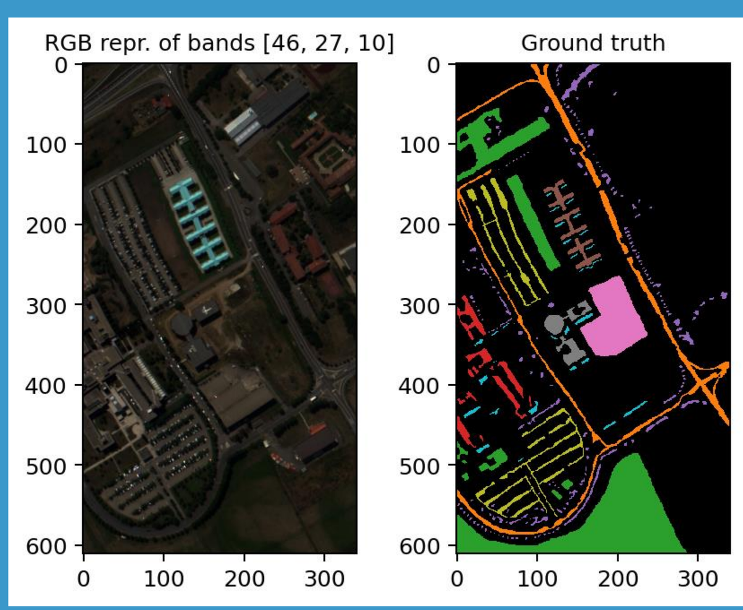
An approach to quantum machine learning using tensor network inspired algorithms. Image: Rieser et al.

Favourable features

- Simple application centred circuit structure
- Large reduction of input dimension possible
- Direct quantum-classical correspondence for hybrid approaches
- Local optimization to tackle barren plateaus / vanishing gradients
- NISQ era ready approach through efficient ansatz choices

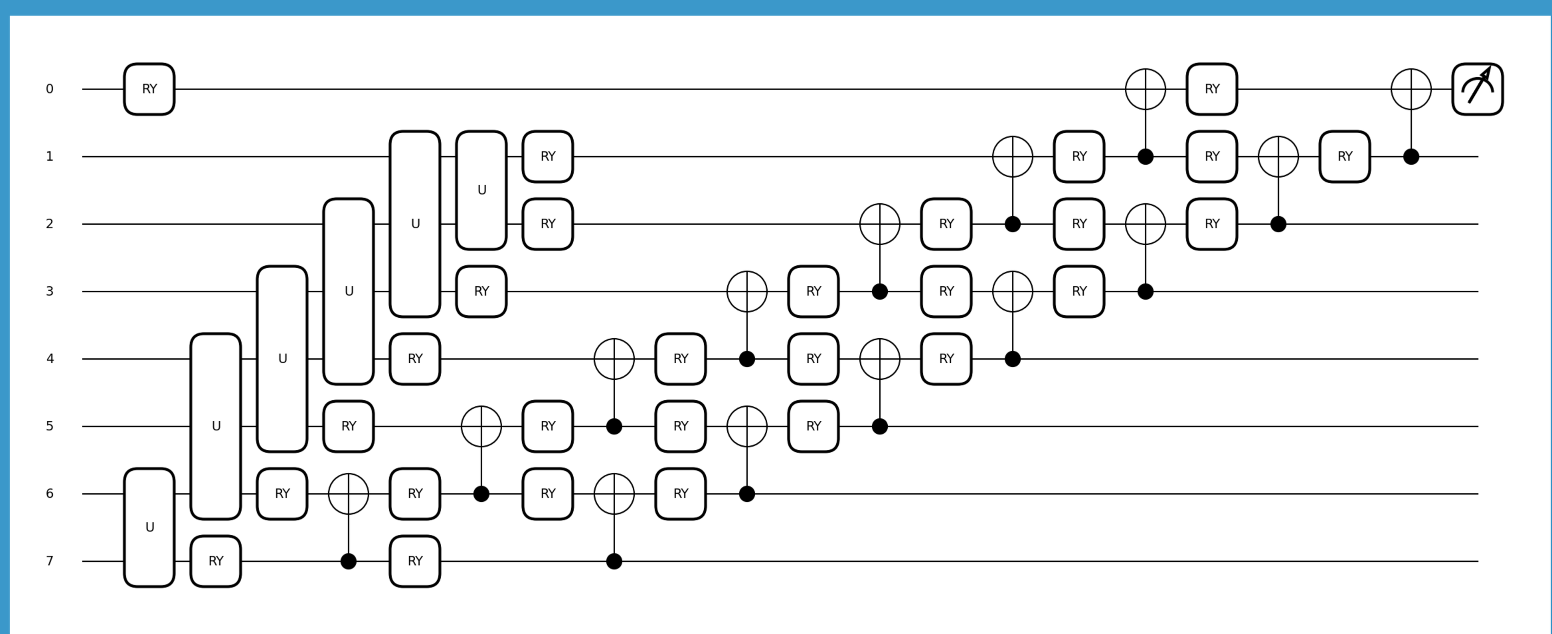
QTN provide a promising way of realizing variational quantum circuits for near to mid term applications.

Hyperspectral pixel classification with MPS



Patch from the Pavia University multi-spectral dataset with ground truth. Image: Fabian Fischbach

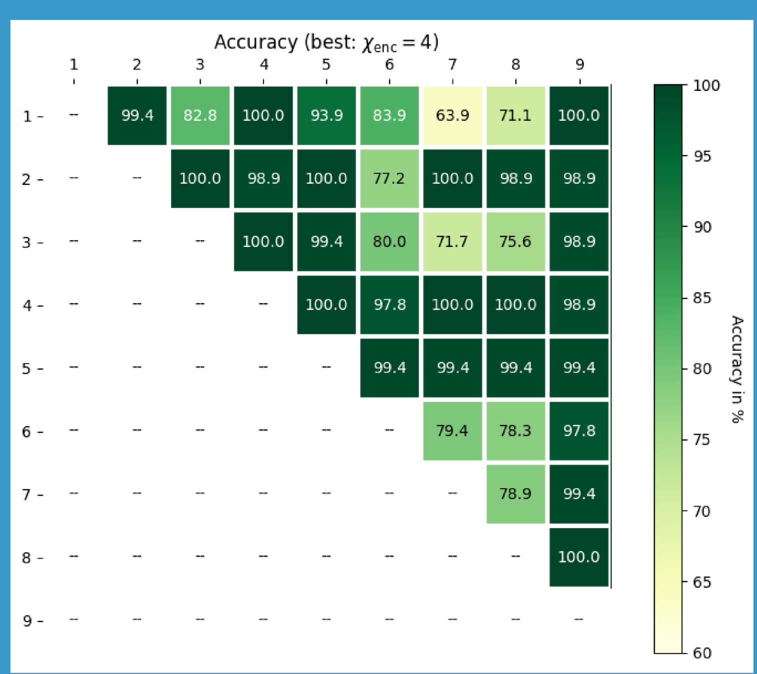
In remote sensing, a typical task is the pixelwise classification of objects. Modern satellites provide a wide range of spectral channels in their datasets.
We compress the one-dimensional spectral data pixelwise into MPS form. The bond dimension was harshly reduced to a very low χ=4.



Circuit using MPS encoding and MPS classification with bond dimension χ=4

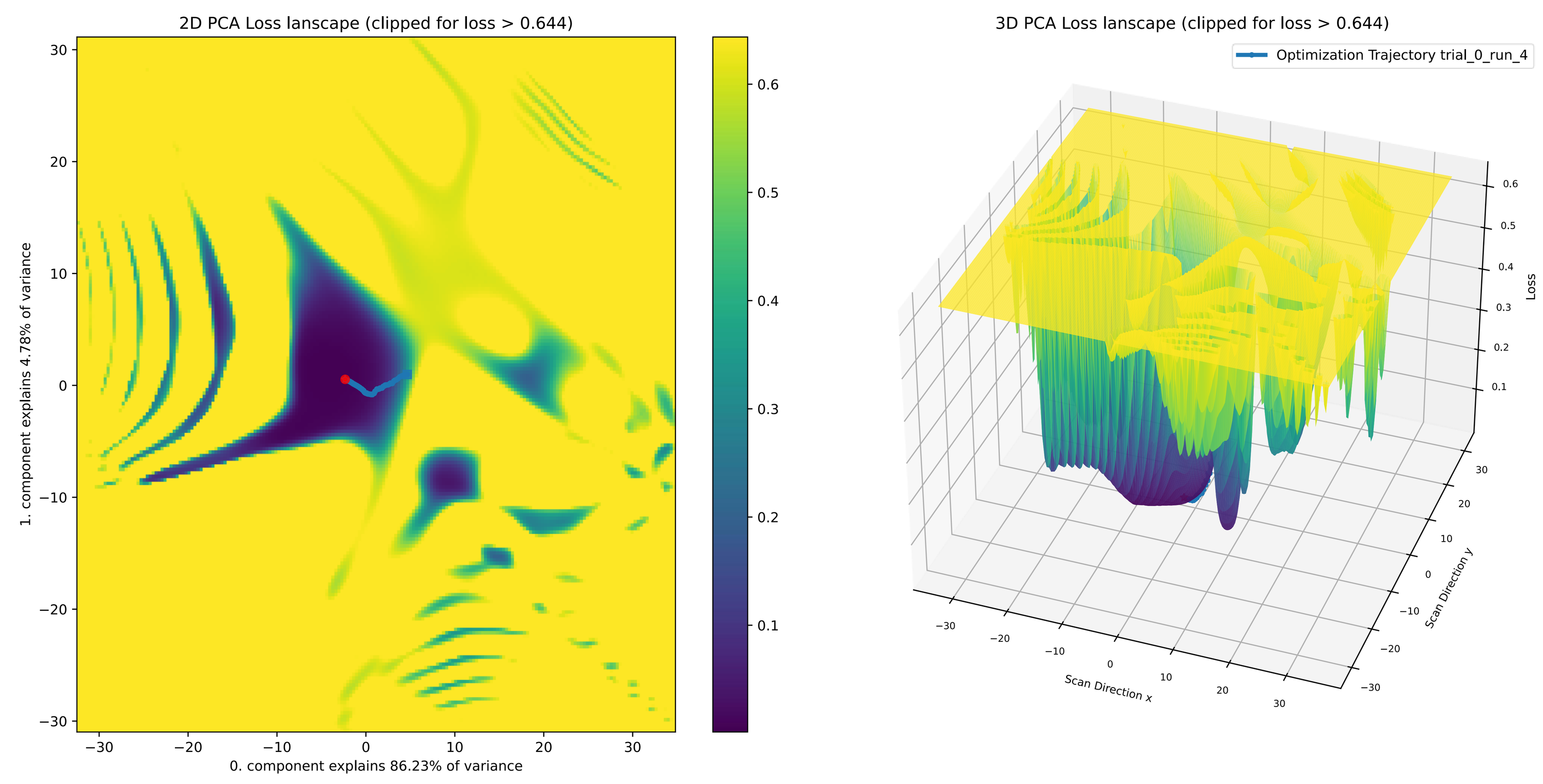
TNs can be used both for encoding and classification

Mapping the tensor nodes to unitary quantum gates gives rise to an MPS encoding scheme. The same structure can be used for the machine learning model using quantum gates with trainable parameters.



Binary classification on Pavia University Pixels. Image: Fabian Fischbach

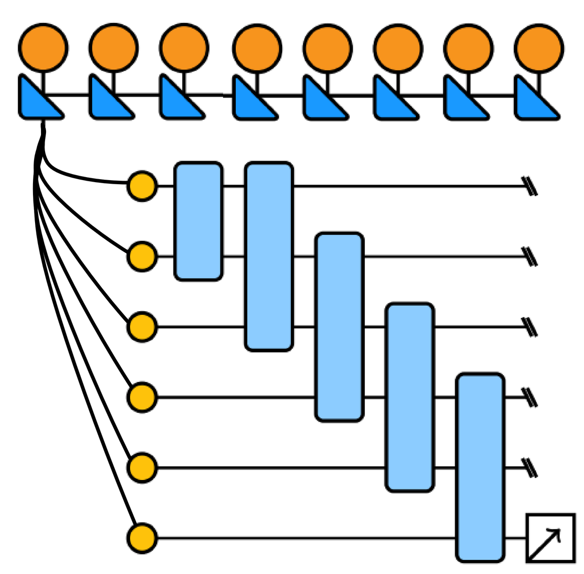
Analysis of wing instabilities using tensor networks



Loss landscape of a quantum MPS classifier circuit. Image: Lautaro Hickmann

When analysing time series, one can make use of periodic features in the data to reduce the encoding effort on the quantum computer. We investigate quantum-classical hybrid approaches inspired by tensor networks for this task. This approach significantly increases the size of problems a quantum computer can handle.

We apply this approach to estimate operating parameters from fluttering of plane wings.



Hybrid circuit with direct latent space mapping.

Ongoing projects

- In ELEVATE, we explore various applications for QTNs in machine learning, e.g. encoding of hyper-spectral images and classification tasks of wing instabilities
- QuTeNet is about joining quantum simulation and machine learning with TNs
- A PhD project focuses on efficiently optimizing QTN machine learning models

Contact: Institute: Project QuTeNet: QTN Review:

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