

- Quantum Stack Futur

New developments

QML theor

Practical Implementation

Ethics, Law and Social

Recap and discussion

Conclusion and further work

References

Quantum Stack Future

Ed Kuijpers¹

HBO-ICT Technical Computing

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¹e.a.kuijpers@hva.nl



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Recent developments and updates

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New developments

Described In

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Conclusion and furthei work

- 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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New developments

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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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New developments

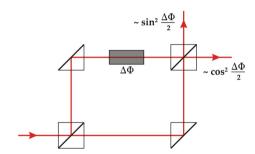
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Quantum Network Explorer

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



Qruise

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- 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

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Conclusion and further work

- 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 installation
- 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

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- 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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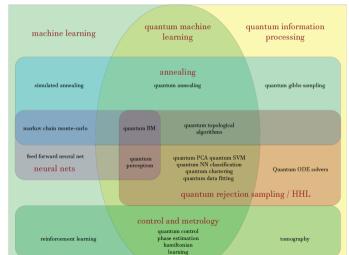
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Doforoncoc







Classical Machine Learning steps

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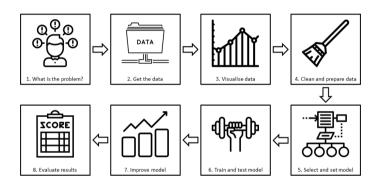
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CRISP-DM = Cross-Industry Standard Process for Data Mining Model for classic machine learning



Classical and Quantm combination

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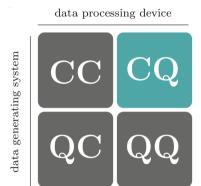
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C - classical, Q - quantum



Multilayer Perceptron

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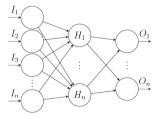
QML theory

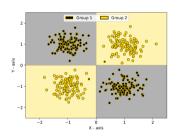
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Need for non-linear

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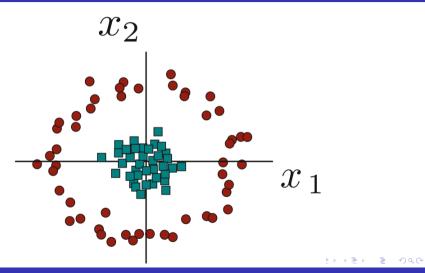
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Playground introduction

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See Tensoflow playground





Need for higher dimensions

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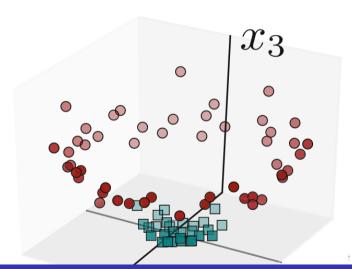
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Support Vector Machinne SVM

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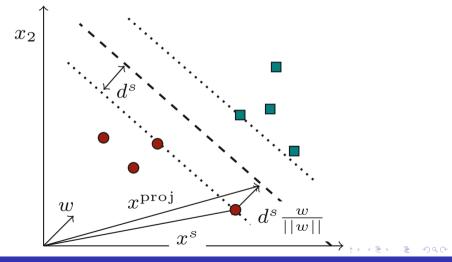
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Clustering, unsupervised learnning

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 $\mathsf{QML}\ \mathsf{theory}$

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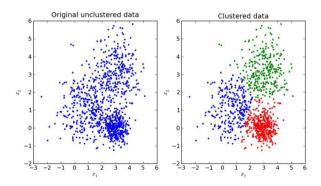
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Unsupervised Learning





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Quanvolutional Neural

Networks



Function fitting with a

photonic quantum

neural network



Data-reuploading

classifier





Quantum transfer learning



Multiclass margin classifier



Pennylane II

Practical Implementations



with neutral atoms



The Quantum Graph

Recurrent Neural

Network

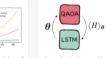




Optimizing a quantum optical neural network







Learning to learn with quantum neural networks



Pennylane III

Practical Implementations





A brief overview of VOE



Variational classifier



Intro to OAOA



OAOA for MaxCut



Training a quantum circuit with PvTorch



3-qubit Ising model in PyTorch



PyTorch and noisy devices



Pennylane I (2024)

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∆ Demo

Running GPU-accelerated quantum circuit simulations...



ă Demo

Quantum Circuit Born Machines



∆ Demo

How to quantum just-in-time compile VQE with Catalyst



∆ Demo

How to optimize a QML model using Catalyst and...



∆ Demo

Symmetry-invariant quantum machine learning...



Ă Demo

Dropout in Quantum Neural Networks



▲ Demo

Learning shallow quantum circuits with local inversions...



▲ Demo

How to optimize a QML model using JAX and Optax



□ Demo
 How to optimize a QML model using JAX and JAXopt



A Demo Circuits as Fourier series



A Demo

Contextuality and inductive bias in QML



Demo
 An equivariant graph embedding





Pennylane II

Practical Implementations



∆ Demo

Quantum natural SPSA optimizer



△ Demo

Generalized parameter-shift rules



△ Demo

Quantum analutic descent



∆ Demo

Feedback-Based Ougntum Optimization (FALOON)



 ■ Demo Intro to QAOA



Accelerating VQEs with quantum natural gradient



A Demo

Alleviating barren plateaus with local cost functions



A Demo

Optimizing a quantum optical neural network



A Demo

Variational Quantum Thermalizer



∆ Demo

Variationally optimizing measurement protocols



□ Demo

The stochastic parametershift rule



A Demo

Frugal shot optimization with Rosalin





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



Code optimization

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- 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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References

• 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

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



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References

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