About Jacob
QML and its applications
Quantum time series analysis
Quantum autoencoders
Barren plateaus and capacity to learn
Quantisation of classical data structures

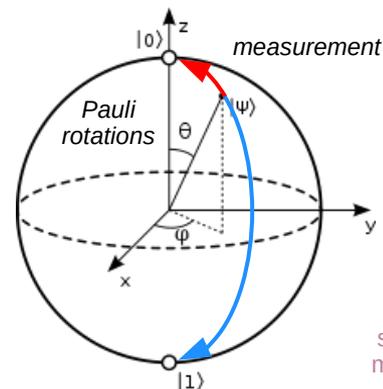*Dreams weave qubits tight,*
Through the lattice of the night—
Code bends time and light.

Quantum Haiku by DeepSeek

Jacob vs Quantum

A first-person view of quantum machine learning

Jacob L. Cybulski
Enquanted, Australia
SIT, Deakin University, Australia

We will assume
some knowledge of
maths and analytics

Dashboard

Jacob Cybulski
quantum@jacobcybulski.com

QTSA in machine condition monitoring

Founder
Researcher
Consultant
Author
at Enquanted

also

Honorary A/Prof
In Quantum Computing
School of IT, SEBE
Deakin University
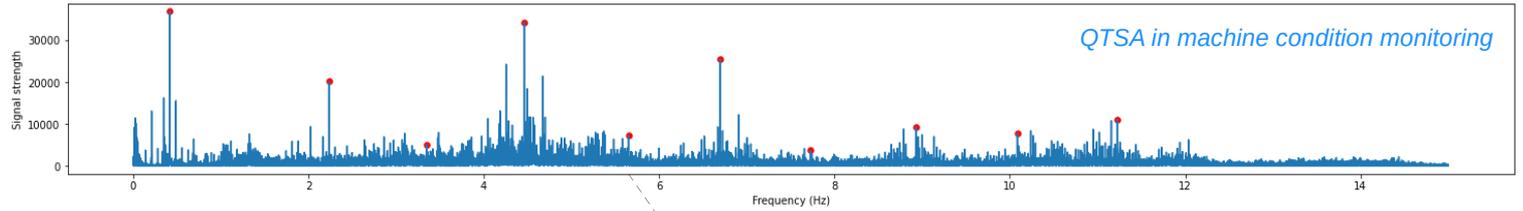**Melbourne, Australia**

Medical QTSA diagnosis

Research
- **Quantum computing**
- **Quantum machine learning**
- **Quantum time series analysis and anomaly detection**
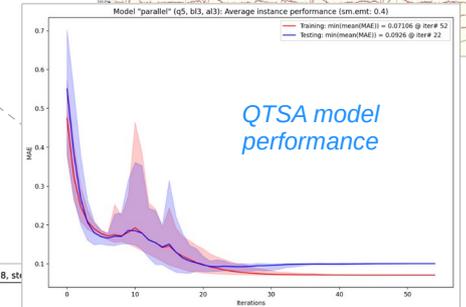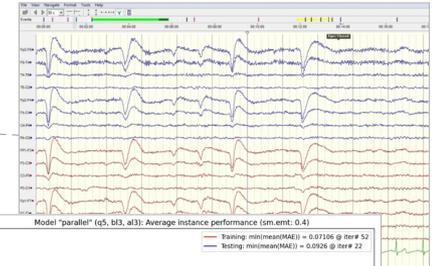- Classical machine learning
- Data visualisation

Personal
- **Recreational cycling**
- **Reading science and Sci-Fi**
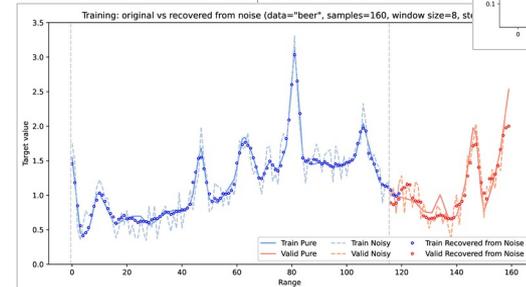- **Quantum challenges and hackathons**

QTSA model performance

Model capacity to learn and barren plateaus

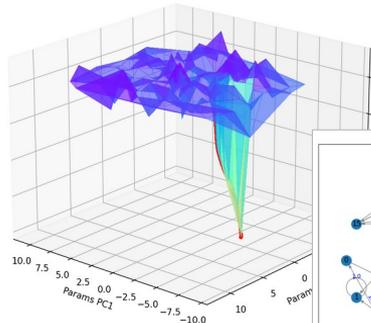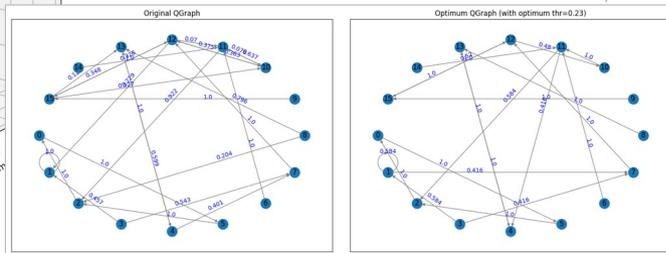*Quantum graphs with community detection*

QTSA in sales forecasting

International collabs, e.g.
QAIF, QPoland, QIndia,
QWorld, Molket,
IBM Open Science,
SheQuantum, Action in
Quantum Time, etc.

Quantum ML
and its applications

Jacob L. Cybulski, Quantum Business Series (Deakin, RMIT, ACS, Warsaw School of Economics)
Jacob L. Cybulski, Quantum Computing Intro Series (SheQuantum, Assoc of Polish Profs in Australia)
2021-2025

Organisations & Society

Economy

People

Environment

highly complex processes of which mathematical models resemble those of quantum phenomena, and where classical algorithms are inefficient or fail completely

processes which are negatively affected by or may greatly benefit from quantum technology and its algorithms
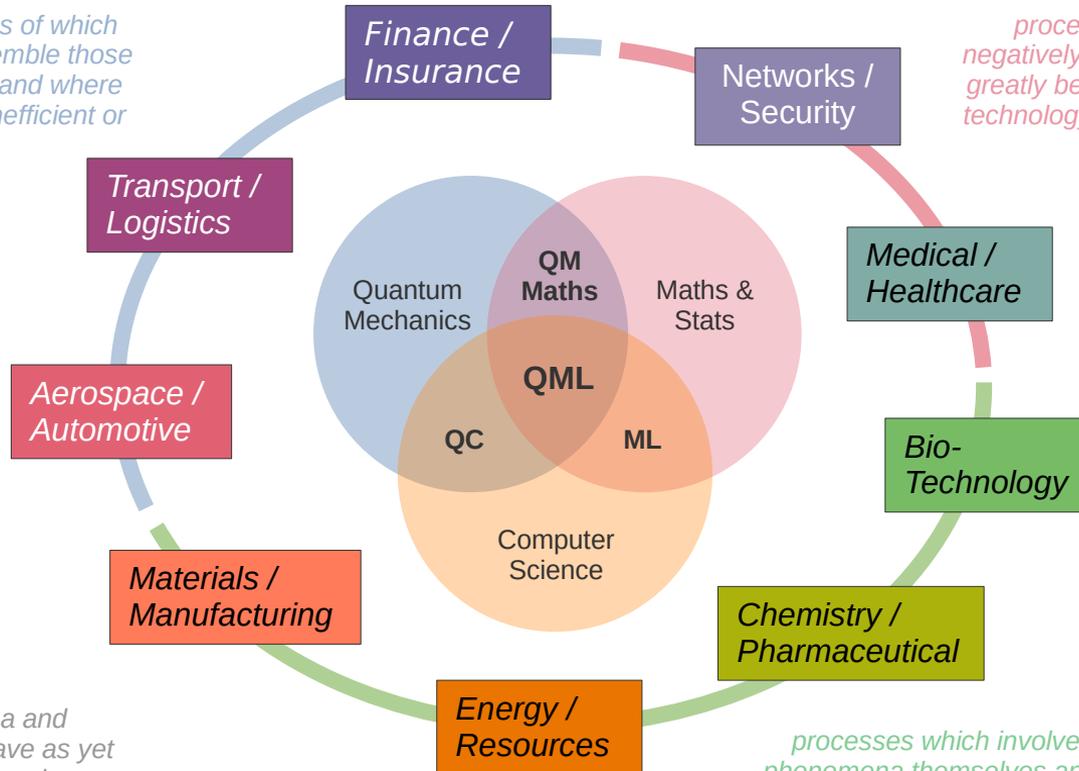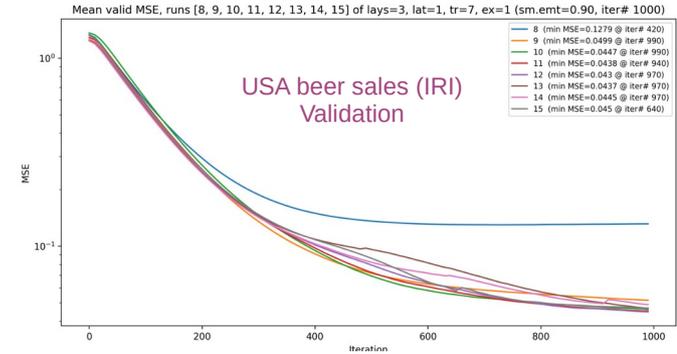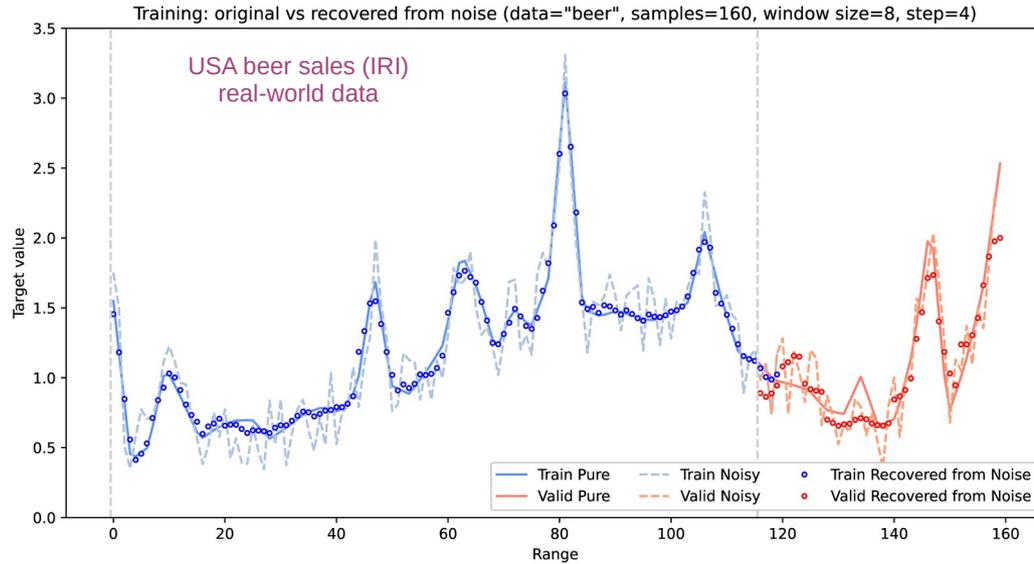
new phenomena and processes which have as yet not been considered as suitable for quantum solutions

processes which involve quantum phenomena themselves and are easily modelled and simulated on quantum machines, resulting in highly efficient and effective solutions, and where classical methods currently fail

Finance / Insurance

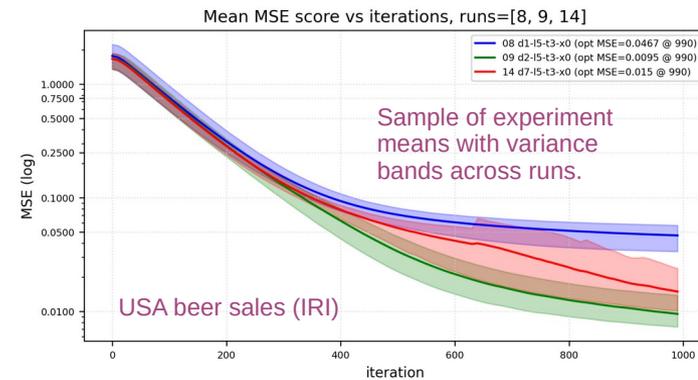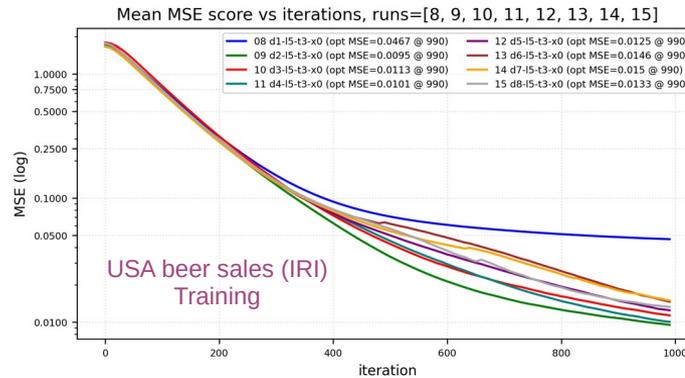Networks / Security

Transport / Logistics

Medical / Healthcare

Aerospace / Automotive

Bio-Technology

Materials / Manufacturing

Chemistry / Pharmaceutical

Energy / Resources

Quantum Mechanics

Maths & Stats

Computer Science

QM Maths

QML

QC

ML

Training: original vs recovered from noise (data="beer", samples=160, window size=8, step=4)

USA beer sales (IRI) real-world data

Mean valid MSE, runs [8, 9, 10, 11, 12, 13, 14, 15] of lays=3, lat=1, tr=7, ex=1 (sm.emt=0.90, iter# 1000)

USA beer sales (IRI) Validation

Quantum Time Series Analysis

**Experiments to assess performance of data encoding and decoding methods using synthetic and real-world data**

Mean MSE score vs iterations, runs=[8, 9, 10, 11, 12, 13, 14, 15]

USA beer sales (IRI) Training

Mean MSE score vs iterations, runs=[8, 9, 14]

Sample of experiment means with variance bands across runs.

USA beer sales (IRI)

QTSA

TS window limited to the number of qubits

Single trainable ansatz at the circuit end only

Investigation of novel quantum models and architectures for quantum time series analysis

feature map
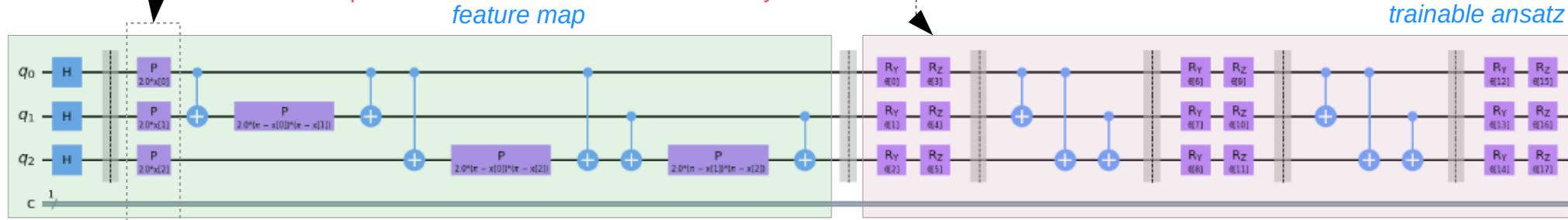
trainable ansatz

Traditional Quantum Neural Network for QTSA

time series with a sliding window

sliding window encoding

X

encoding blocks

trainable ansatz

W1

S1

trainable ansatz

W2

S2

trainable ansatz

W3
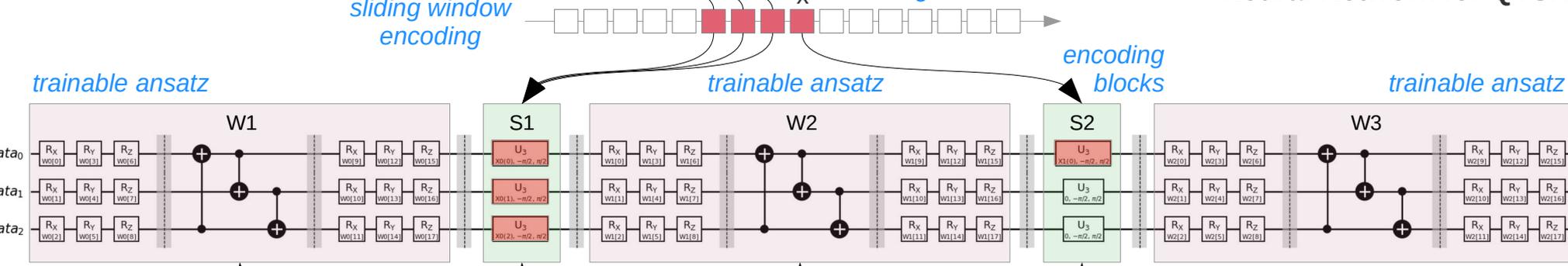
Trainable state preparation

Trainable ansatze separate encoding blocks

Potential for encoding multivariate TS

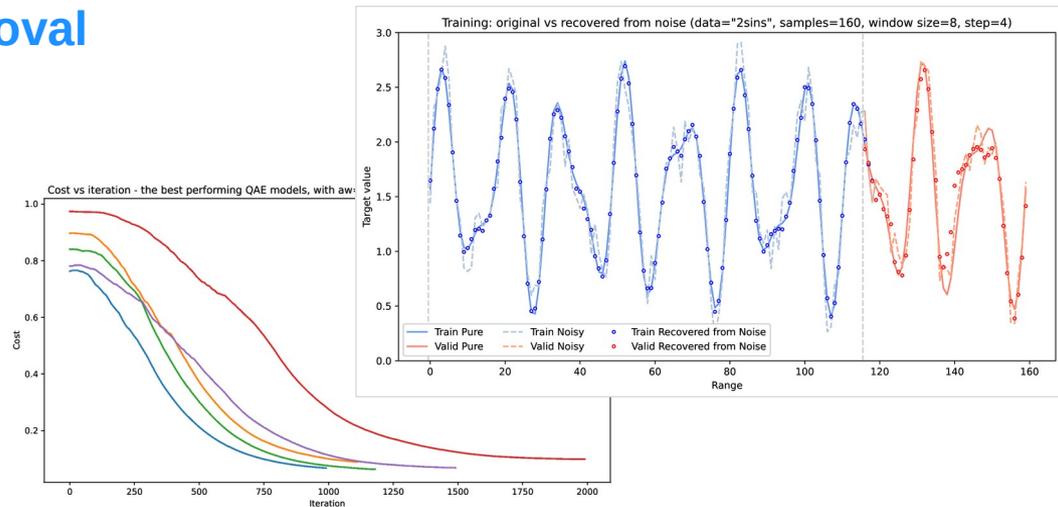Data overloading / Unlimited size of TS window

Overloading and Re-uploading Model for QTSA

Jacob Cybulski, keynote "Time Series Analysis Using Quantum Machine Learning", *Workshop on Quantum Machine Learning*, 13 October 2022, organised in collaboration with QWorld, QPoland, QIndia and Quantum AI Foundation. In assoc with IEEE Conf *Trends in Quantum Computing and Emerging Business Technologies* (TQCEBT), 2022.
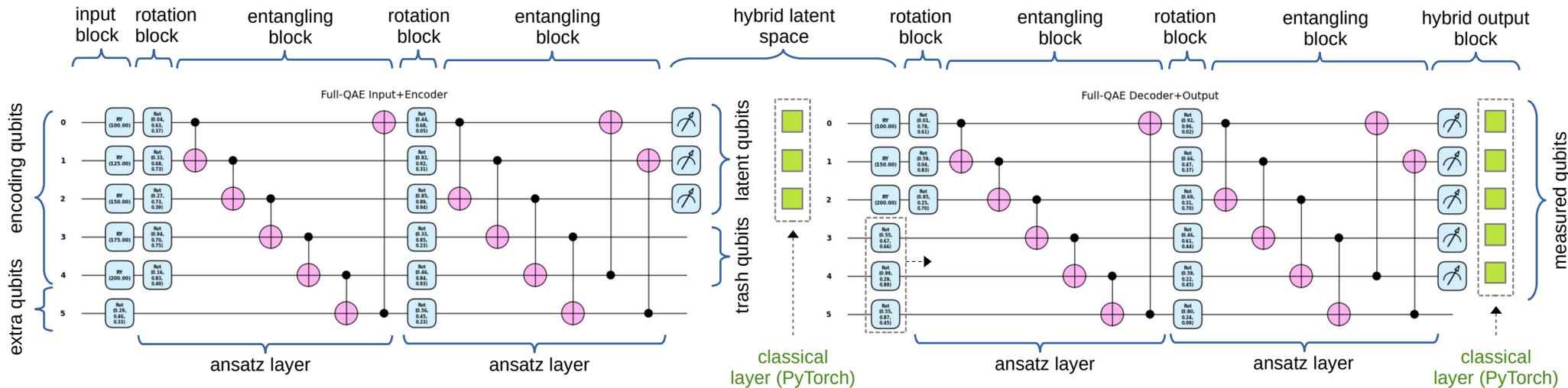
Quantum Autoencoder
Time Series Analysis with Noise Removal

Development of complex quantum models, such as Quantum Autoencoders (both pure and hybrid), for time series and signal analysis. The models can reduce noise, analyse and forecast temporal data, and detect complex anomaly patterns.
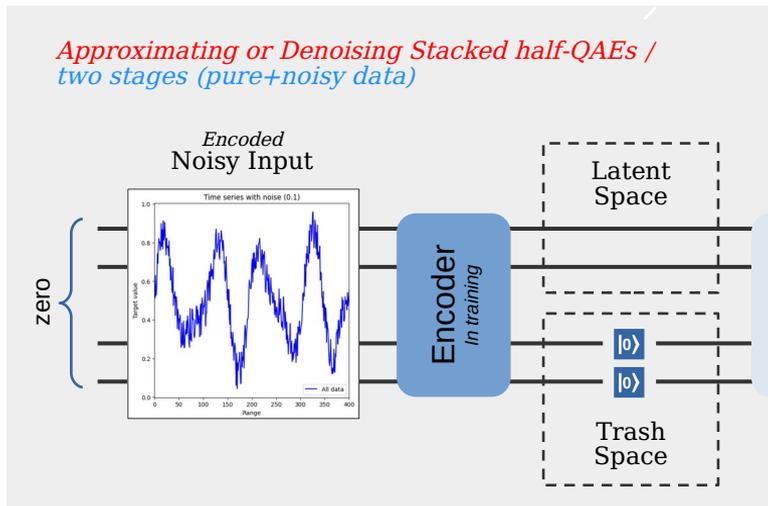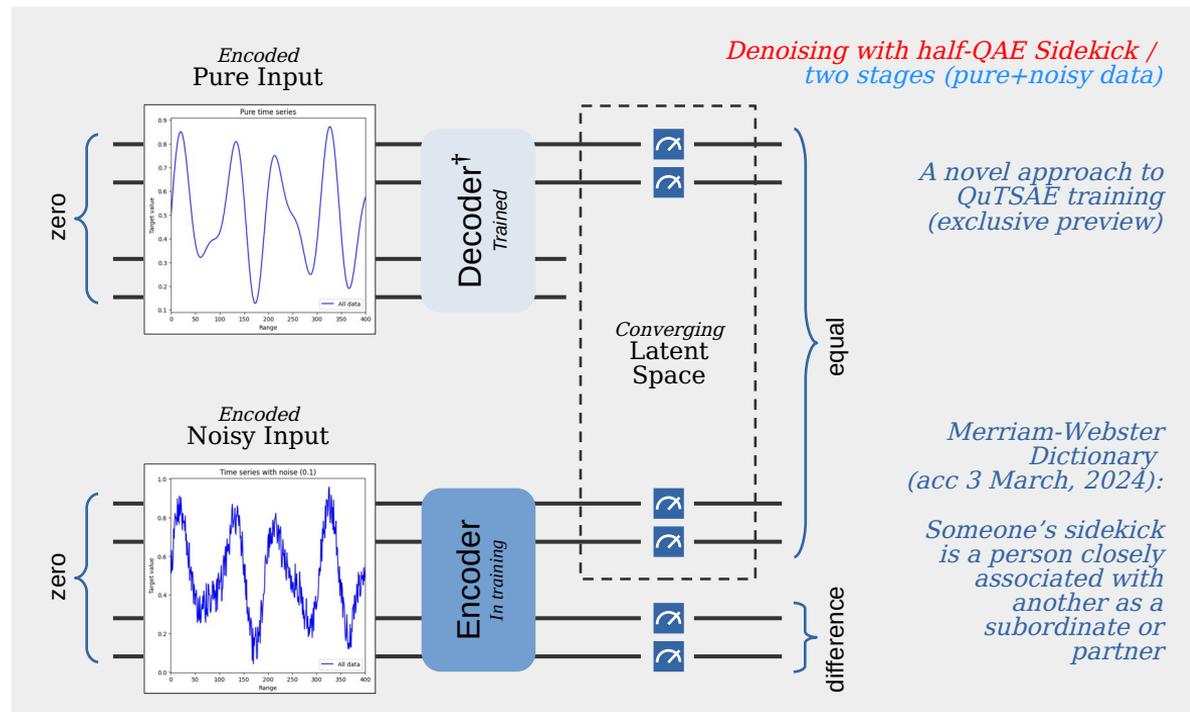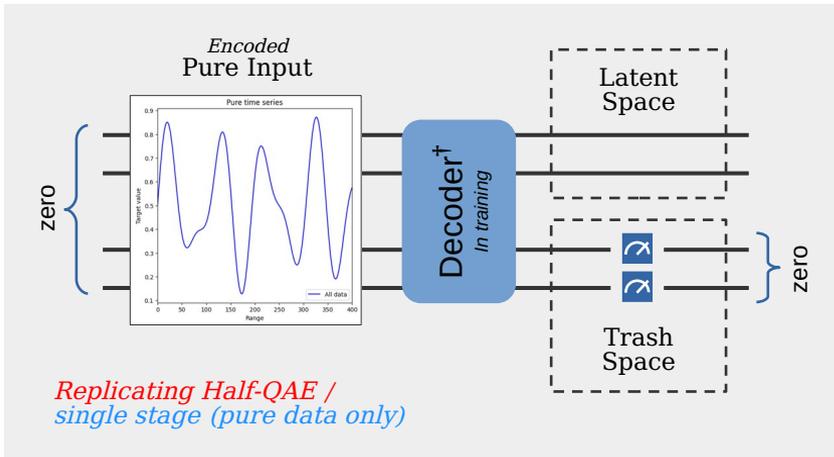

Hybrid quantum QAE TSA model for noise reduction

QTSAE
Algorithms and Architectures

Encoded
Pure Input

Latent Space

Trash Space

Decoder† *In training*

zero

zero

Replicating Half-QAE / single stage (pure data only)

Denoising with half-QAE Sidekick / two stages (pure+noisy data)

Encoded
Pure Input

Decoder *Trained*

zero

A novel approach to QuTSAE training (exclusive preview)

Converging Latent Space

Encoded
Noisy Input

Encoder *In training*

zero

equal

difference

Merriam-Webster Dictionary (acc 3 March, 2024):

Someone's sidekick is a person closely associated with another as a subordinate or partner

Approximating or Denoising Stacked half-QAEs / two stages (pure+noisy data)

Encoded
Noisy Input

Latent Space

Trash Space

Encoder *In training*

Decoded - Inverted
Noise-Free Output

Decoder *Trained*

$|0\rangle$

$|0\rangle$

zero

zero

Review of methods and algorithms, creation of new training approaches, for quantum auto-encoders and their application to time series analysis

Jacob Cybulski and Sebastian Zając, "Development of Quantum Autoencoders", Washington DC / Toronto / Warsaw Quantum Computing Meetups, 5 Oct 2024.

Barren plateaus
Making quantum models trainable

Barren plateaus (BPs) are large "flat" areas in the quantum model's cost landscape, which impede model optimisation.
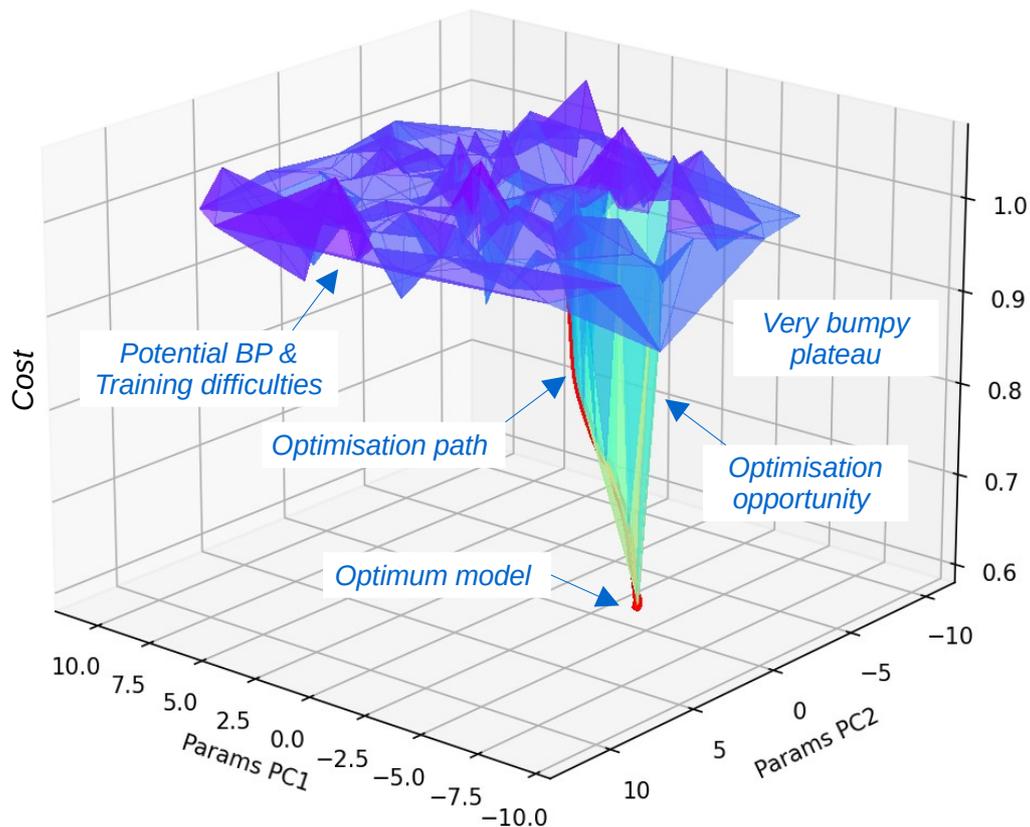
- QNNs have similar training difficulties as Nns
- BPs are related to vanishing gradients in NNs
- BPs presence does not mean the model is bad, its training is just more difficult
- BPs are the natural feature of measurements in high dimensional space of model parameters
- BPs do not just "exist", they emerge in training
- BPs are commonly flat, however, their surface may become rough and bumpy due to noise
- BP countermeasures can make your model worse
- There exist well-known causes of BPs and there are well-known BP countermeasures, e.g.
    1) use fewer qubits / layers / parameters
    2) use local cost functions
    3) beware of random params initialisation
    4) use BP-resistant model design (e.g. layerwise)
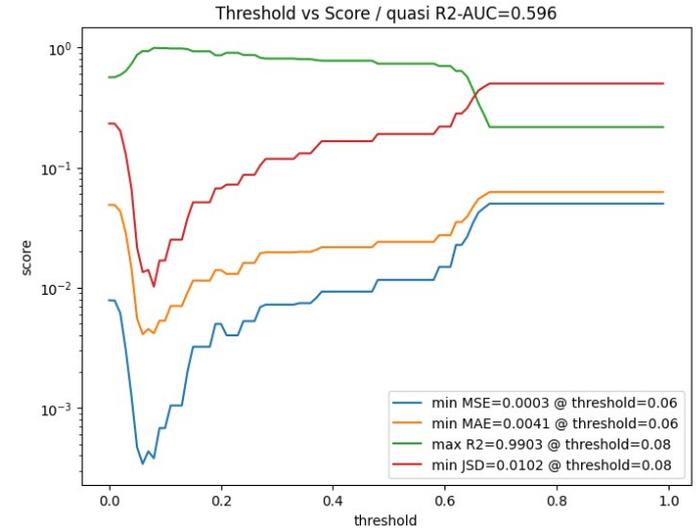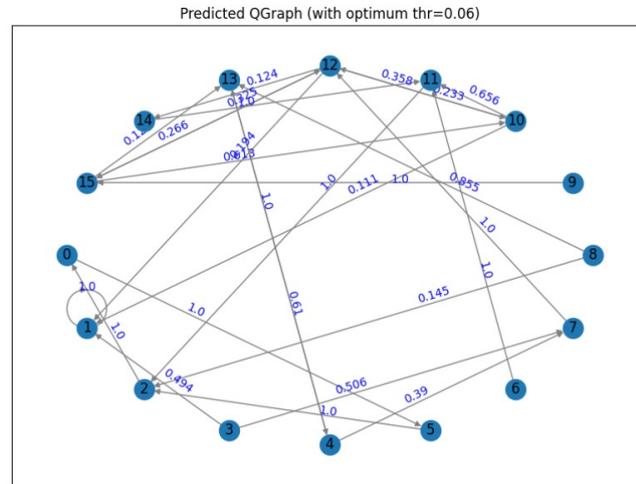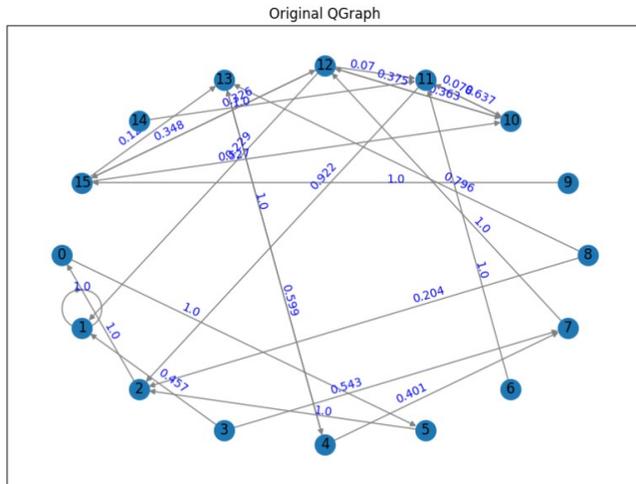   5) use BP-resistant models (e.g. QCNNs)

Cybulski, J.L., Nguyen, T., 2023. "Impact of barren plateaus countermeasures on the quantum neural network capacity to learn", *Quantum Inf Processing* 22, 442.

Nguyen Ngo Cong Thanh and Jacob L. Cybulski (2023): "Investigation of Barren Plateaus in Quantum Neural Network Development." Presented at *10th Int Congress on Industrial and Applied Mathematics* (ICIAM 2023), Waseda University, Tokyo, Japan, Poster 13568, August 20-25, 2023.

Current Work

**Neurons hum, entrained,
Quantum states in circuits chained—
Truth blooms, unrestrained.**

Quantum Haiku by DeepSeek

Original QGraph

Predicted QGraph (with optimum thr=0.06)

Threshold vs Score / quasi R2-AUC=0.596

- min MSE=0.0003 @ threshold=0.06
- min MAE=0.0041 @ threshold=0.06
- max R2=0.9903 @ threshold=0.08
- min JSD=0.0102 @ threshold=0.08

Quantum Graphs

Development of concepts and formalisms related to "quantisation" of classical data structures, such as time series, signals and graphs.

Quantum graphs for instance will assist highly efficient representation and processing of very large interconnected structures, e.g. when assisting management of social networks, identification of sub-graph communities and detection of anomalies in graphs.
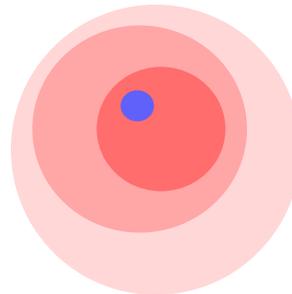
Enquanted is being somewhere in-between Enchanted and Entangled