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

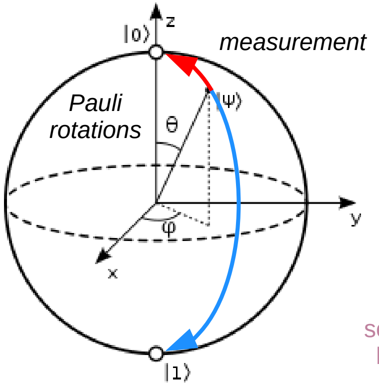
Dreams weave qubits tight,
Through the lattice of the night—
Code bends time and light.

Quantum Haiku by DeepSeek

Jacob vs Quantum

A first-person view of quantum machine learning

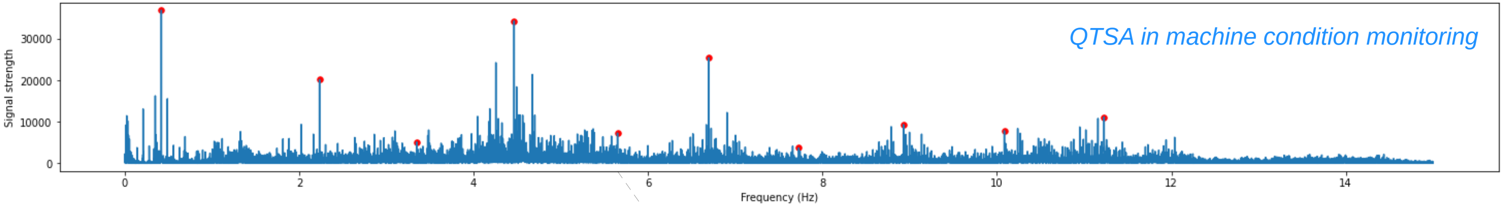
Jacob L. Cybulski
Enquanted, Australia
SIT, Deakin University, Australia



We will assume
some knowledge of
business analytics

Dashboard

Jacob Cybulski
quantum@jacobcybulski.com



QTSA in machine condition monitoring

Founder
Researcher
Consultant
Author
at Enquanted

also

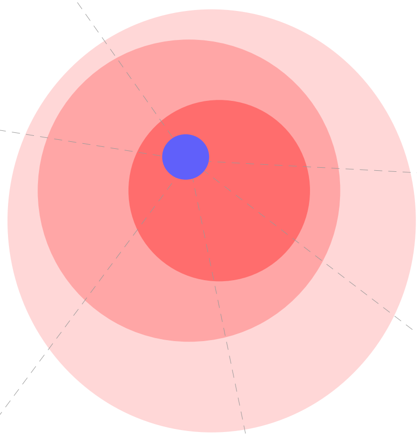
Honorary A/Prof
In Quantum Computing
School of IT, SEBE
Deakin University
Melbourne, Australia

Research

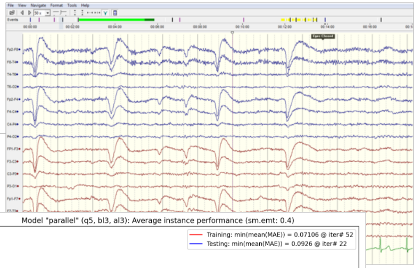
- Quantum computing
- Quantum machine learning
- Quantum time series analysis and anomaly detection
- Classical machine learning
- Data visualisation

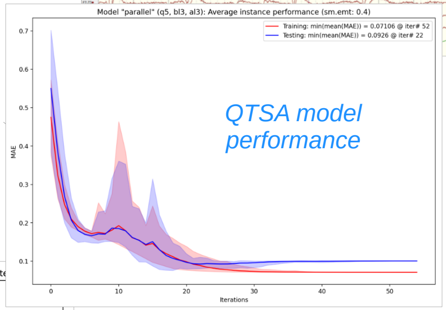
Personal

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

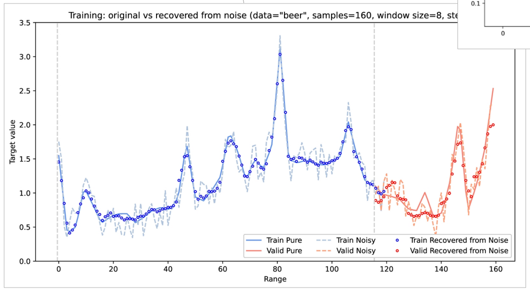


Medical QTSA diagnosis



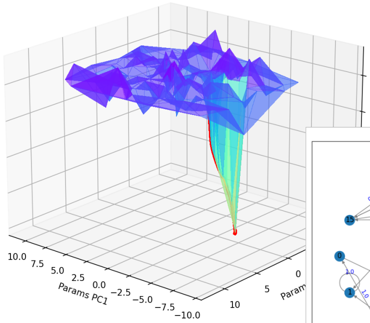


QTSA model performance

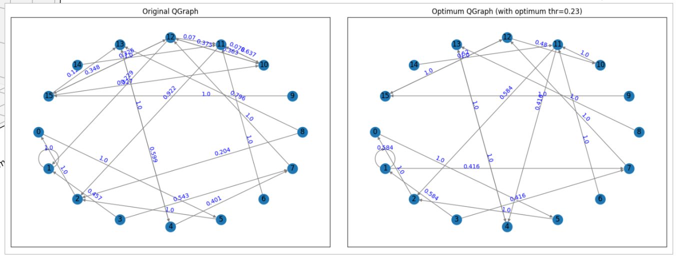


QTSA in sales forecasting

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



Model capacity to learn and barren plateaus



Quantum graphs with community detection

Quantum ML

and its applications

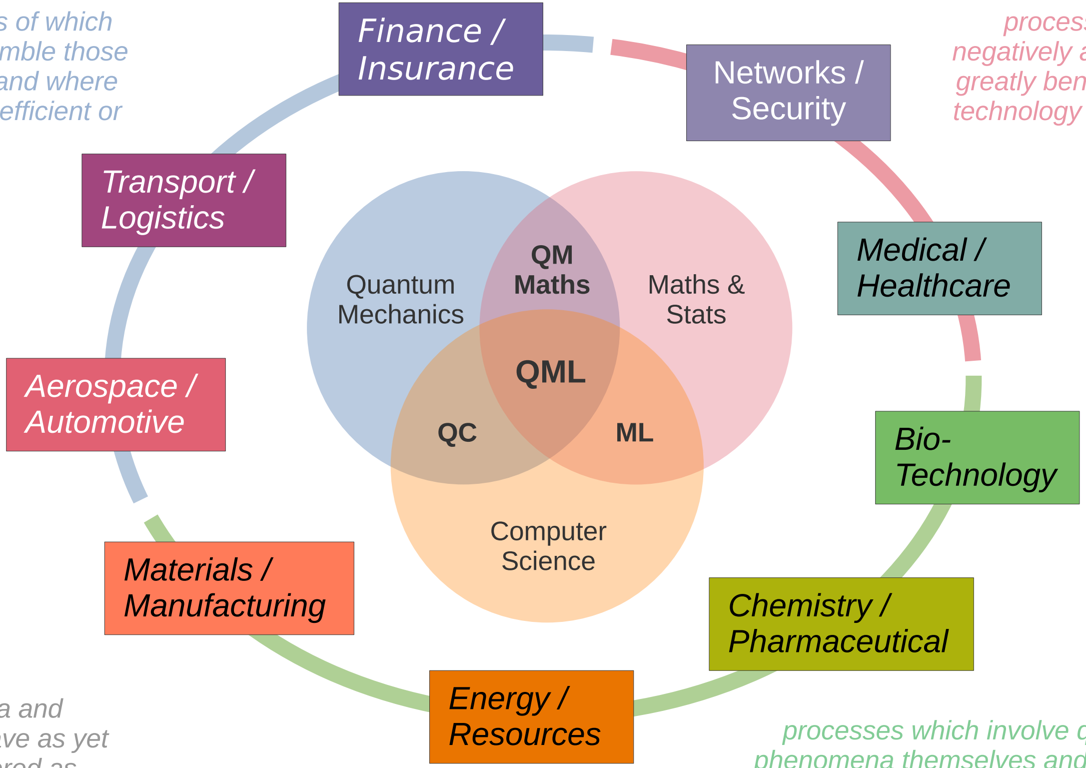
Jacob L. Cybulski, Quantum Business Series (Deakin, RMIT, ACS, Warsaw School of Economics)
Jacob L. Cybulski, Quantum Computing Intro Series (SheQuantum, Assoc of Polish Profs in Australia)
2021-2025

Organisations & Society

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

Economy



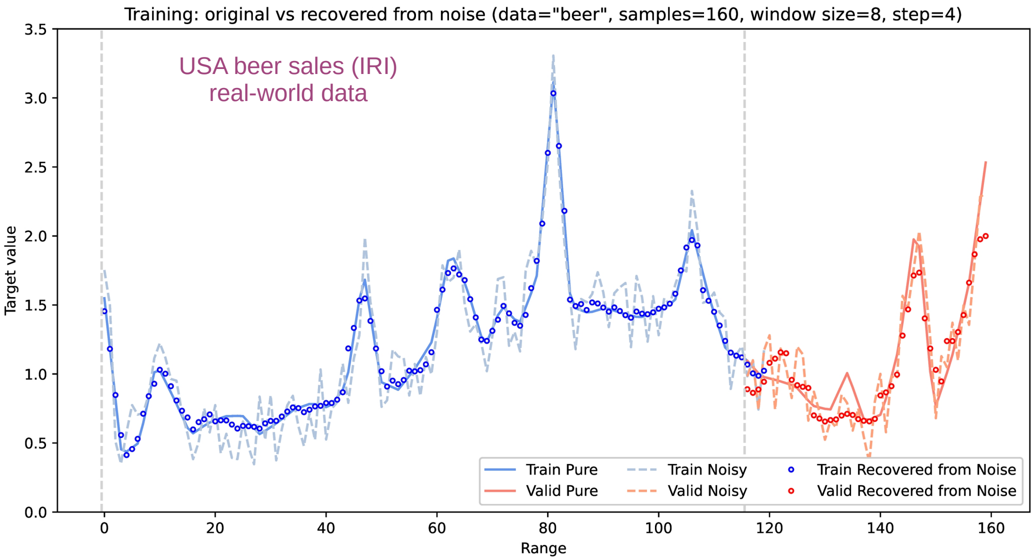
People

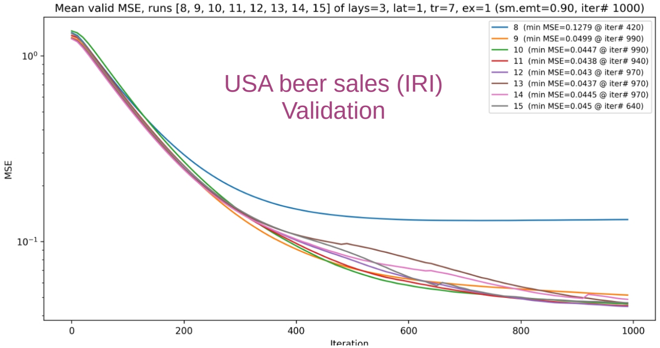
new phenomena and processes which have as yet not been considered as suitable for quantum solutions

Environment

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

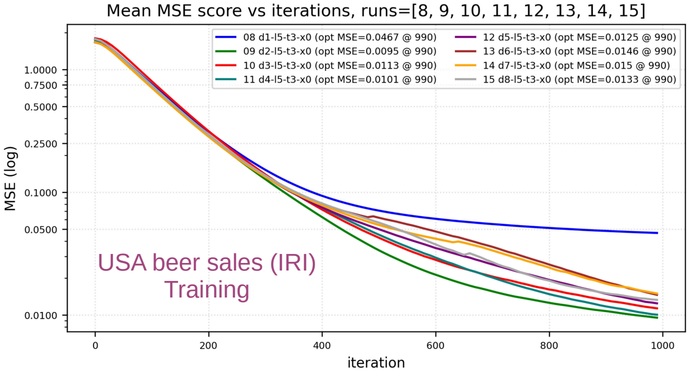
Jacob L. Cybulski and Sebastian Zając (2024): "The Art of Data Encoding and Decoding for Quantum Time Series Analysis."
8th Intl Conf on *Quantum Techniques in Machine Learning*
University of Melbourne, Melbourne, Australia, 25-29 Nov 2024.
In preparation for journal publication

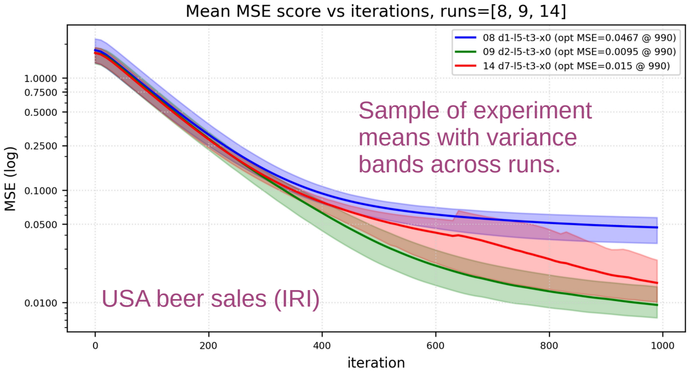


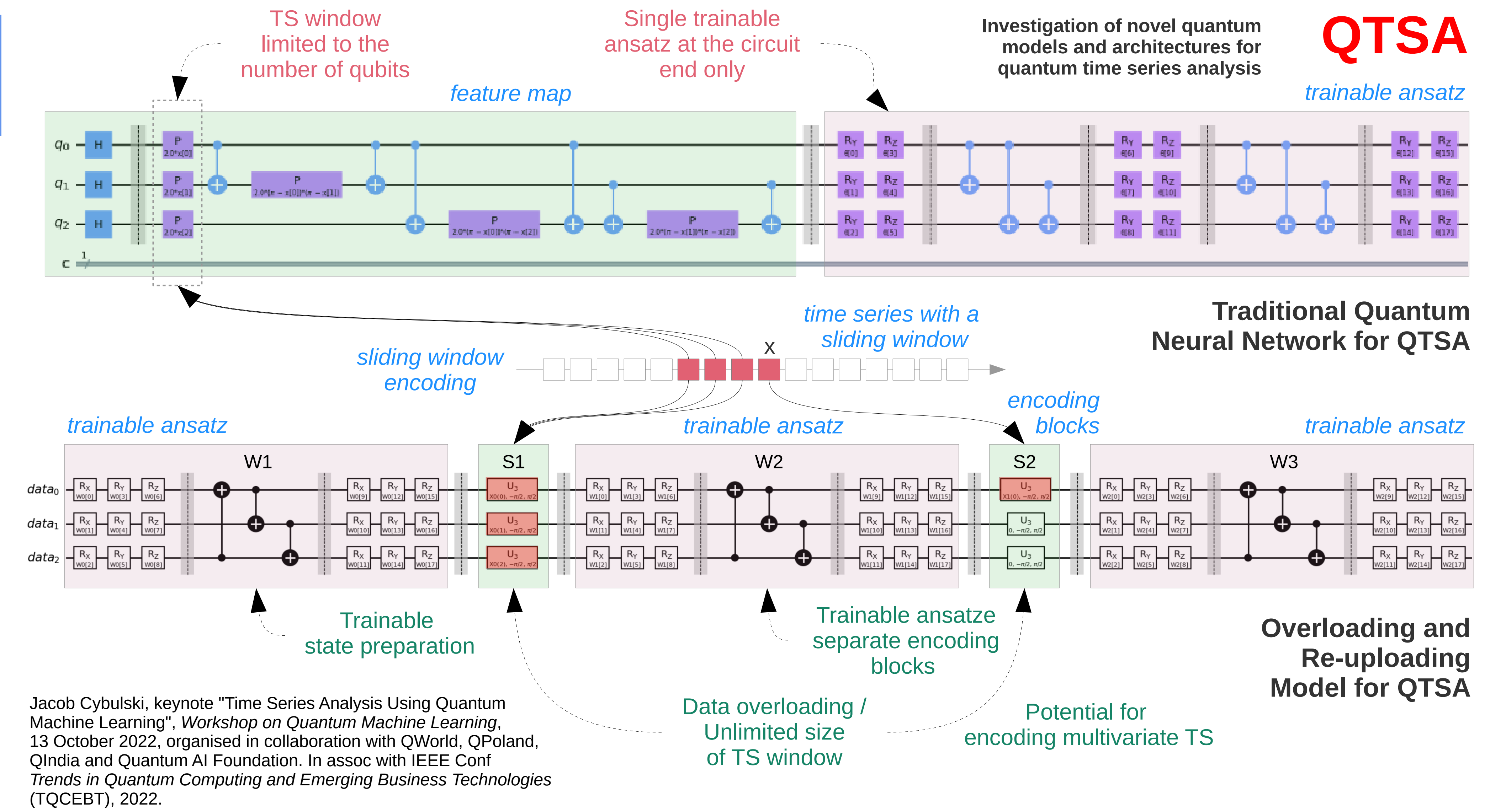


Quantum Time Series Analysis

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







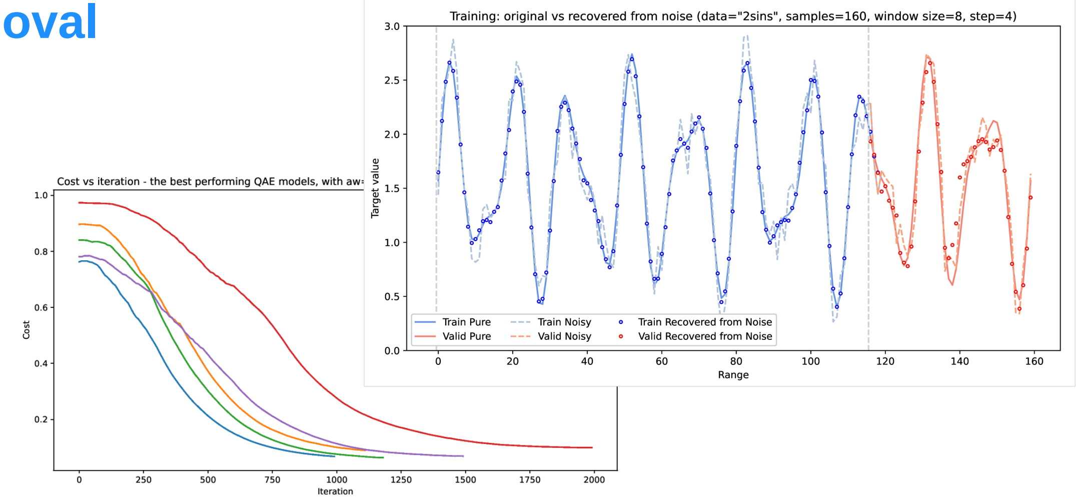
QTSA
Investigation of novel quantum models and architectures for quantum time series analysis
TS window limited to the number of qubits
Single trainable ansatz at the circuit end only
feature map
trainable ansatz
Traditional Quantum Neural Network for QTSA
time series with a sliding window
X
sliding window encoding
encoding blocks
trainable ansatz
trainable ansatz
trainable ansatz
W1
S1
W2
S2
W3
Trainable state preparation
Trainable ansatze separate encoding blocks
Overloading and Re-uploading Model for QTSA
Data overloading / Unlimited size of TS window
Potential for encoding multivariate TS
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.

Jacob L. Cybulski and Sebastian Zając (2024): "Design Considerations for Denoising Quantum Time-Series Autoencoder." In *24th Int Conf on Computational Science (ICCS)*, Lecture Notes in Computer Science, LNCS, vol. 14837, Part VI, 252–67, July 2-4, 2024, Malaga, Spain.

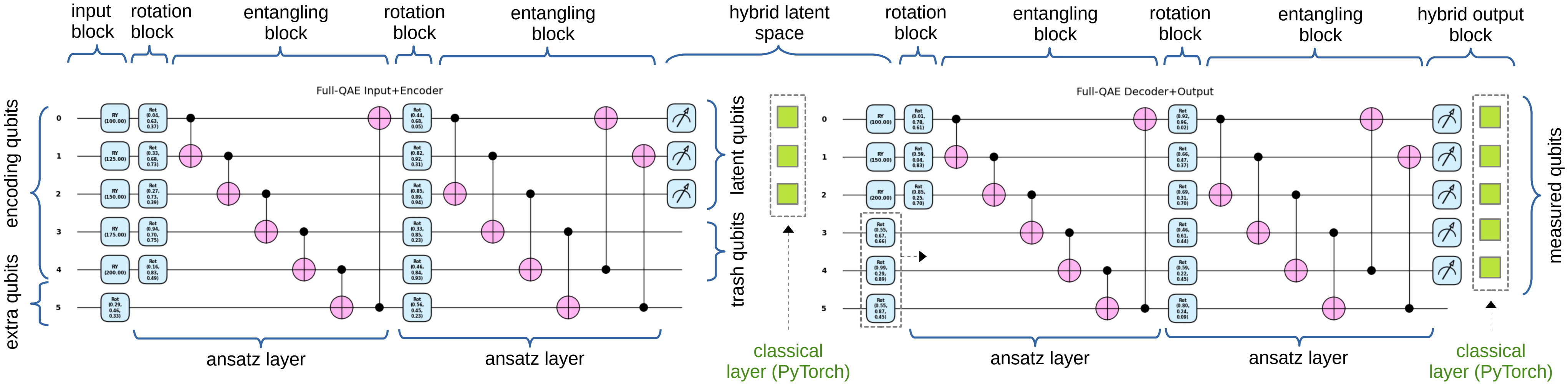
Quantum Autoencoder

Time Series Analysis with Noise Removal

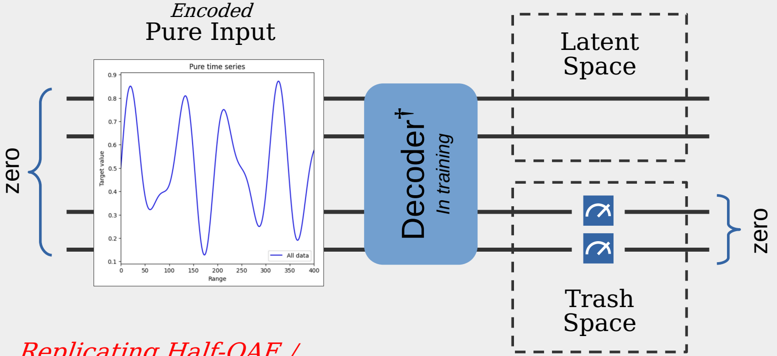
Development of complex quantum models, such as Quantum Autoencoders (both pure and hybrid), for time series and signal analysis. The models can reduce noise, analyse and forecast temporal data, and detect complex anomaly patterns.



Hybrid quantum QAE TSA model for noise reduction

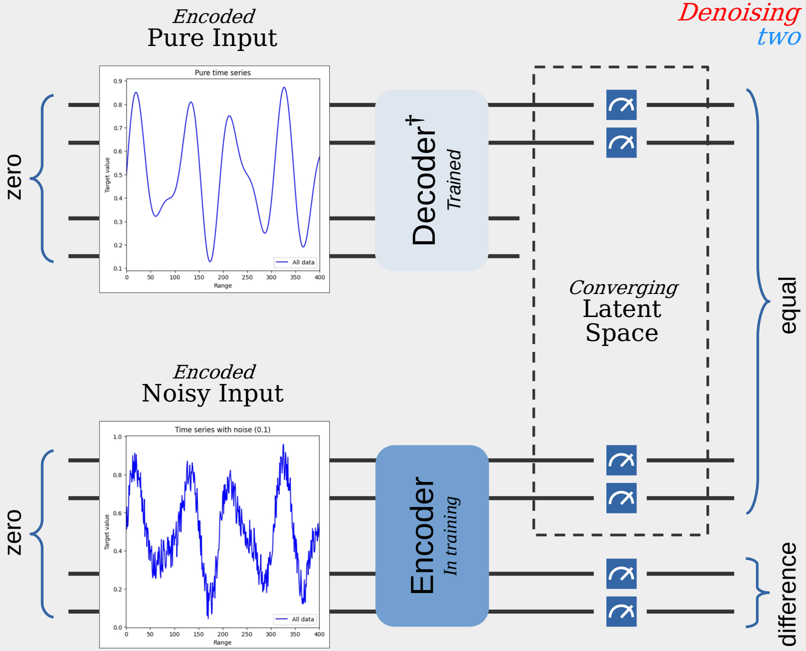


QTSAE
Algorithms and Architectures



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

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

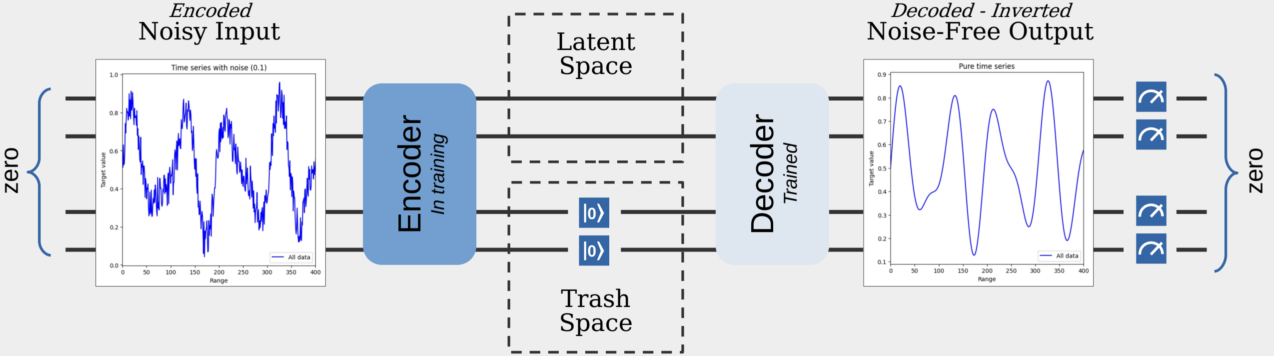


A novel approach to QuTSAE training (exclusive preview)

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)



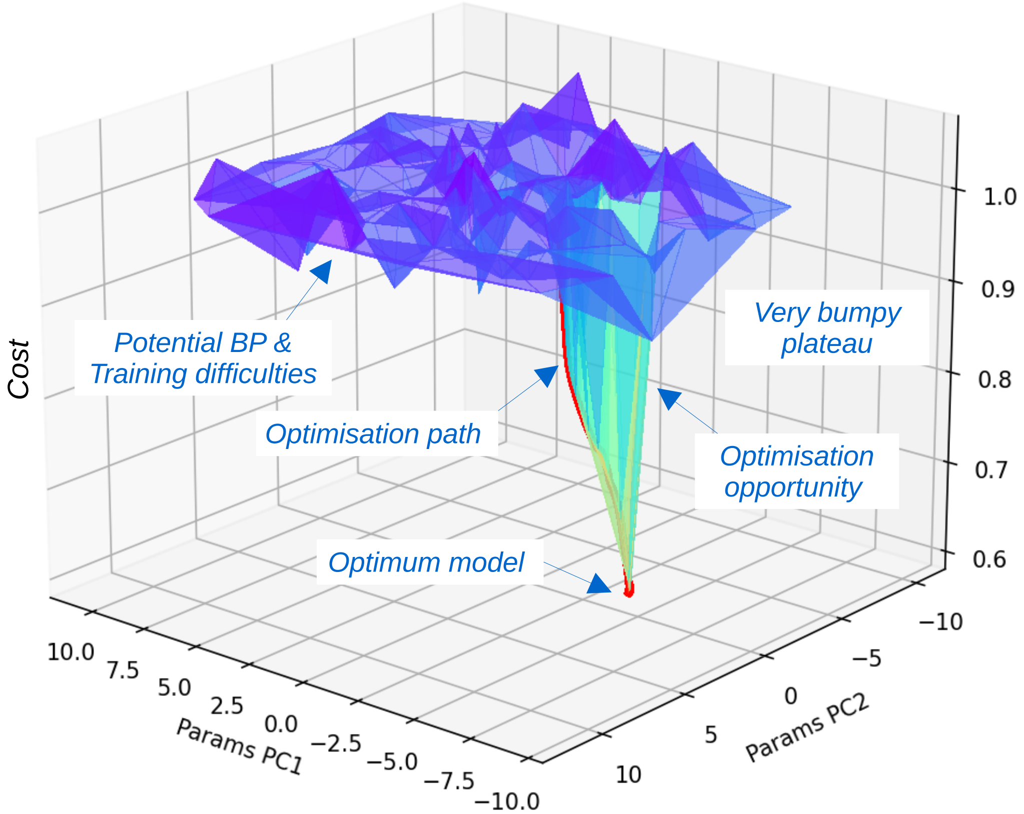
Review of methods and algorithms, creation of new training approaches, for quantum auto-encoders and their application to time series analysis

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)

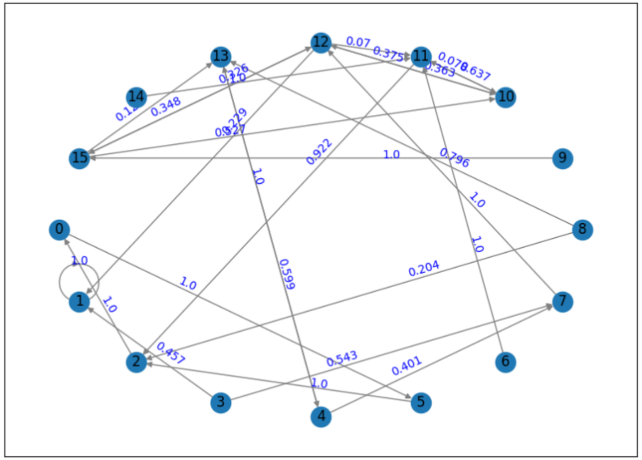
Cybulski, J.L., Nguyen, T., 2023. "Impact of barren plateaus countermeasures on the quantum neural network capacity to learn", *Quantum Inf Processing* 22, 442.

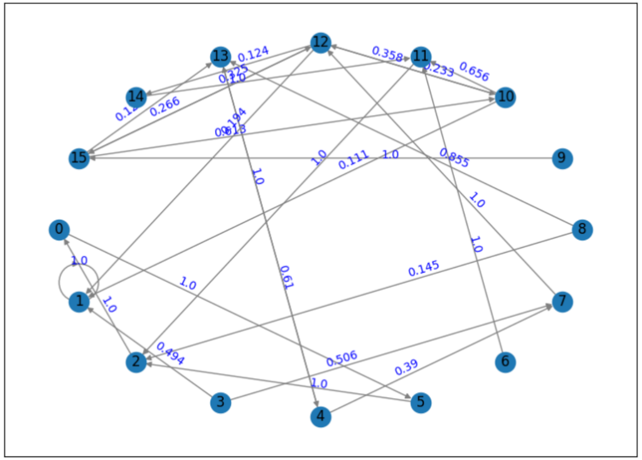
Nguyen Ngo Cong Thanh and Jacob L. Cybulski (2023): "Investigation of Barren Plateaus in Quantum Neural Network Development." Presented at *10th Int Congress on Industrial and Applied Mathematics* (ICIAM 2023), Waseda University, Tokyo, Japan, Poster 13568, August 20-25, 2023.

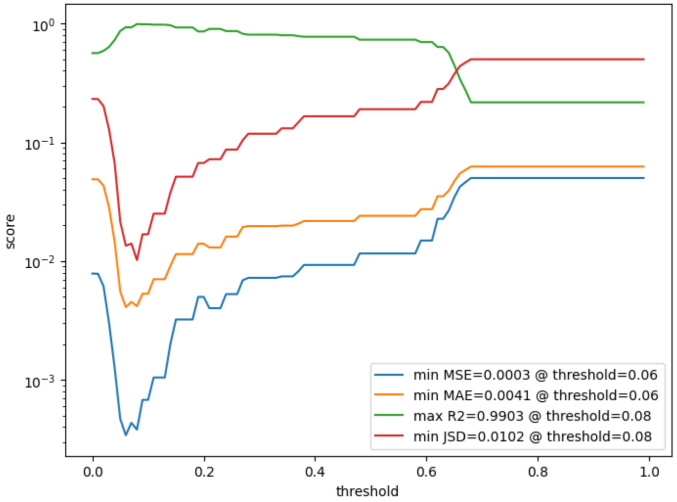
Current Work

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

Quantum Haiku by DeepSeek



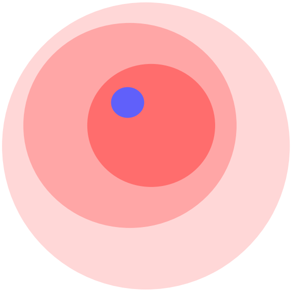




Quantum Graphs

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