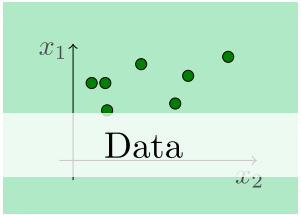
Quantum Machine Learning

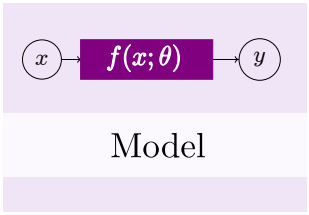
Maria Schuld, Xanadu

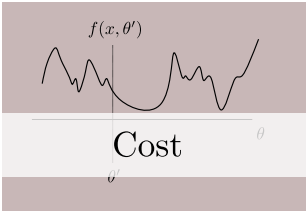
Hackaday Meetup, October 2020

XANADU

Machine Learning

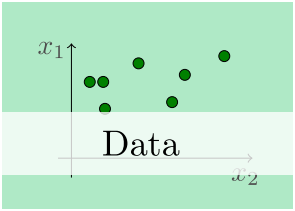


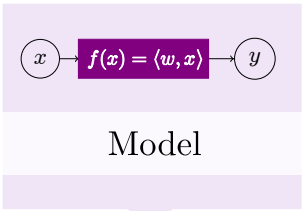


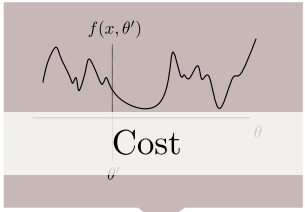


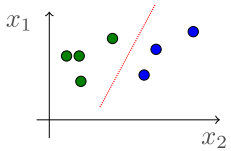
Use data samples
to construct model
that minimises cost
on unseen data.

Linear models

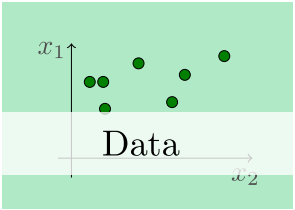


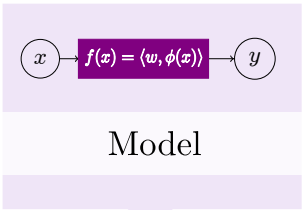


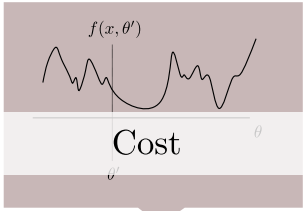


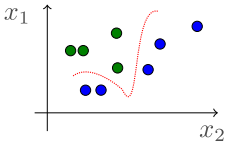


Kernel methods









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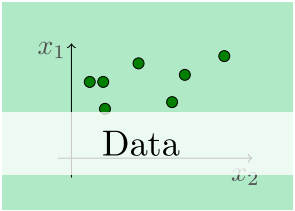
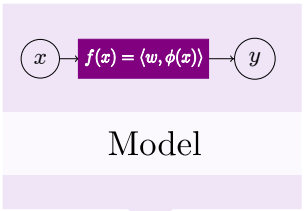
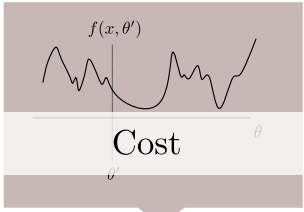
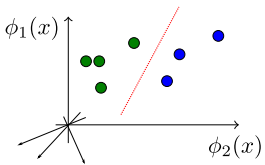
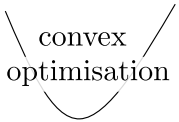


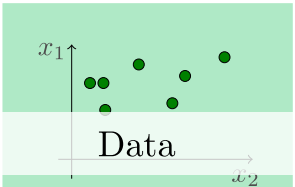


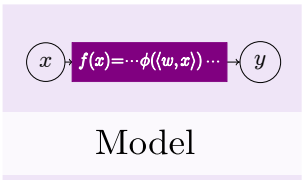


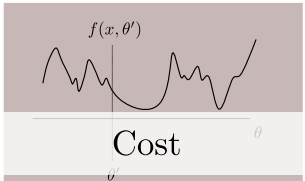




Deep learning

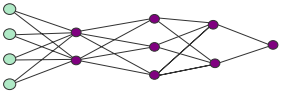






Big

Composable & differentiable



nonconvex optimisation

- gradient descent
- high performance hardware
- special purpose software

How could quantum computing help?

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  - use fewer data samples (Arunachalam 1701.06806)
  - process “quantum data“ (folklore)

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  - speed up optimisation (Wiebe et al. 1204.5242, Rebentrost et al. 1307.0471, Denil & Freitas ~ 2012 `cs.ubc.ca/~nando/`)
  - find better solutions (?)

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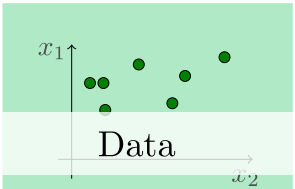
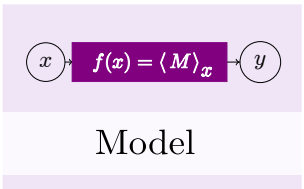
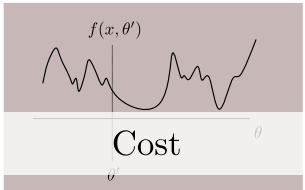
  - find better solutions (?)
- Model
  - speed up existing models (Pararo et al. 1401.4997, Low et al. 1402.7359, Allcock et al. 1812.03089)
  - design new models (Amin et al. 1601.02036, Benedetti et al. 1906.07682)

We can train quantum circuits like neural nets.







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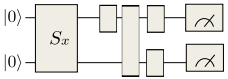

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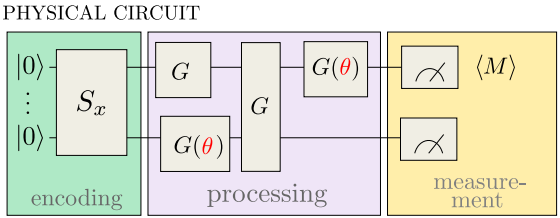
Variational circuits as composable & differentiable models.

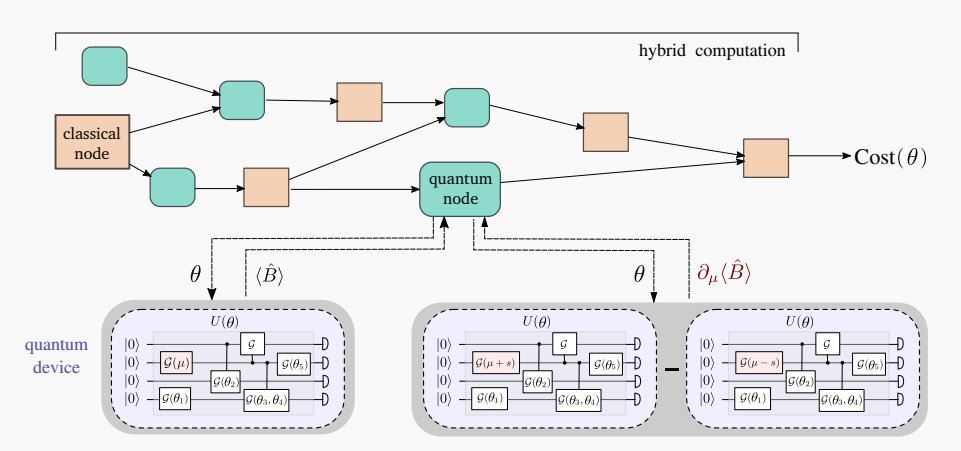


MATHEMATICAL DESCRIPTION

$$10 \quad s^*_{ji}(x) \quad g^*_{ji} \quad \cdots \quad g^*_{ji}(\theta) \quad M \quad g_{ji}(\theta) \quad \cdots \quad g_{ji} \quad s_{ij}(x) \quad \begin{matrix}1\\0\end{matrix}$$

Farhi & Neven 1802.06002, Schuld et al. 1804.00633

Variational circuits as composable & differentiable models.



Guerreschi & Smelyanskiy 1701.01450, Mitarai et al. 1803.00745, Schuld et al. 1811.11184

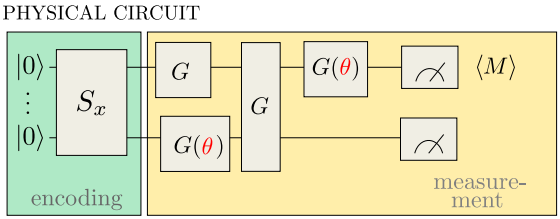
Variational circuits as composable & differentiable models.

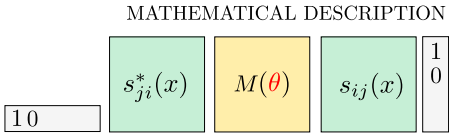
```python
import torch
from torch.autograd import Variable

data = torch.tensor([(0., 0.), (0.1, 0.1), (0.2, 0.2)])



def model(phi, x=None):
    return x*phi



def loss(a, b):
    return torch.abs(a - b) ** 2

def av_loss(phi):
    c = 0
    for x, y in data:
        c += loss(model(phi, x=x), y)
    return c

phi_ = Variable(torch.tensor(0.1), requires_grad=True)
opt = torch.optim.Adam([phi_], lr=0.02)

for i in range(5):
    l = av_loss(phi_)
    l.backward()
    opt.step()
```

```python
from pennylane import *
import torch
from torch.autograd import Variable

data = [(0., 0.), (0.1, 0.1), (0.2, 0.2)]

dev = device('default.qubit', wires=2)

@qnode(dev, interface='torch')
def circuit(phi, x=None):
    templates.AngleEmbedding(features=[x], wires=[0])
    templates.BasicEntanglerLayers(weights=phi, wires=[0, 1])
    return expval(PauliZ(wires=[1]))

def loss(a, b):
    return torch.abs(a - b) ** 2

def av_loss(phi):
    c = 0
    for x, y in data:
        c += loss(circuit(phi, x=x), y)
    return c

phi_ = Variable(torch.tensor([[0.1, 0.2],[-0.5, 0.1]]), requires_grad=True)
opt = torch.optim.Adam([phi_], lr=0.02)

for i in range(5):
    l = av_loss(phi_)
    l.backward()
    opt.step()
```

pennylane.ai

Quantum models are similar to kernel methods.





Schuld & Killoran 1803.07128, Havlicek et al. 1804.11326, Lloyd et al. 2001.03622

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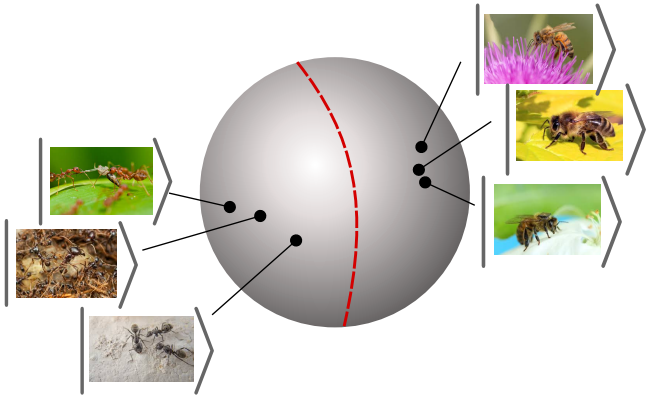

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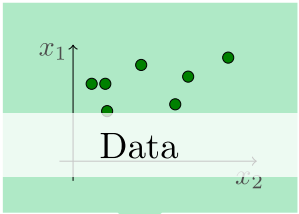

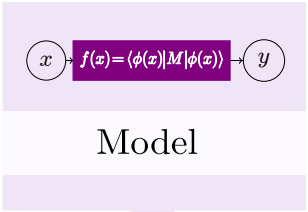

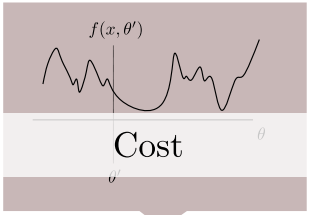

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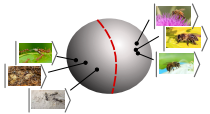

nonconvex optimisation

OR

convex optimisation

Thank you!

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