Cirq Quantum Framework

Masters of Advanced Cybersecurity,
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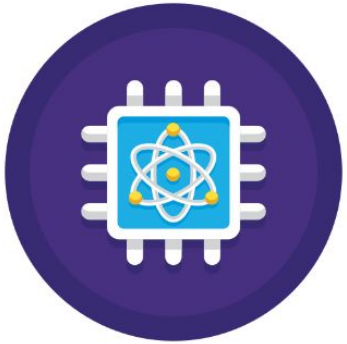
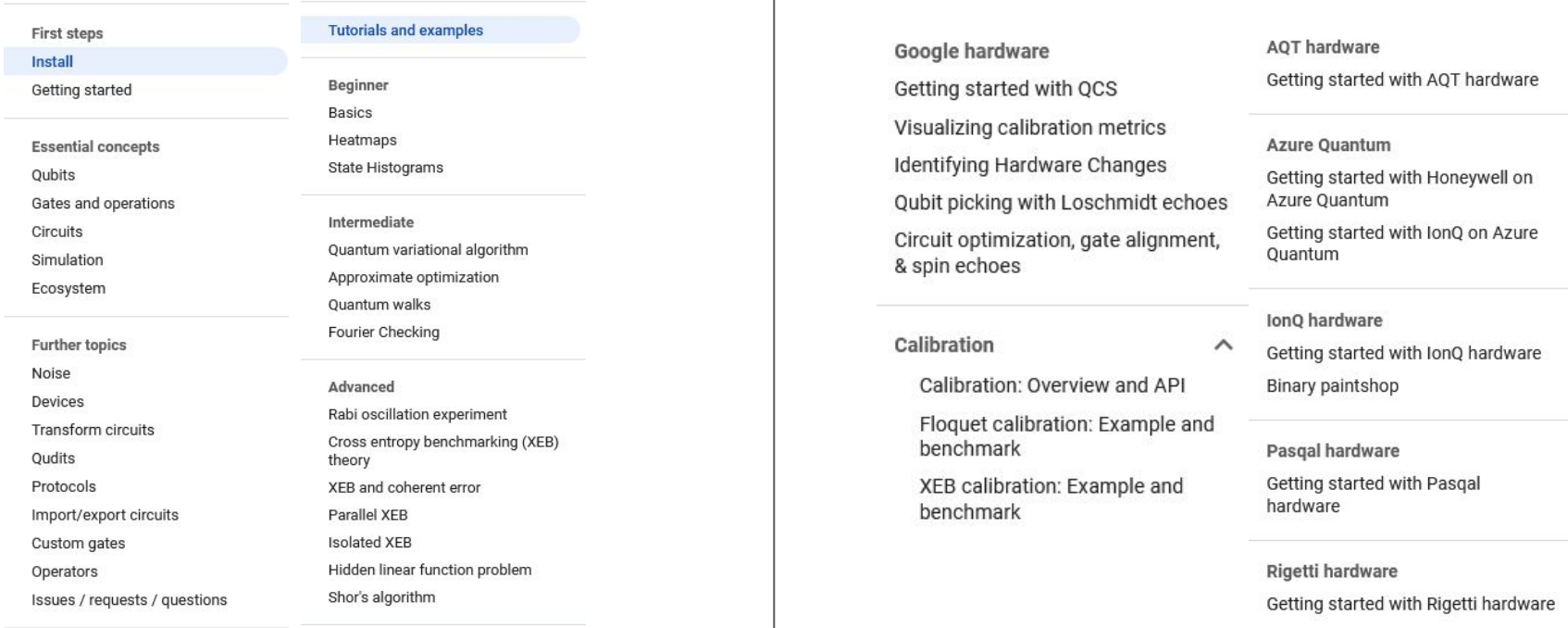
Google + 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Getting started with IonQ hardware
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Pasqal hardware
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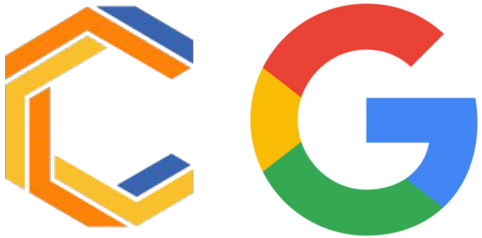
Rigetti hardware
Getting started with Rigetti hardware

- Qubits on a grid
- Measurements really slow
- Measurements only at the end
- Limited set of gates
- Limited at ~400ms long circuits
- Limited qubits for real world-compatible circuits (23q/54q/72q)



Overview

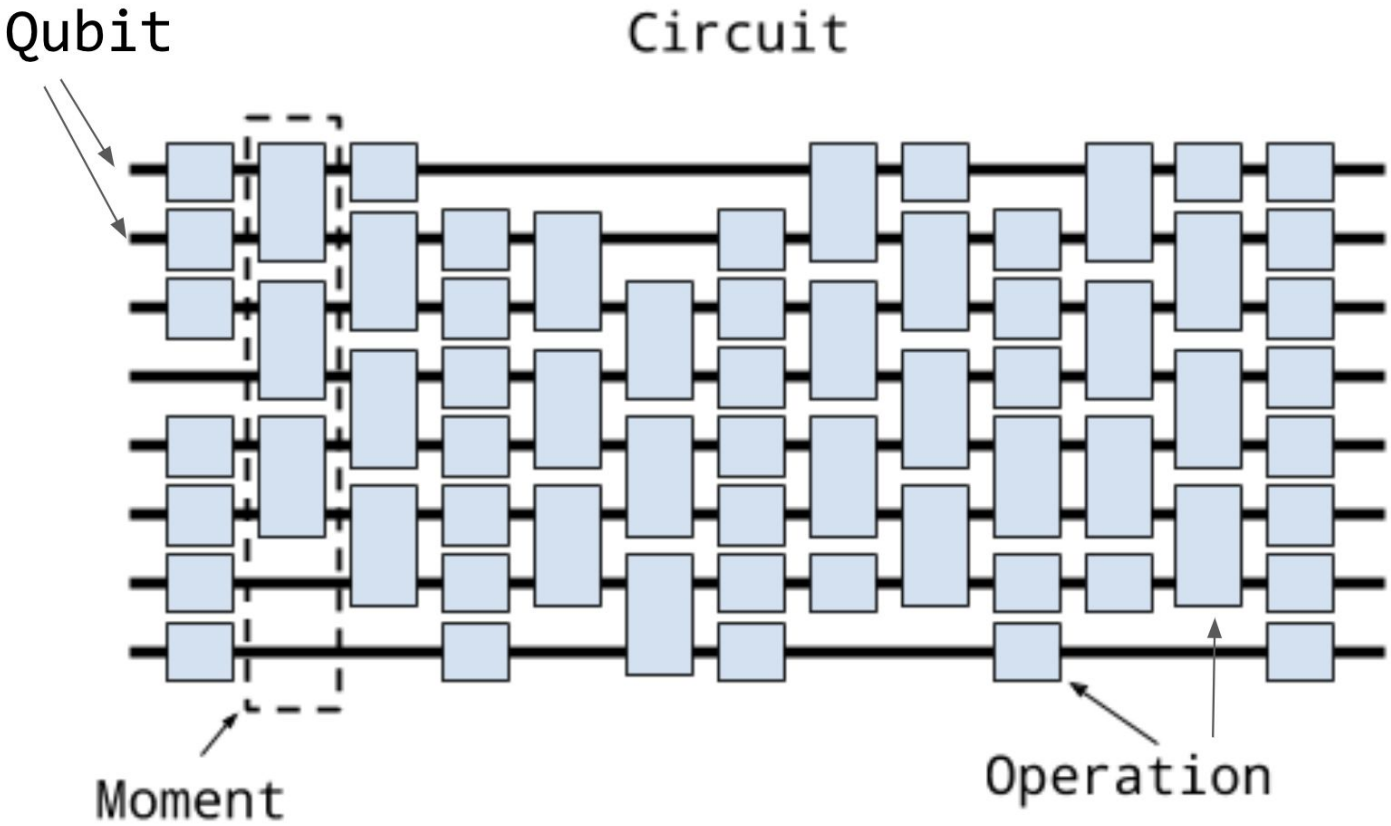
ID	Title	Path	Type
0	Cirq Setup	0-setup	Setup
1	Basic Quantum gates	1-gates	Basic
2	Superdense-Coding Implementation	2-superdense	Intermediate
3	Deutsch Implementation	3-deutsch	Intermediate
4	Quantum Linear Equation Solving	4-hhl	Advanced
5	Quantum MNIST Classification	5-mnist	Advanced
6	Cirq-Specific Tools	6-bonus	Bonus

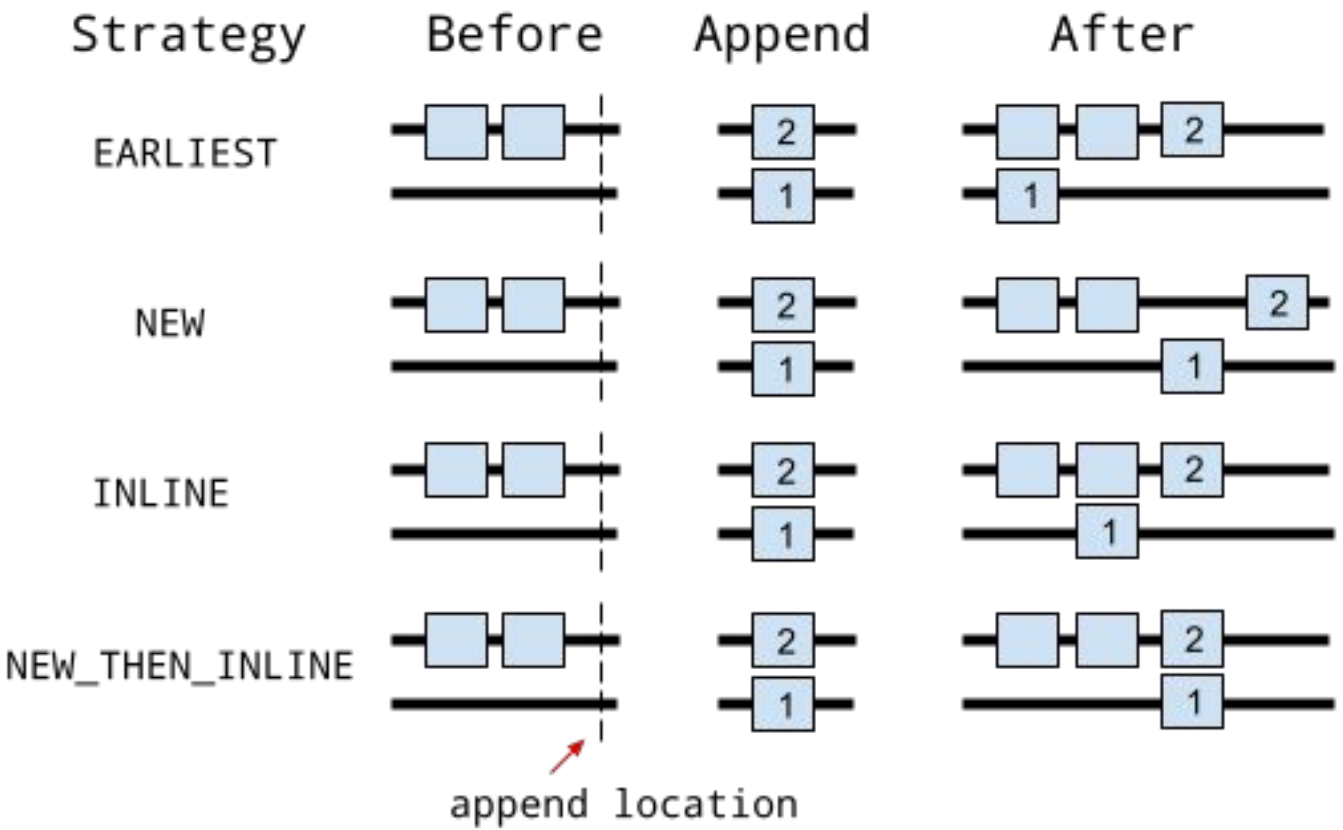
0. Cirq Setup

Everything starts with Github: https://github.com/craciunoiuc/IQC-lab-presentation

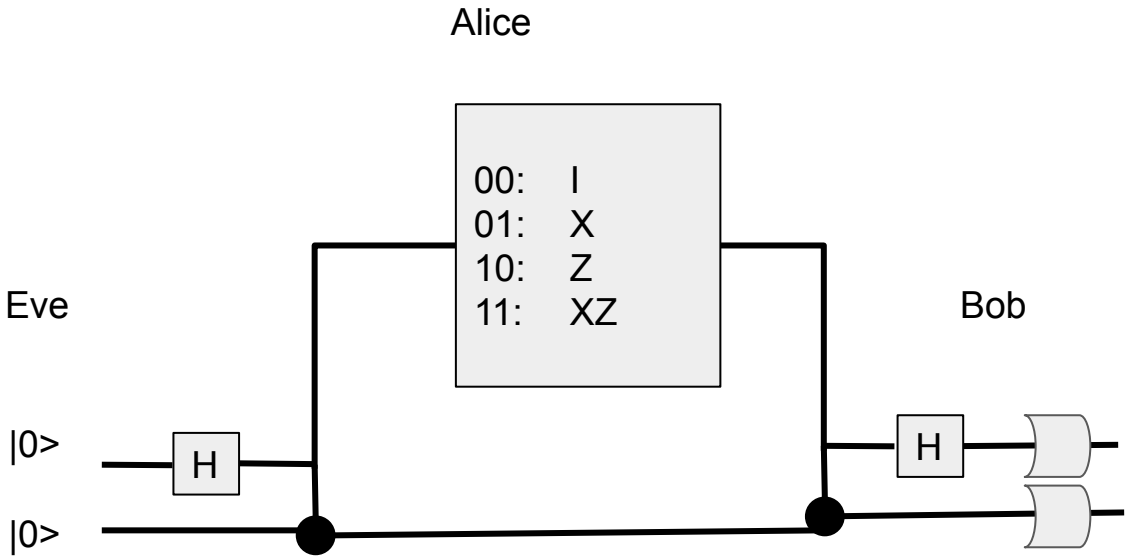
Clone the repository and let the fun begin!

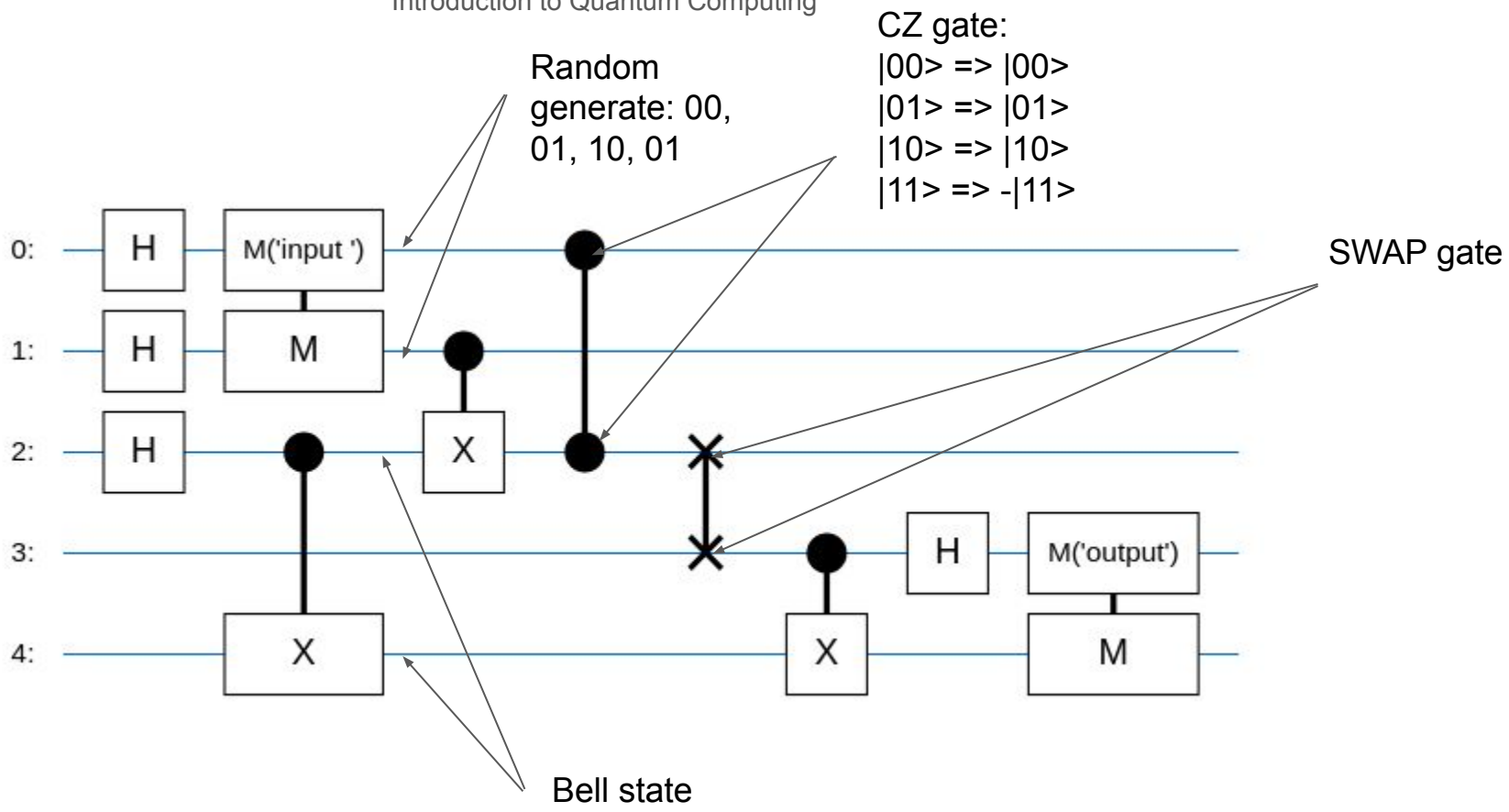
1. Basic Code In Cirq

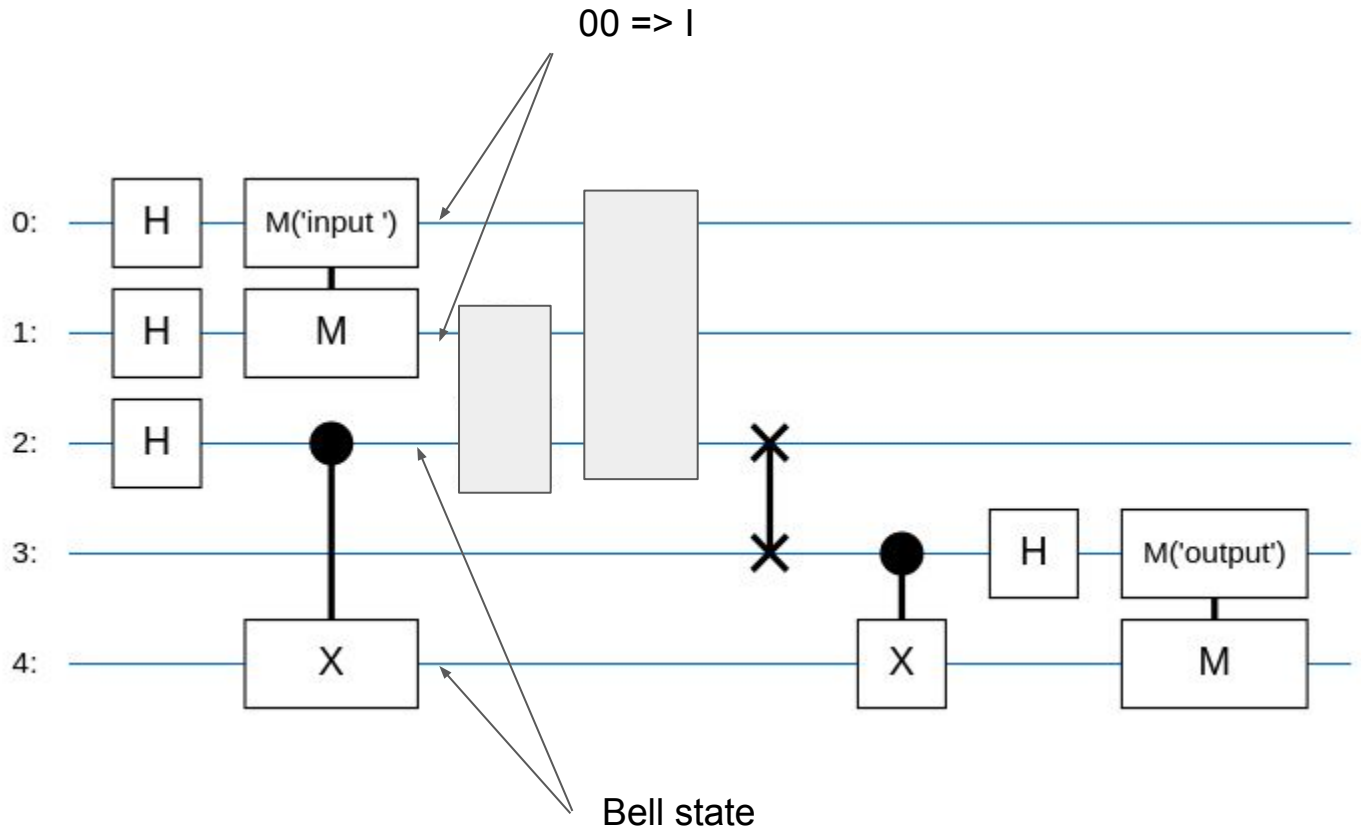

Qubit
Circuit
Moment
Operation

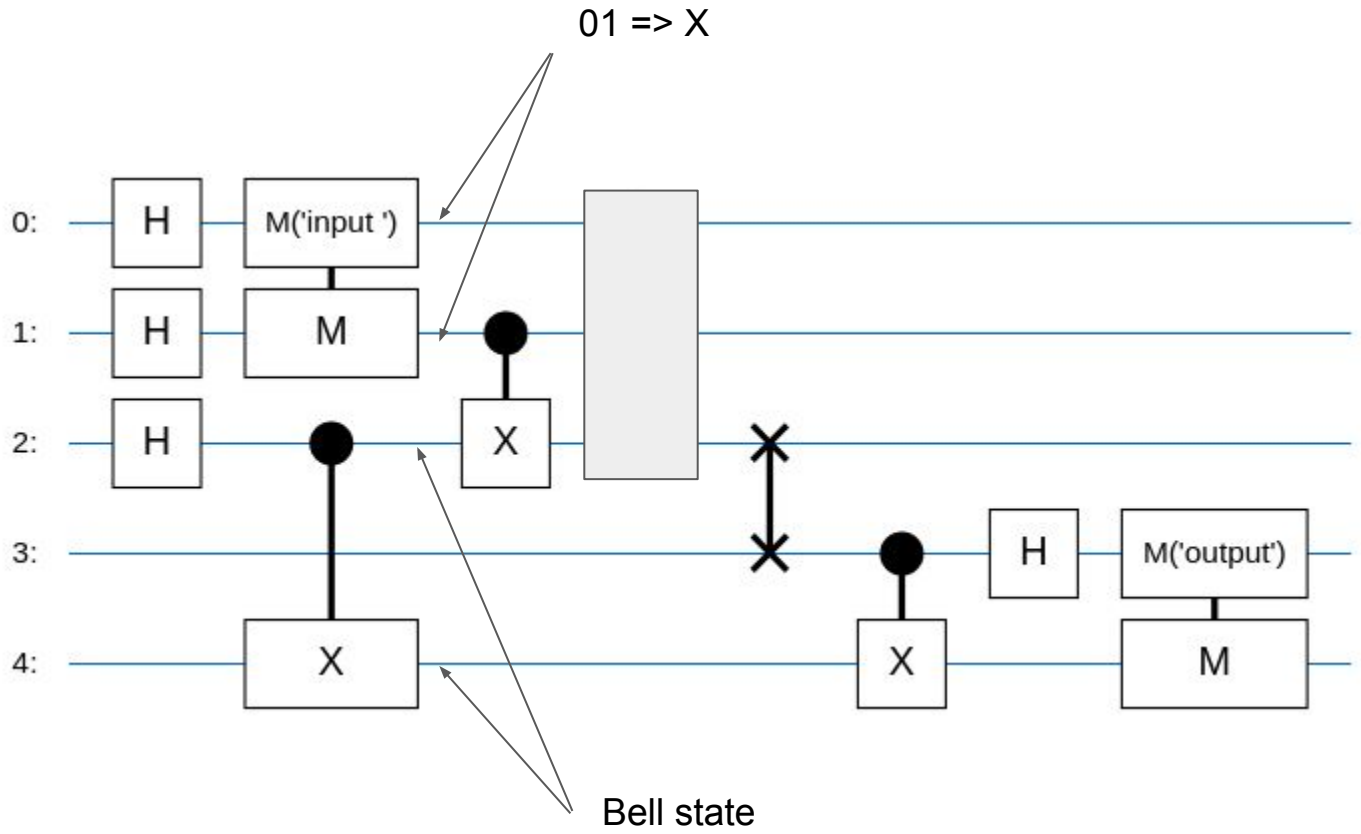

Strategy
Before
Append
After
EARLIEST
NEW
INLINE
NEW_THEN_INLINE
2
1
append location

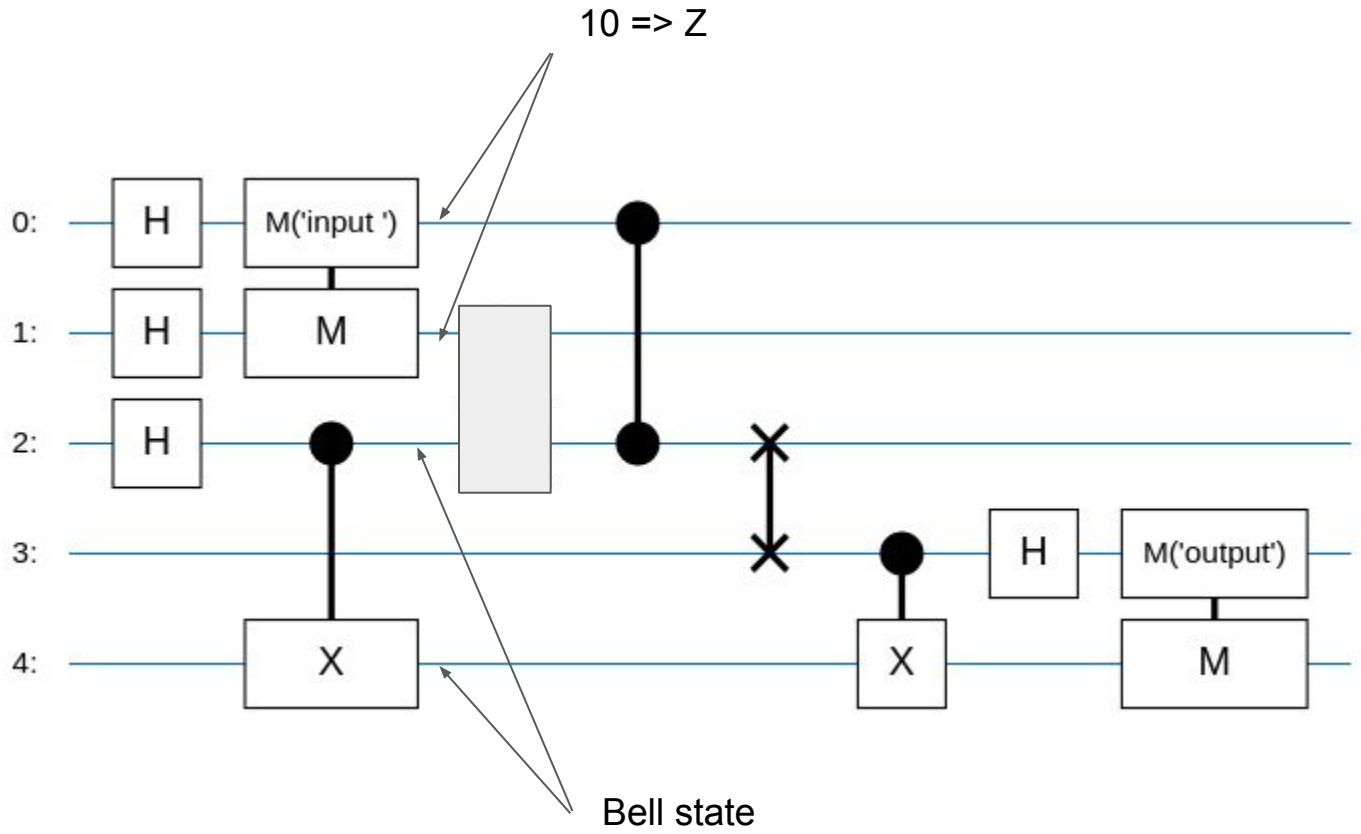
2. Superdense Coding

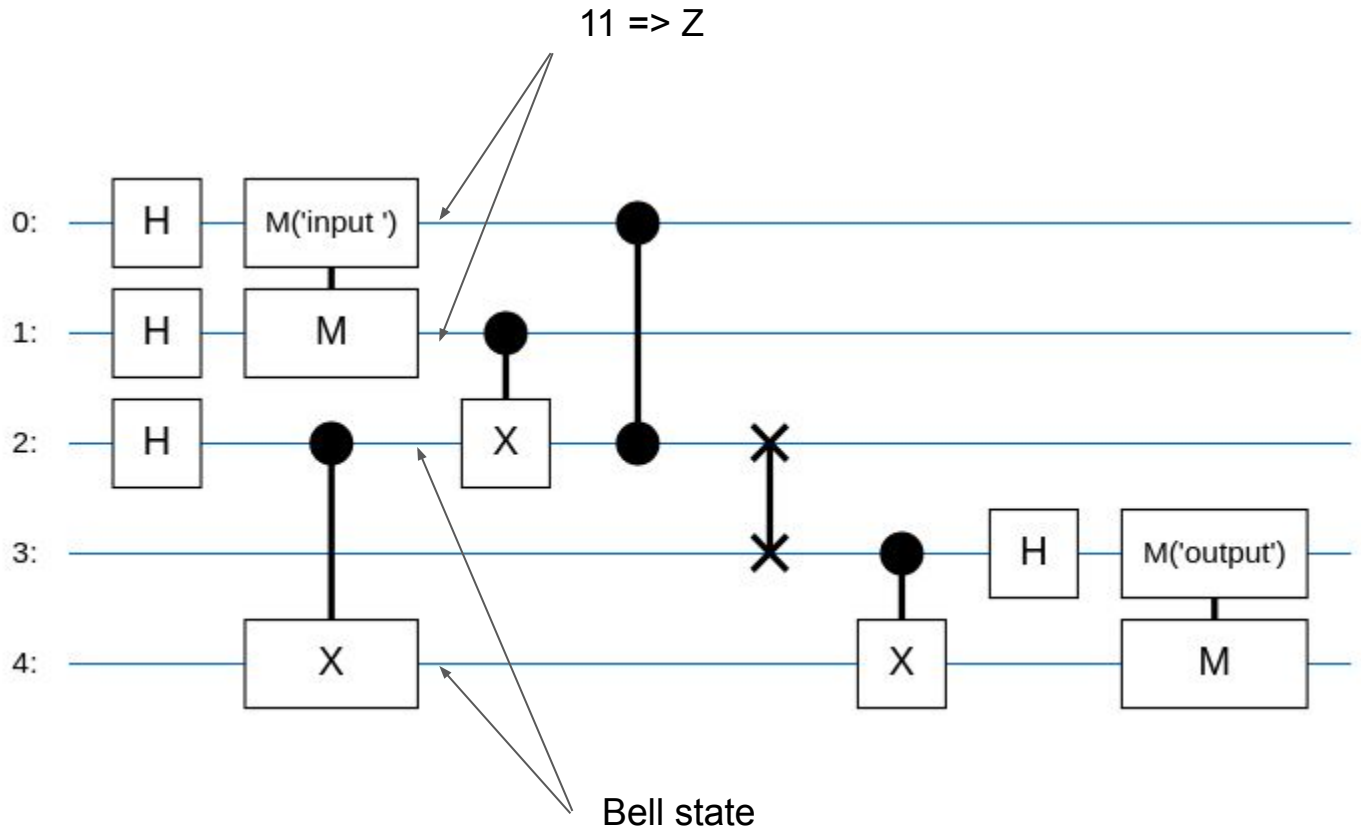

Alice
00: I
01: X
10: Z
11: XZ
Eve
Bob
|0>
|0>
H
H


Random generate: 00, 01, 10, 01
CZ gate:
|00> => |00>
|01> => |01>
|10> => |10>
|11> => -|11>
SWAP gate
0:
1:
2:
3:
4:
H
H
H
M('input ')
M
X
X
H
M('output')
X
M
Bell state

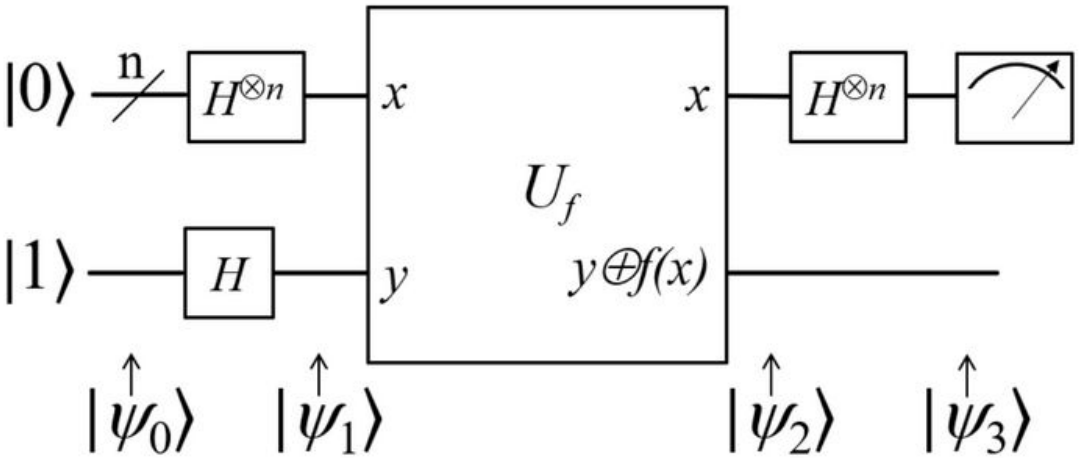

00 => I
0:
1:
2:
3:
4:
H
H
H
M('input ')
M
X
X
H
M('output')
M
Bell state


01 => X
0:
1:
2:
3:
4:
H
H
H
M('input ')
M
X
X
H
M('output')
X
M
Bell state


10 => Z
0:
1:
2:
3:
4:
H
H
H
M('input ')
M
X
X
H
M('output')
M
Bell state

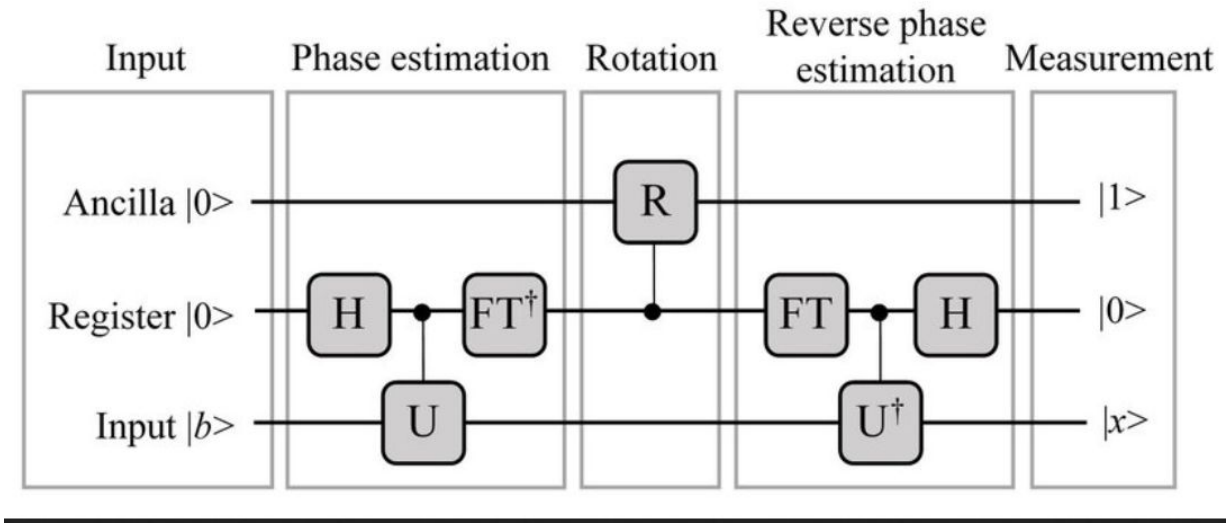

11 => Z
0:
1:
2:
3:
4:
H
H
H
M('input ')
M
X
X
H
M('output')
M
Bell state

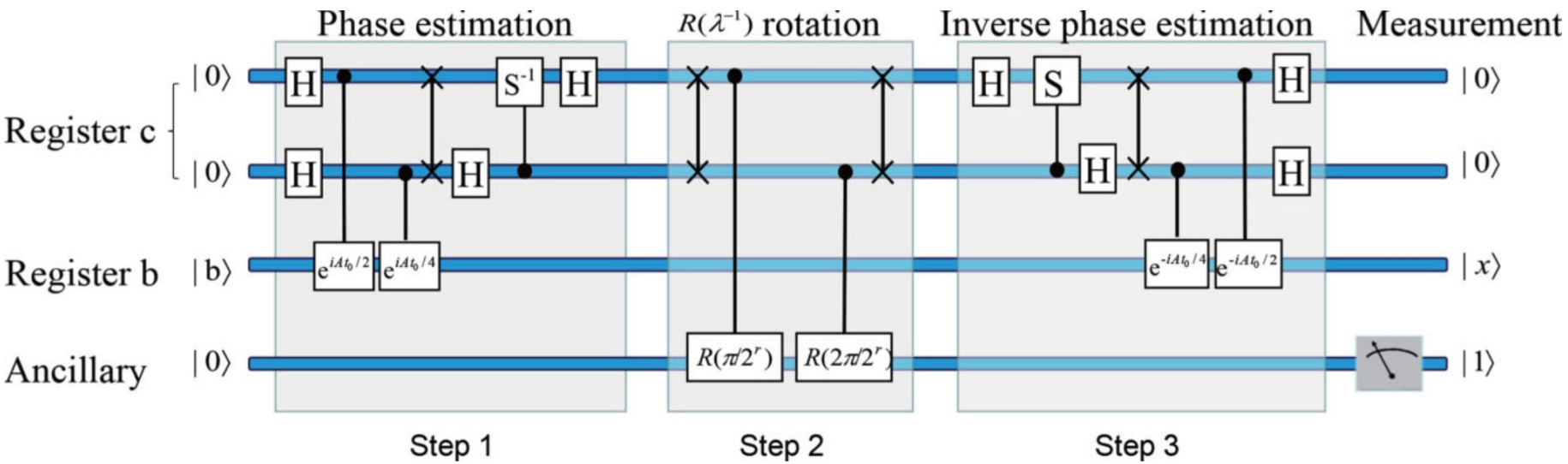
3. Deutsch Algorithm

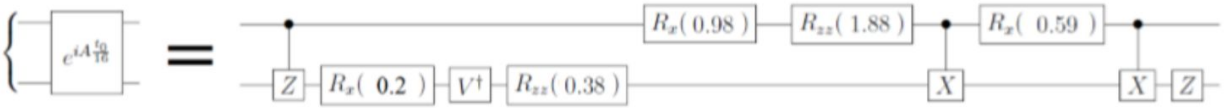

|0⟩
n
H⊗n
x
x
H⊗n
Uf
|1⟩
H
y
y⊕f(x)
|ψ0⟩
|ψ1⟩
|ψ2⟩
|ψ3⟩

To the drawing board!

4. HHL Algorithm


Input
Phase estimation
Rotation
Reverse phase estimation
Measurement
Ancilla |0>
Register |0>
Input |b>
H
FT†
U
R
FT
H
U†
|1>
|0>
|x>

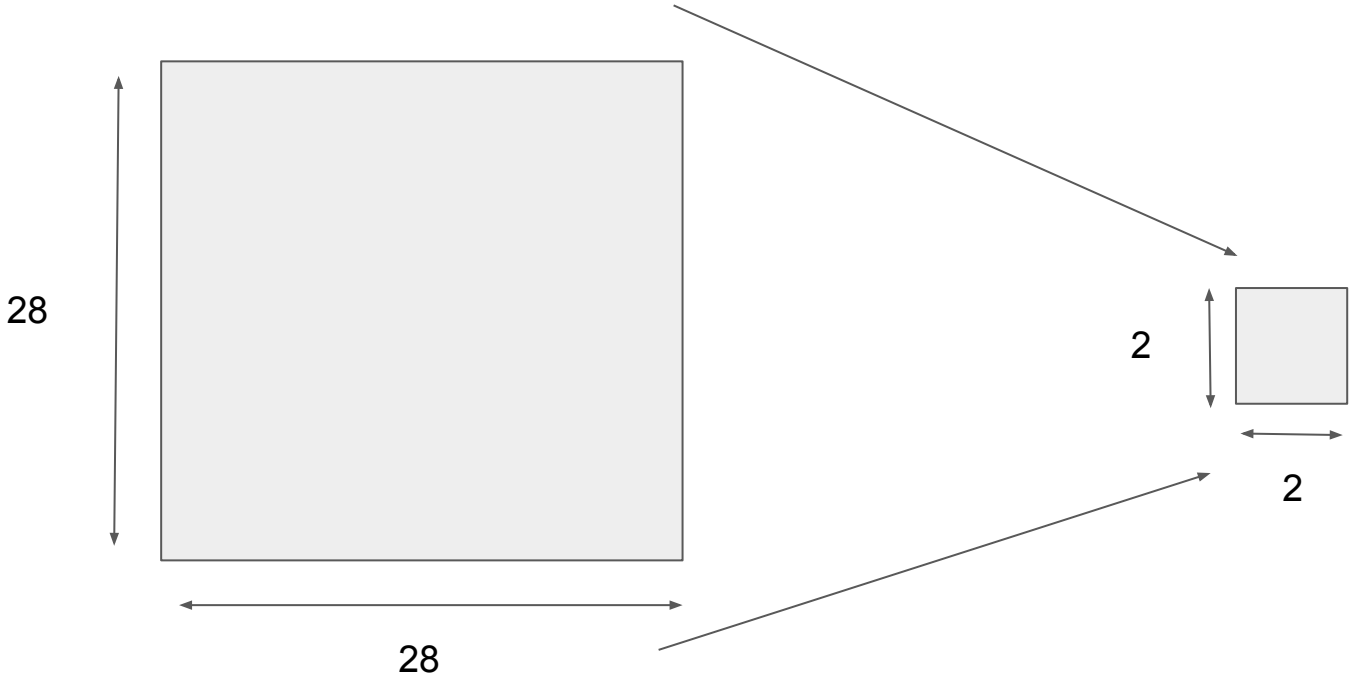

Phase estimation
$R(\lambda^{-1})$ rotation
Inverse phase estimation
Measurement
Register c
Register b
Ancillary
$|0\rangle$
$|0\rangle$
$|b\rangle$
$|0\rangle$
H
H
S^{-1}
H
$e^{iAt_0/2}$
$e^{iAt_0/4}$
$R(\pi/2^r)$
$R(2\pi/2^r)$
H
S
H
H
$e^{-iAt_0/4}$
$e^{-iAt_0/2}$
H
$|0\rangle$
$|0\rangle$
$|x\rangle$
$|1\rangle$
Step 1
Step 2
Step 3


$e^{iA\frac{t_0}{16}}$
=
$R_x(0.98)$
$R_{zz}(1.88)$
$R_x(0.59)$
Z
$R_x(0.2)$
$V^\dagger$
$R_{zz}(0.38)$
X
X
Z

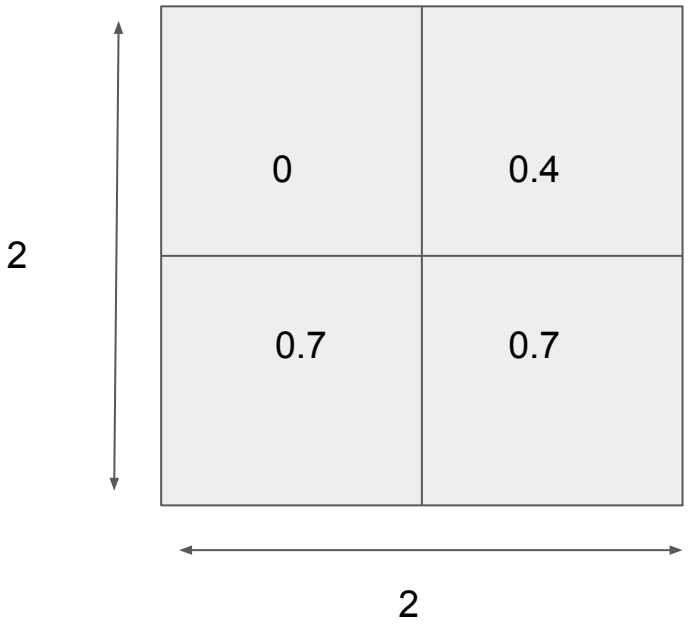
To the drawing board!

5. Quantum Neural Network

Fashion MNIST - dataset


28
28
2
2

if pixel > 0.5 => 1
else => 0



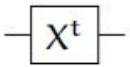

```
(1, 0): ———X———

(1, 1): ———X———
```

Parameterized gates

$$X^t = e^{-i\frac{\pi}{2}t(X-I)} = e^{i\frac{\pi}{2}t}R_x(\pi t)$$

$$= e^{i\frac{\pi}{2}t}\begin{bmatrix} \cos(\frac{\pi}{2}t) & -i\sin(\frac{\pi}{2}t) \\ -i\sin(\frac{\pi}{2}t) & \cos(\frac{\pi}{2}t) \end{bmatrix}$$



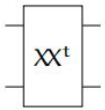

```
import sympy

q0 = cirq.LineQubit(0)
circuit = cirq.Circuit()
circuit.append(cirq.X(q0) ** sympy.Symbol('t'))
print(circuit)
```

```
0: ——X^t——
```

Parameterized gates

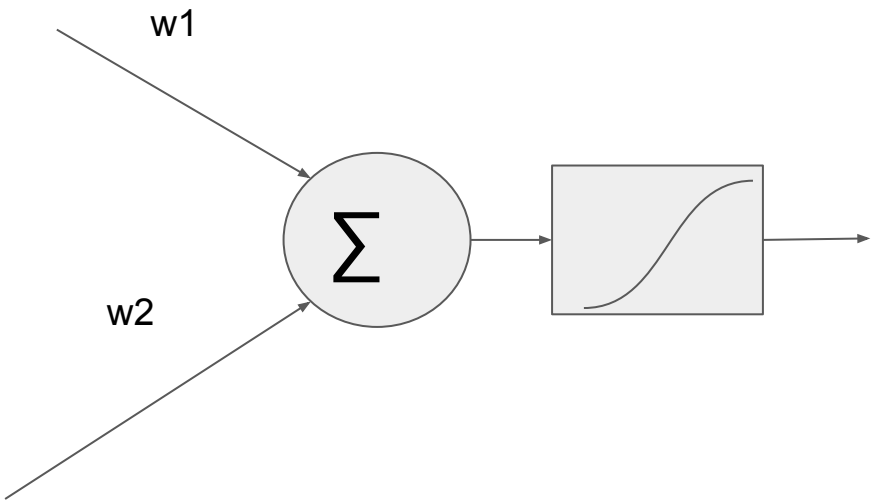
$$XX(t) = e^{-i\frac{\pi}{2}tX\otimes X}$$
$$= \begin{bmatrix} \cos(\frac{\pi}{2}t) & 0 & 0 & -i\sin(\frac{\pi}{2}t) \\ 0 & \cos(\frac{\pi}{2}t) & -i\sin(\frac{\pi}{2}t) & 0 \\ 0 & -i\sin(\frac{\pi}{2}t) & \cos(\frac{\pi}{2}t) & 0 \\ -i\sin(\frac{\pi}{2}t) & 0 & 0 & \cos(\frac{\pi}{2}t) \end{bmatrix}$$
$$= \mathrm{Can}(t, 0, 0)$$

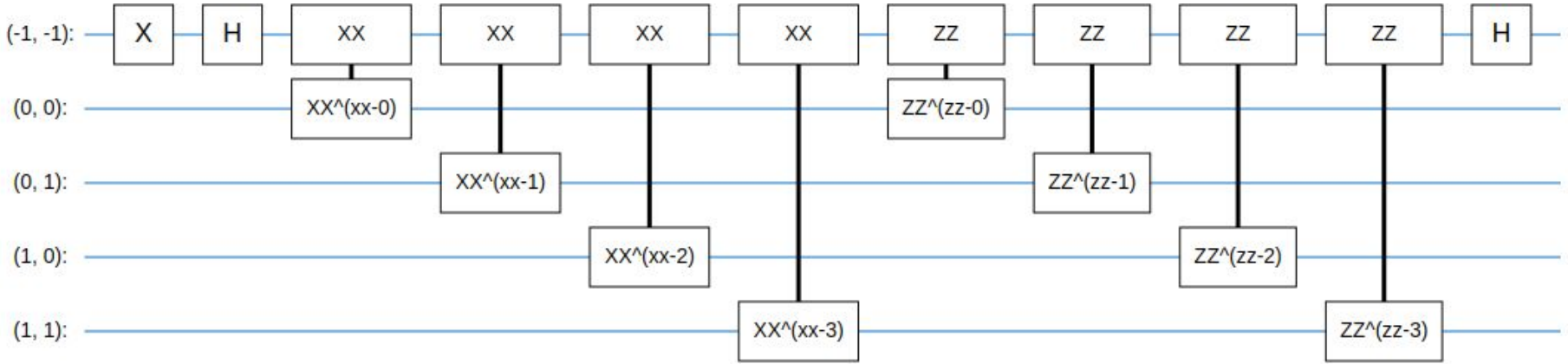



```
import sympy

q0, q1 = cirq.LineQubit.range(2)
circuit = cirq.Circuit()
circuit.append(cirq.XX(q0, q1) ** sympy.Symbol('t'))
print(circuit)
```

```
0: ──XX──────
     │
1: ──XX^t────
```

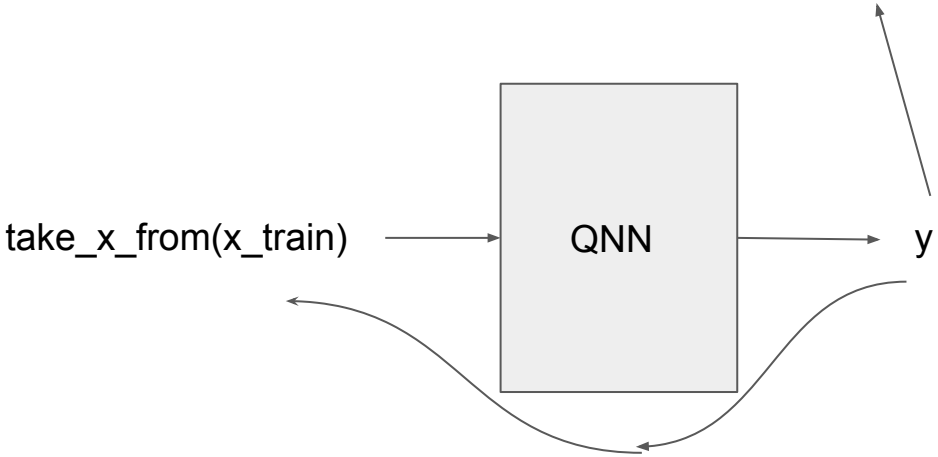

w1
w2
∑


(-1, -1):
(0, 0):
(0, 1):
(1, 0):
(1, 1):
X
H
XX
XX
XX
XX
ZZ
ZZ
ZZ
ZZ
H
XX^(xx-0)
XX^(xx-1)
XX^(xx-2)
XX^(xx-3)
ZZ^(zz-0)
ZZ^(zz-1)
ZZ^(zz-2)
ZZ^(zz-3)

Hinge loss

y_train:	1	0	0	1	0	…
y_train_hinge:	1	-1	-1	1	-1	…

$$l(y) = \max(0, 1-ty)$$



References

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