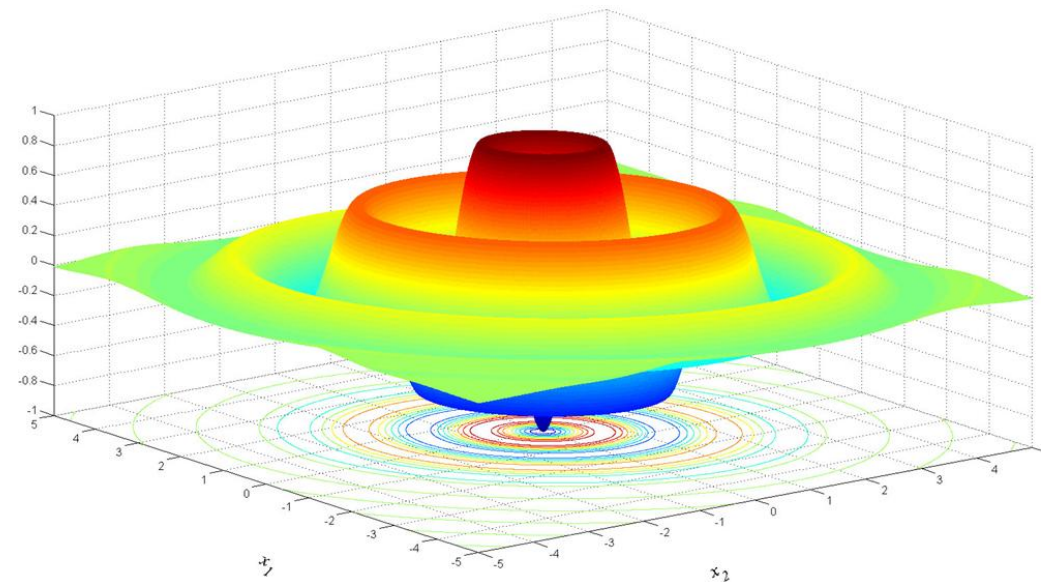


Leveraging Quantum Principles for Efficient Machine Learning

Jean Michel Sellier,
Senior AI Technology Leader,
Ericsson, Montreal, Canada

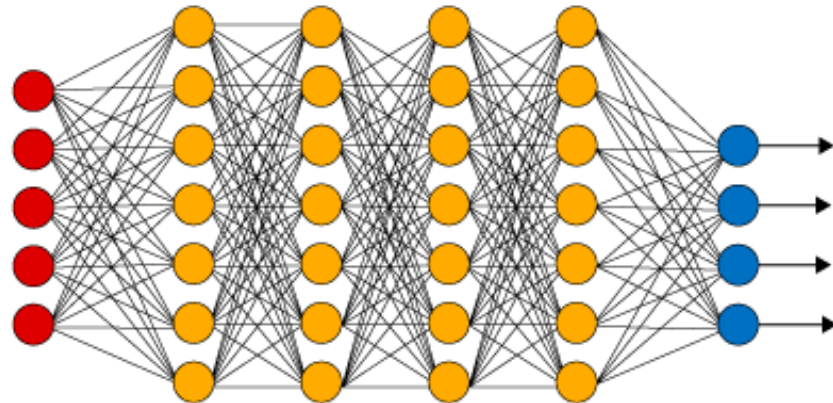
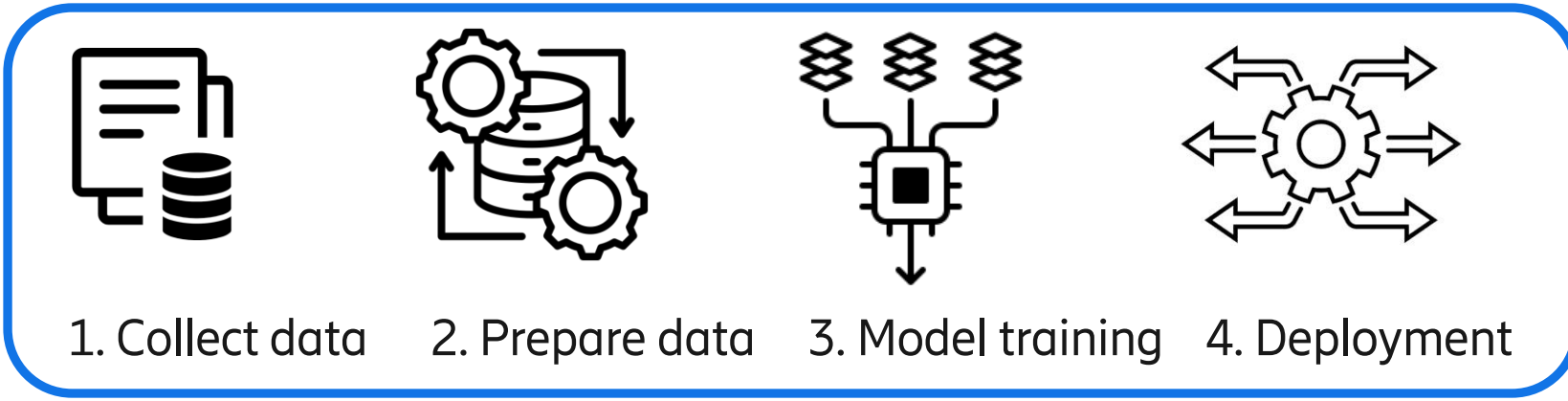
Agenda

- Quantum-inspired training methods,
- Selected computational advantages,
- Selected Telecom applications,
- Conclusions.

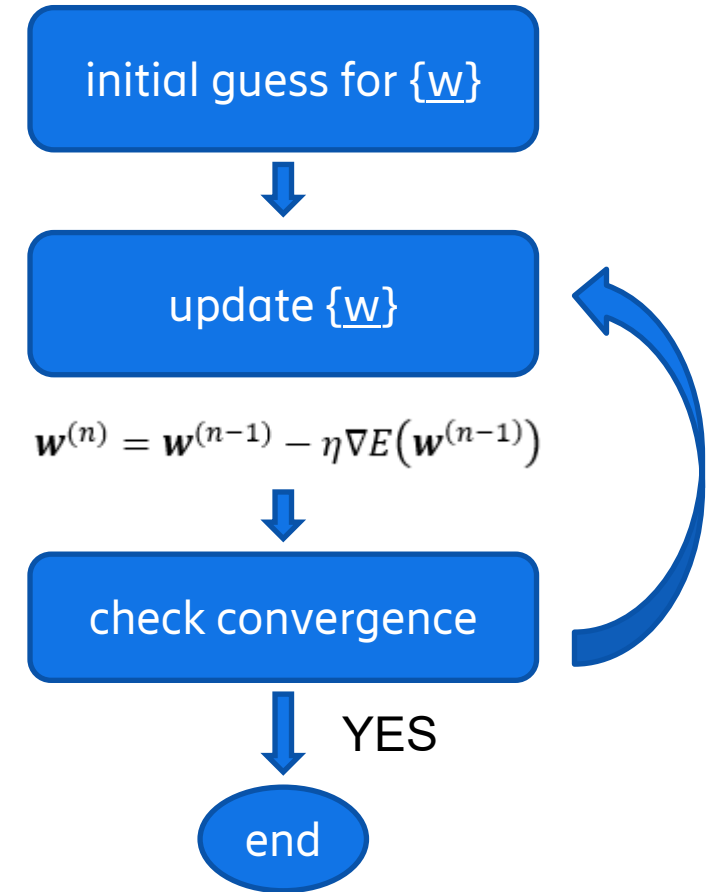


Quantum-inspired Training Methods

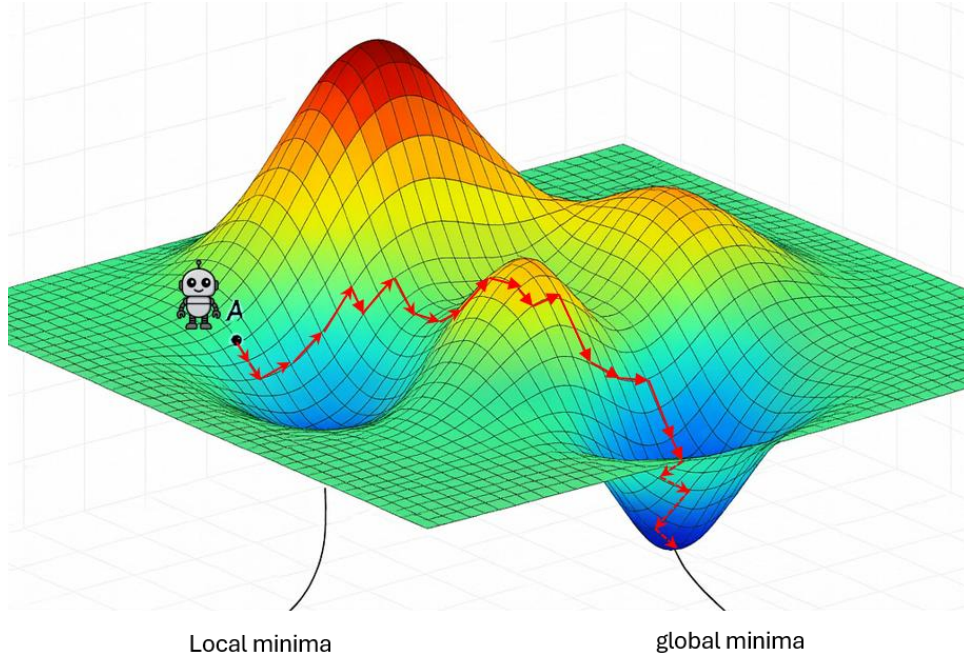
Main problem: training AI/ML models



Artificial Neural Networks: the value of hyper-parameters to be optimized is represented by weights and biases.



The quantum-inspired training method *



Strategy:
Physical systems evolve in a way which minimizes their total energy.

* J.M. Sellier, "On a quantum inspired approach to train machine learning models", Applied AI Letters, Wiley, (2023).

Gradient computation

Typical update rules

$$w_i^{n+1} = w_i^n - \lambda \nabla E(w_i^n)$$

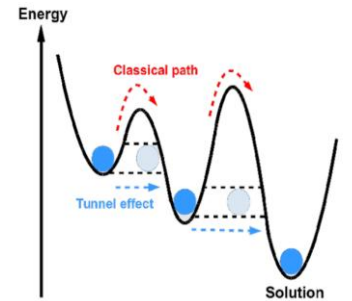


Function evaluation only

Quantum-inspired method**

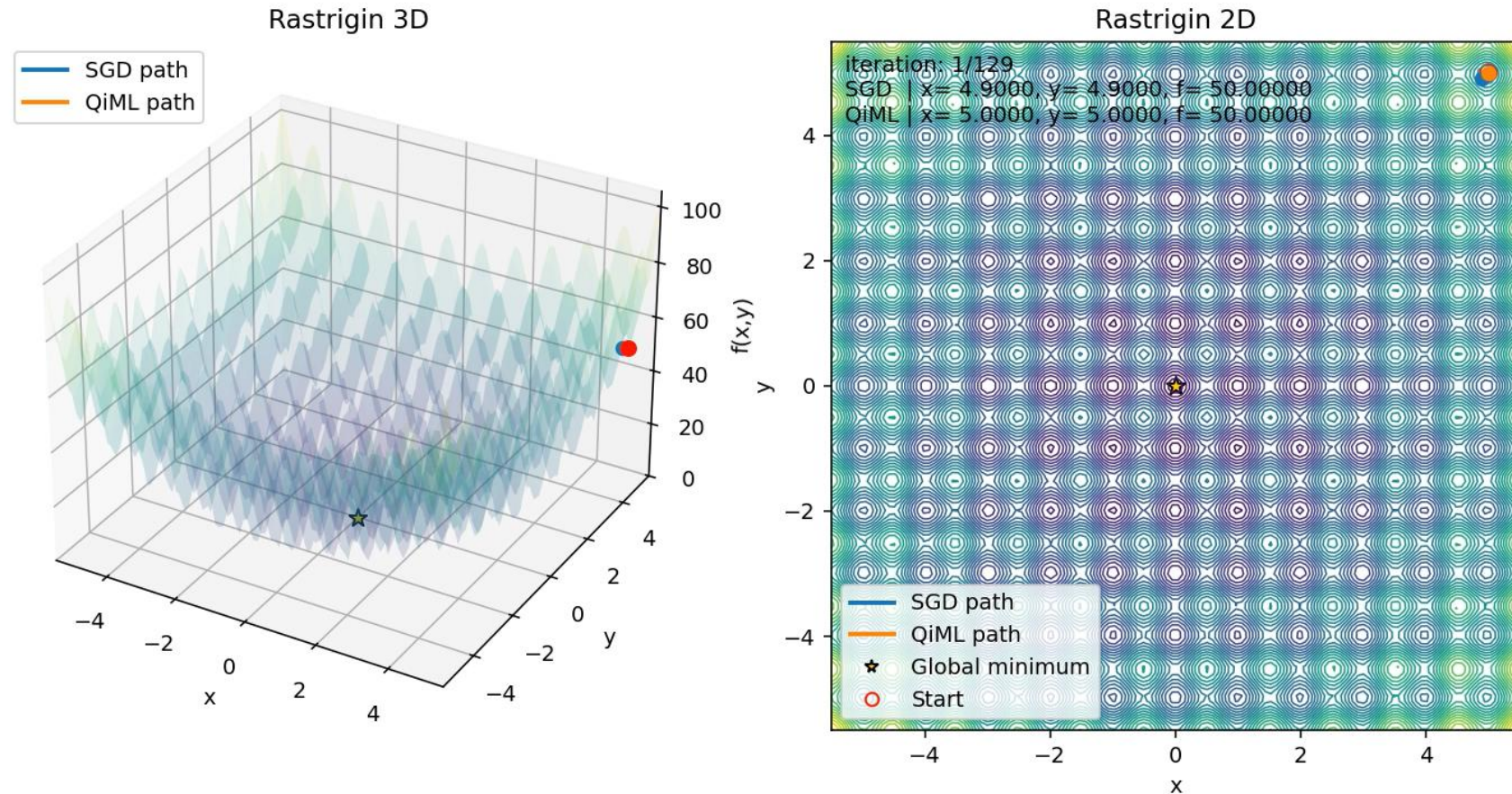
$$i\hbar \frac{\partial \Psi_i}{\partial t} = \left[-\frac{\hbar^2}{2m} \frac{\partial^2}{\partial x_i^2} - qE(W) \right] \Psi_i$$

$$E(W) = \frac{1}{N_s} \sum_{i=1}^{N_s} (y_i - Wx_i)^2$$



** we can use any available solver for the Schrödinger equation.

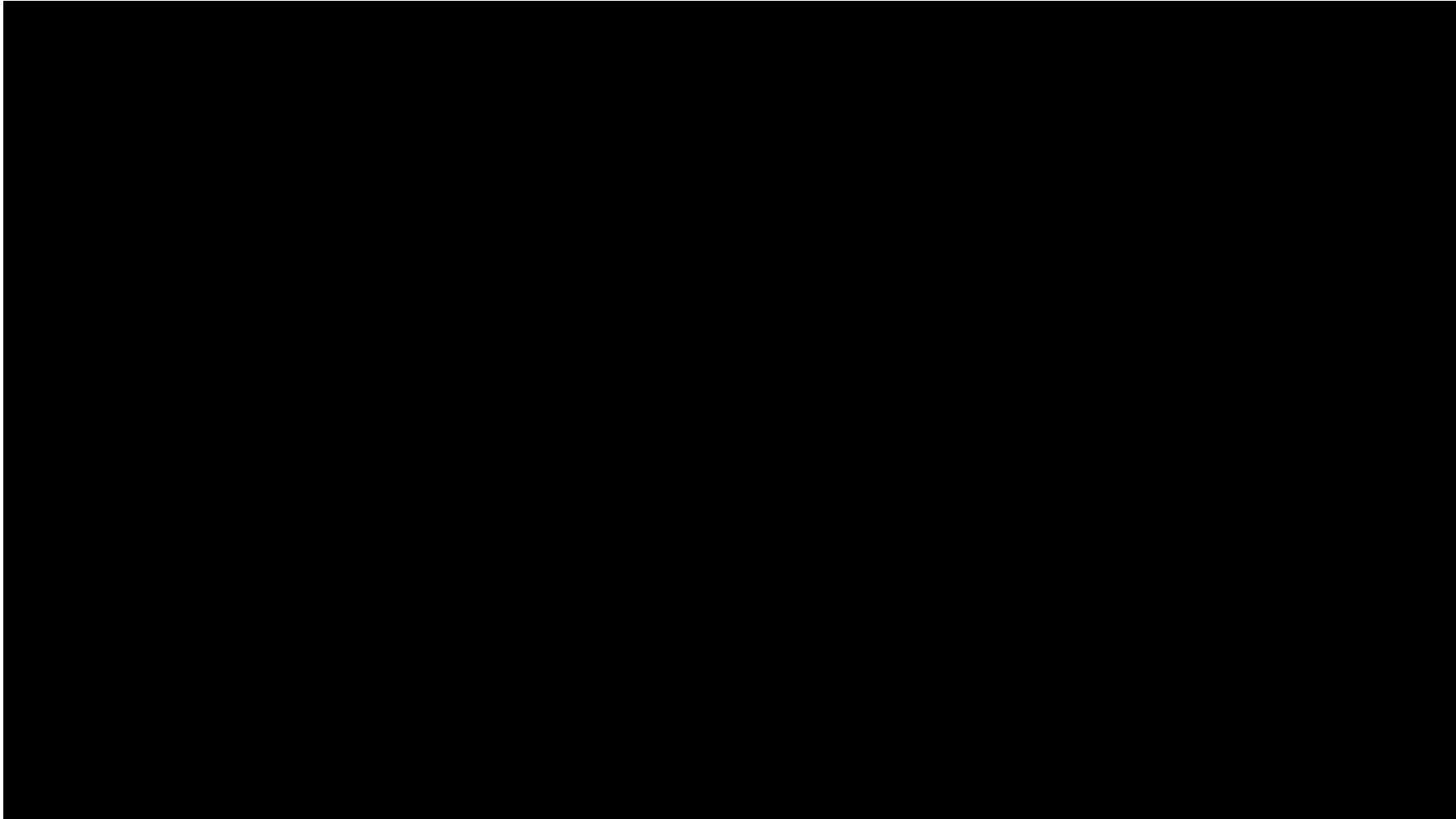
Quantum Tunneling and Convergence



Quantum tunneling provides a natural mechanism to escape local minima.

Selected Computational Advantages

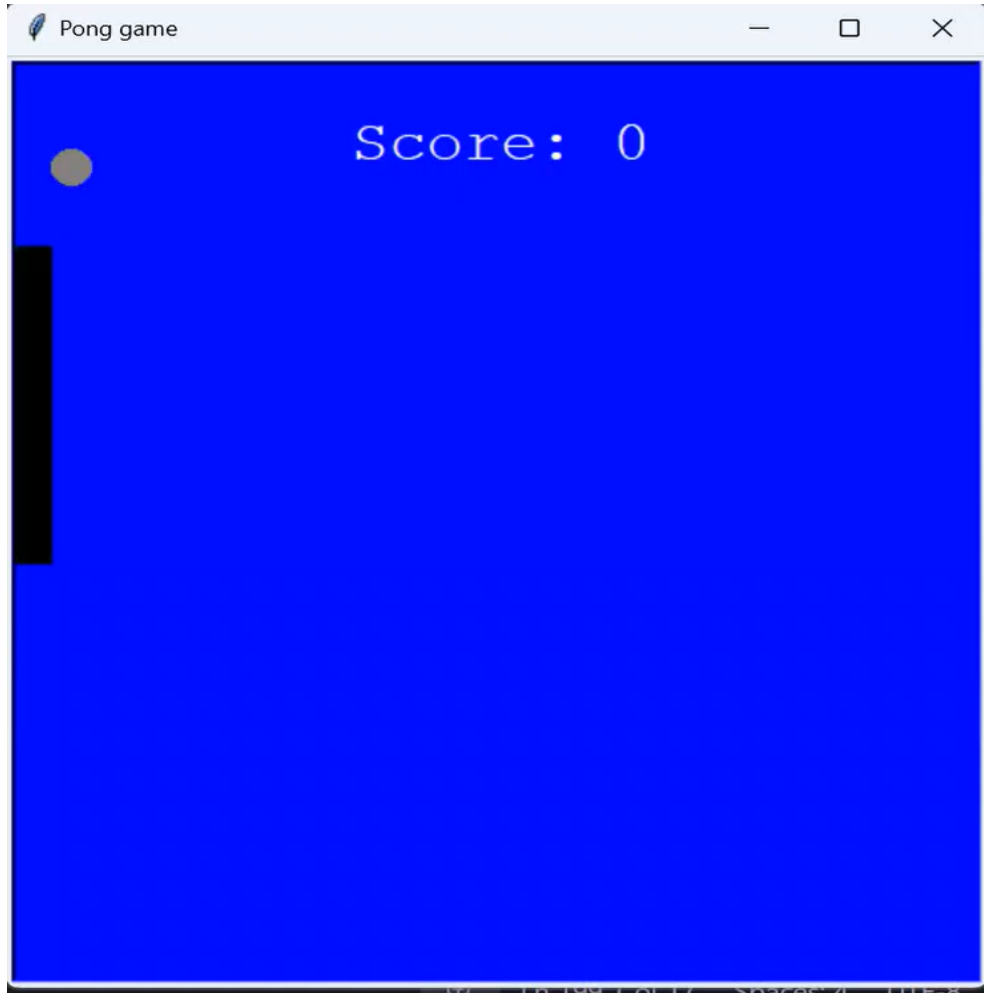
Compressed neural networks with Expressive activation functions



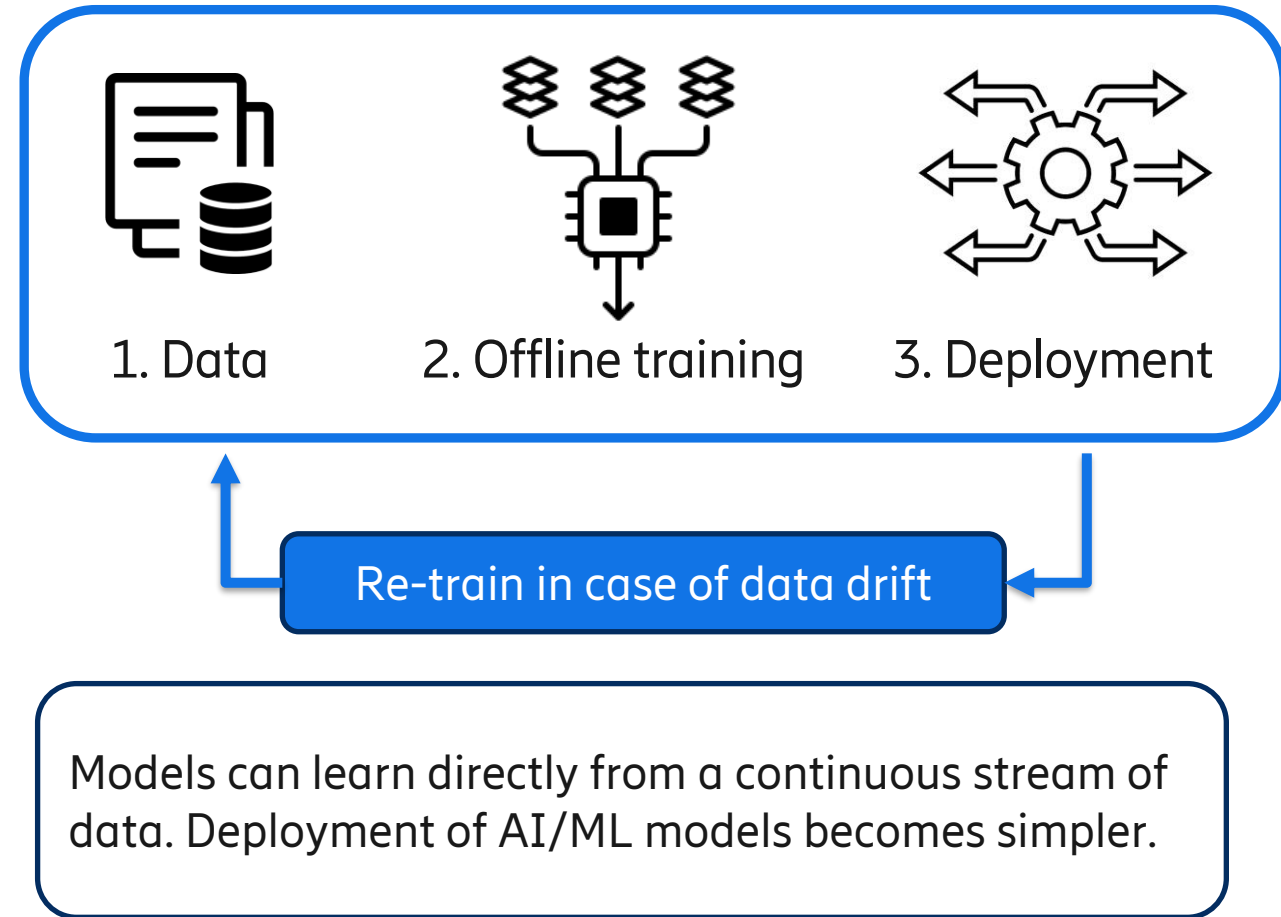
| | |
|--------------|----------|
| Year: | 1979 |
| Processor: | 6502 |
| Clock speed: | 1.79 MHz |
| RAM: | 35K |

Neural Network (<15K):
196 input neurons, 12 hidden
neurons (tanh), 8 neurons +
1 softmax, on MNIST.

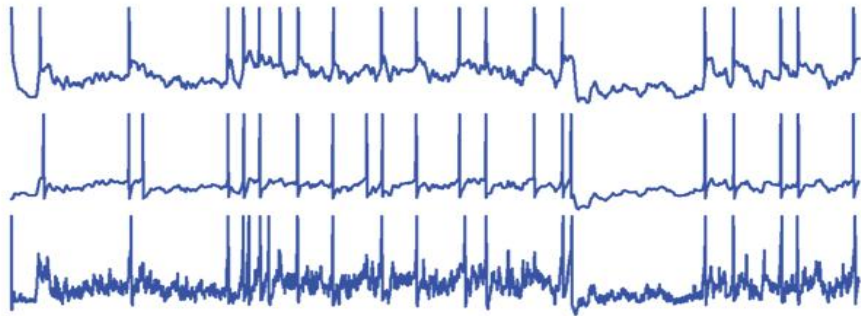
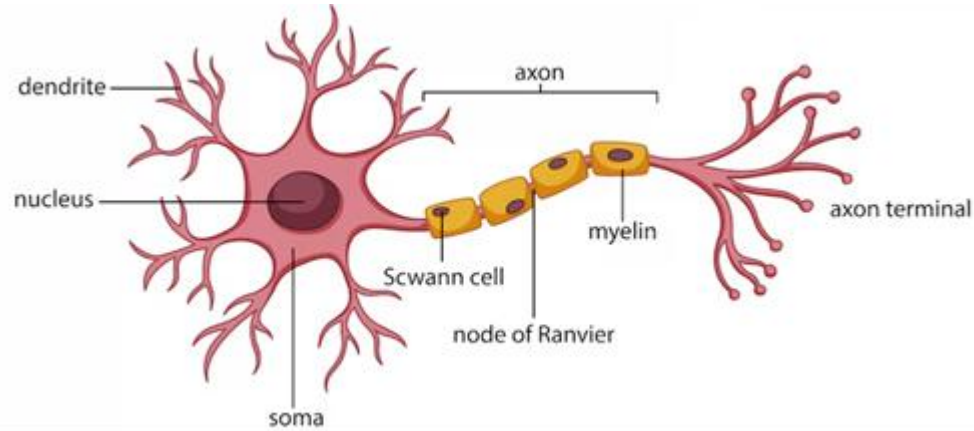
Online Learning and Data Drift



Offline deployment pipeline of a neural network



Spiking neurons and Temporal patterns



Main conclusions:

Spiking neural networks can be trained by QiML to reach high accuracies (not possible with mainstream methods).



1. Temporal pattern recognition
2. Accurate anomaly detection, and predictions for time series.

Selected Telecom Applications

Selected Telecom Applications

| Application | Description | Outcome |
|---|---|--|
| Antenna Tilting | 420,000 samples, 15 input features, 1 output feature | ADAM requires around 280 neurons, QiML uses only 6 neurons. |
| User allocation in sub-bands | Multi-objective optimization problem, tested on different number of users and/or channel conditions. Maximization of the total throughput. | GA, SA, and rnd. search methods fail when reaching a certain complexity threshold, while QiML continues to perform well. |
| Modulation and coding schemes selection | Comparison of distillation techniques with QiML. Data set with millions of samples are generated by an RL agent, 15 input features, 28 output features. | We have been able to drastically reduce 1) the training pipeline, 2) the dimensions of the ANNs in use. |

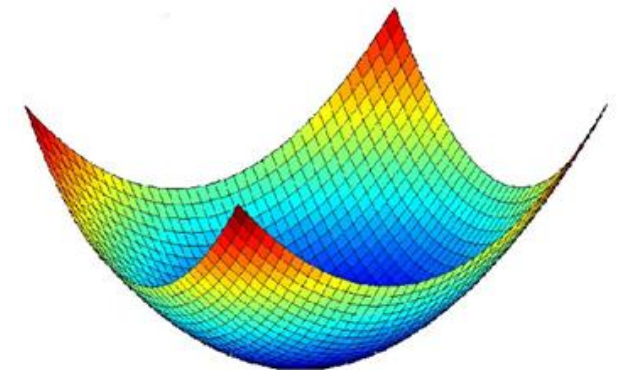
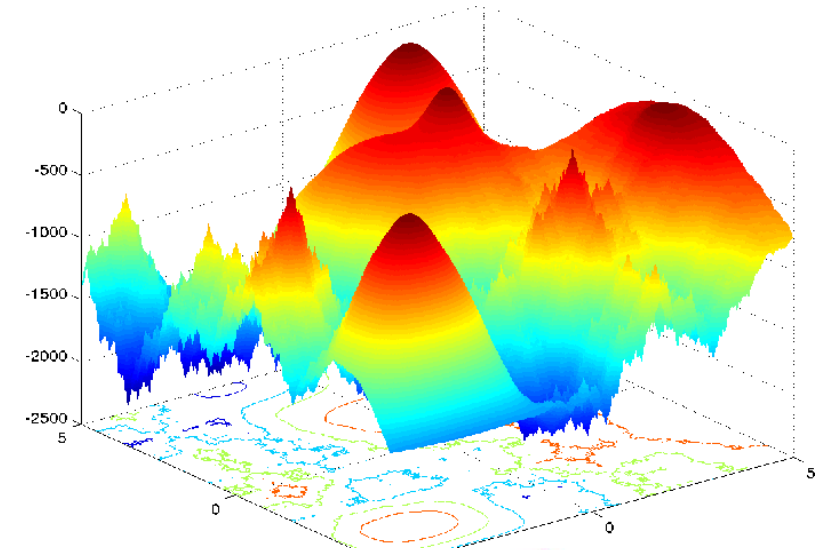
Conclusions

Conclusions

Quantum tunneling provides the following advantages:

- Explores the space of solutions without any need for gradient,
- Not limited to differentiable activation and/or loss functions,
- No dependence on initial guess,
- Non-convex problems can be solved.

Quantum-inspired methods are not useful in the presence of simple convex problems. In that case, the gradient can be exploited in a meaningful way using SGD.



Papers and Reports

1. J.M. Sellier, “Quantum-inspired machine learning”, Ericsson Technology Report, (2024).
2. J.M. Sellier, “Why you should be interested in quantum-inspired technologies?”, Ericsson Blog, (2024).
3. J.M. Sellier, “*On a quantum inspired approach to train machine learning models*”, Applied AI Letters, Wiley, (2023).
4. J.M. Sellier and A. Martini, “*On Training Spiking Neural Networks by Means of a Novel Quantum Inspired Machine Learning Method*”, Applied AI Letters, Wiley, (2025).
5. J.M. Sellier, “*A signed particle formulation of non-relativistic quantum mechanics*”, Journal of Computational Physics, Elsevier, (2015).

Thank You!

How to solve the Schrodinger equation efficiently?

- **Finite differences/elements:**
classical deterministic methods,
highly accurate for chemistry and physics purposes.
- **Signed particle formulation of quantum mechanics:**
stochastic method,
accuracy is to be fine tuned depending on the task at hand,
embarrassingly parallelizable.
- **Mesoscopic models:**
stochastic method,
accuracy is specialized for machine learning purposes,
highly parallelizable.

