Quantum Stack Future
Ed Kuijpers
New developments
QML theory
Practical Implementations
Ethics, Law and Social Aspects
Recap and discussion
Conclusion and further work
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Quantum Stack Future

Ed Kuijpers[1]

HBO-ICT Technical Computing

June 14, 2024

[1] e.a.kuijpers@hva.nl

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Recent developments and updates

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- Revolutionary qubit technology in Basel
- Pseudomagic quantum states
- New quantum technology
- Quantum communicationvia standard optic fiber Teleportation and noise
- Desktop quatum accelerator
- Scalable Majorana roadmap
- Quantum Gravity?

Topics not covered in detail

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- Physics of qubits and gates
- Software quality and standards
- Ethics, Law, Social Aspects, e.g. Ethics, Law and Social Aspects
- ML and Quantum Stack
- and much more (in the Netherlands alone already at least 600 people working in the field

Future of Digital Infrastructure event

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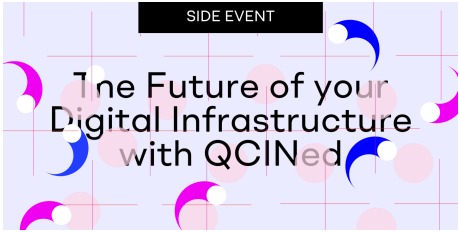
Future of quantum internet event part of Quantum meets 2024



New details QKD systems

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- Q-Bird next-generation Quantum Cryptography
- Quantum Industries
- 200-350 km on groundlinks, commercial products available

Quantum Optical computing

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- QuiX Quantum Photonic Quantum Computing
- reconfigurable interferometers with thermal control phase shifting(1 kHz range)

Mach-Zehnder interferometer

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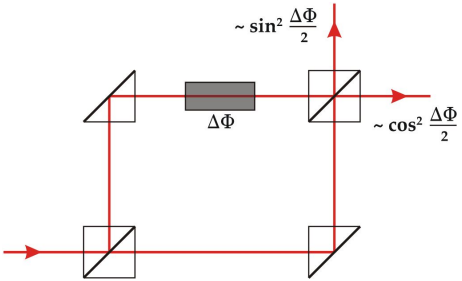

Quantum Network Explorer

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- Short workshop on QNE
- QuTech (P.o.C. Nico Seidler, A.V. Ravisankar)

Qruise

- Qruise
- Predictive models
- Development toolkit for accelerationo of quantum hardware

Software Engineering and Quantum Computing

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- Quantum software engineering: landscap and Horizons ([1])
- eScience Center guide
- Best practices ML software
- Five recommendations for FAIR software
- Victor Eijkhout's Art of High Performance Computing textbooks(includes parallel processing on supercomputers)

Software delivery projects

- Include library version, use "'pip freeze > requirements.txt"
- Document the python version used
- Include webreferences to datasets used
- Include introduction and reflectioin in Jupyter notebooks
- Provide installation instructions and demo to check proper installatiion
- Write software with reuse by other people in mind (Personal names not included in directory names)
- Include professional flavour(use of badges, markdown, CI/unit-testing, show validation on real-data next to testing)

Relevance quantum stack

1.) QML depending on underlying technology
2.) ML part of calibration and initialization
3.) Closely related to optimization

Relationship with architecture

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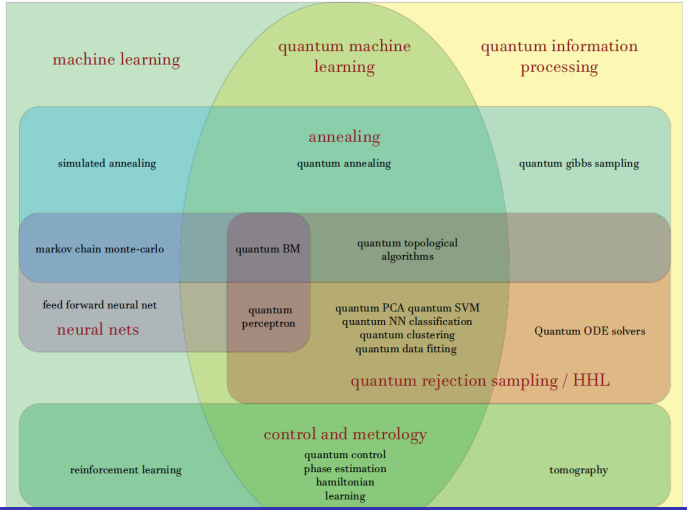
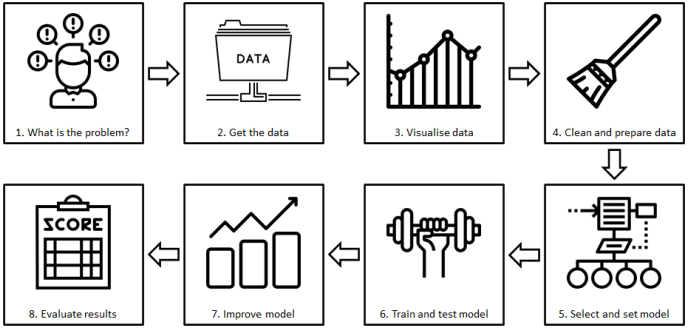


Classical Machine Learning steps



CRISP-DM = Cross-Industry Standard Process for Data Mining Model for classic machine learning

Classical and Quantm combination

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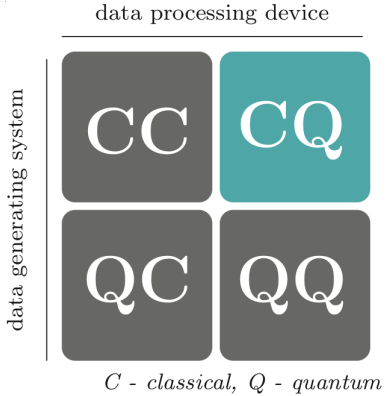

Multilayer Perceptron

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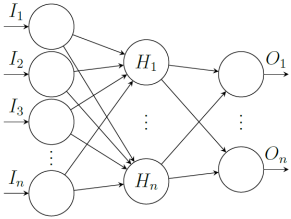
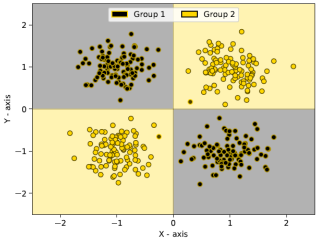
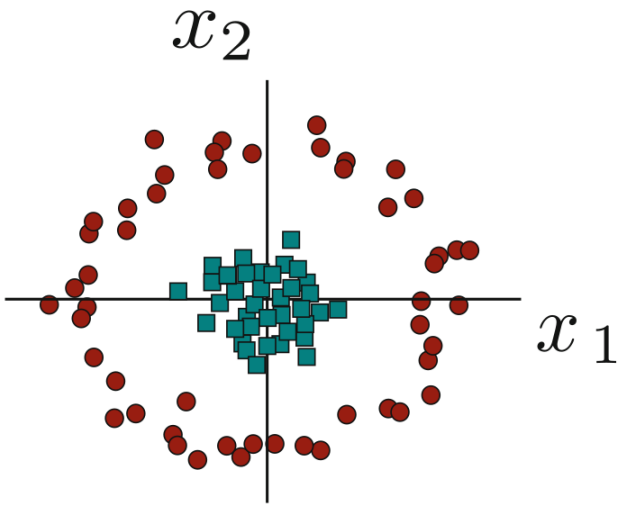


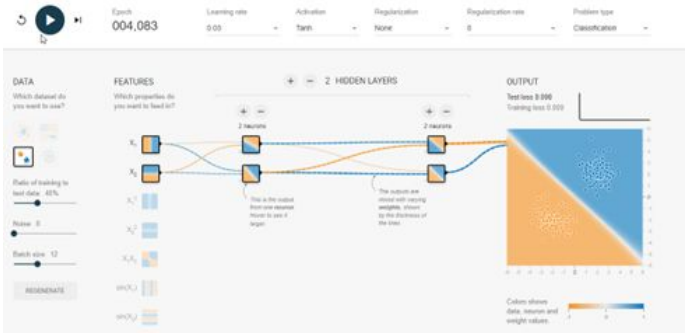


Need for non-linear



Playground introduction

See Tensoflow playground



Need for higher dimensions

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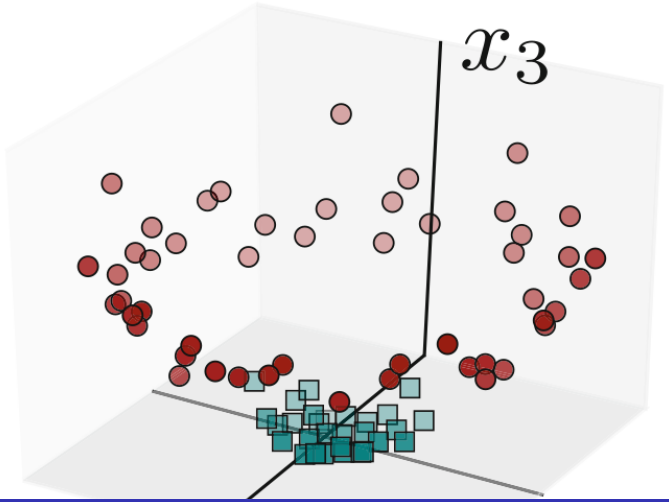
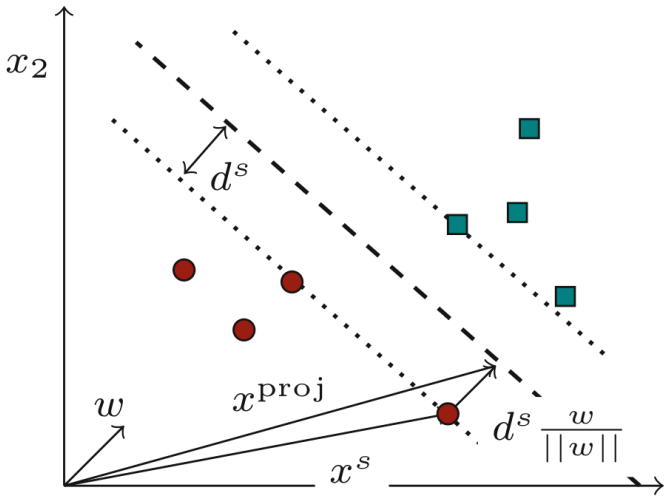


Support Vector Machinne SVM



Clustering, unsupervised learnning

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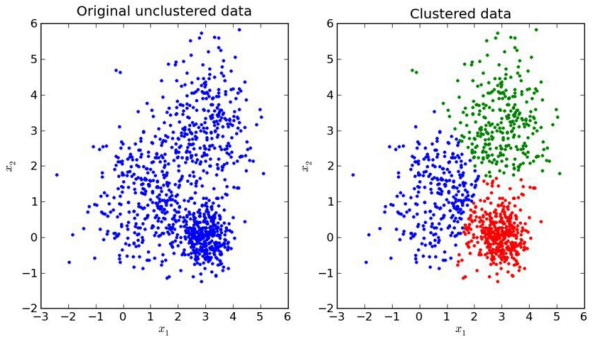
Unsupervised Learning



Pennylane I (2022)

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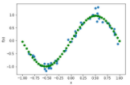
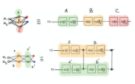
Quantum Generative Adversarial Networks with Cirq + TensorFlow



Function fitting with a photonic quantum neural network

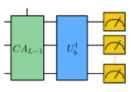


Data-reuploading classifier

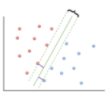
Quantum transfer learning

Quanvolutional Neural Networks

Variational Quantum Linear Solver



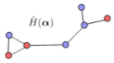
Coherent Variational Quantum Linear Solver



Multiclass margin classifier

Pennylane II

The Stochastic Parameter-Shift Rule

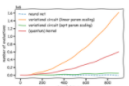


The Quantum Graph Recurrent Neural Network

Optimizing a quantum optical neural network

Quantum models as Fourier series

Quantum computation with neutral atoms



Kernel-based training of quantum models with scikit-learn

Learning to learn with quantum neural networks

Pennylane III

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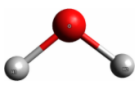
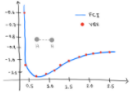
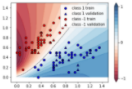


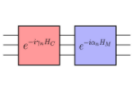
Quantum Chemistry with PennyLane



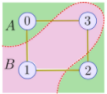
A brief overview of VQE



Variational classifier

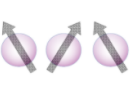


Intro to QAOA

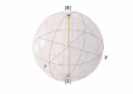


QAOA for MaxCut

Training a quantum circuit with PyTorch



3-qubit Ising model in PyTorch



PyTorch and noisy devices

Pennylane I (2024)

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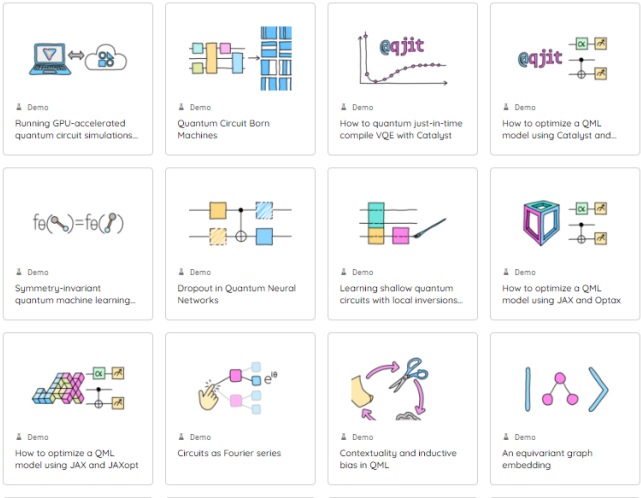
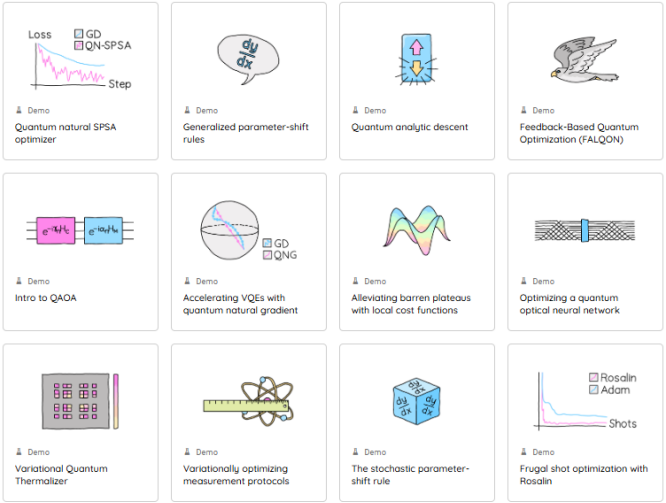
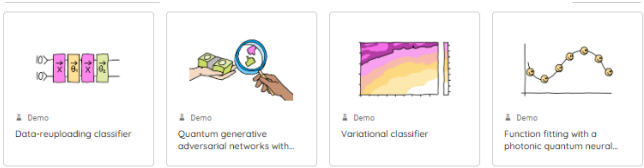


Pennylane II



Pennylane III



Which algorithms were implemented in projects of the ACQ minor and are not demos in Pennylane? (regression? Diffusion? GAN?)

Code optimization

- How to optimize python code? (numba JIT compiler, python compiler, etc.)
- How to develop Explainable models(XAI)?
- How to avoid bias?
- How to define performance metrics?
- How to select hardware and software platform?
- Relationships with optimization
- Etc.

Ethics, Law and Social Aspects

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- Society Application in Quantum Delta program (incl. White papers to learn from past AI)
- Ethics, Law and Social Aspects
- Netherlands AI coalition
- 17 Sustainable development goals
- Rules of conduct professinal organizations(ACM,IEEE)
- Philosophy

Recap and evaluation

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Conclusion

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- Lesson 1: Introduction topics
- Lesson 2: Programming Languages
- Lesson 3: Hardware, sensing
- Lesson 4: Transpiling and hardware
- Lesson 5: Information Theory
- Lesson 6: Quantum Internet and sensing
- Lessnn 7: Recent developments, QML and stack

Assessment

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- 18 June presentation
- reading paper and final grading after checks
- resit opportunity August

Conclusion

- Rapid developments for quantum computing
- AI algorithms currently more powerful than QML
- Many new developmets
- Many questions to be resolved

References I

[1] Jianjun Zhao. *Quantum Software Engineering: Landscapes and Horizons*. 2020. arXiv: 2007.07047 [cs.SE].