A photograph of a man standing in a dark room. He is wearing a white shirt, blue jeans, and glasses. He is looking down at a table in front of him. On the table, there is a laptop displaying a software interface, a small white device with a red screen, and some electronic components. In the background, a grand piano is visible, with many wires and cables attached to it. The room has dark walls and a white ceiling with recessed lighting.

Prof. Eduardo Reck Miranda

Interdisciplinary Centre for Computer Music Research (ICCMR)
University of Plymouth, UK

- Ultra contemporary composer
- Working with AI since the 1980s
- Championed the development of Brain-Computer Music Interfaces
- Pioneered research into unconventional computing in music
- Pioneered the field of *Quantum Computer Music*

[Show simple item record](#)

Sound design: an artificial intelligence approach

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I am interested in programming and using actual quantum computers to compose music.

*I am **not** so interested in music that is simply inspired by quantum concepts, nor am I looking for poetic or philosophical parallels between quantum mechanics and musical composition.*

For me, music serves primarily as a form of human communication, rather than a metaphorical exploration of quantum mechanics or vice versa.

I see quantum computers as unprecedented musical instruments.

My focus is on harnessing the unique computational power of quantum mechanics (e.g., qubits, qutrits, qudits, superposition, entanglement and interference) to develop methods and build systems for the composition and performance of music in ways that might not have been possible with classical digital computers alone.

BBC Concert Orchestra

Jarvis Cocker



Queen Elisabeth Hall, South Bank Centre, London

Peter Gabriel

Brian Eno



Book launch at The Goethe Institute, London: <https://www.goethe.de/prj/lqs/en/eve/sou.html>

State of the art AI for music is great, but ...

- One-shot interaction; click & generate
- Makes it easy to create.
- Does not make it easy to be creative.
- Text-to-music oriented.
- Unfaithful to the submitted prompt; add extra descriptors the system is tuned to respond to.
- Inhibit critical engagement with compositional practice; e.g., no support for contemplation.
- Can lead to overreliance on AI, promoting downfall of problem-solving skills.

Opportunity to improve

- AI systems do not necessarily need to BE creative. But SUPPORT creative compositional practices.
- Music-to-music oriented
- Small-data, ephemeral, volatile machine learning

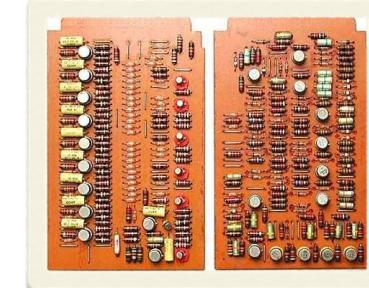
Artificial Intelligence today



Relays



Vacuum tubes



Transistors

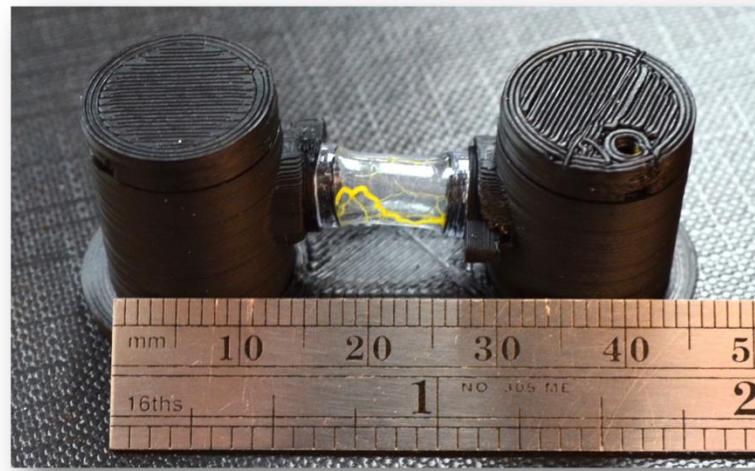
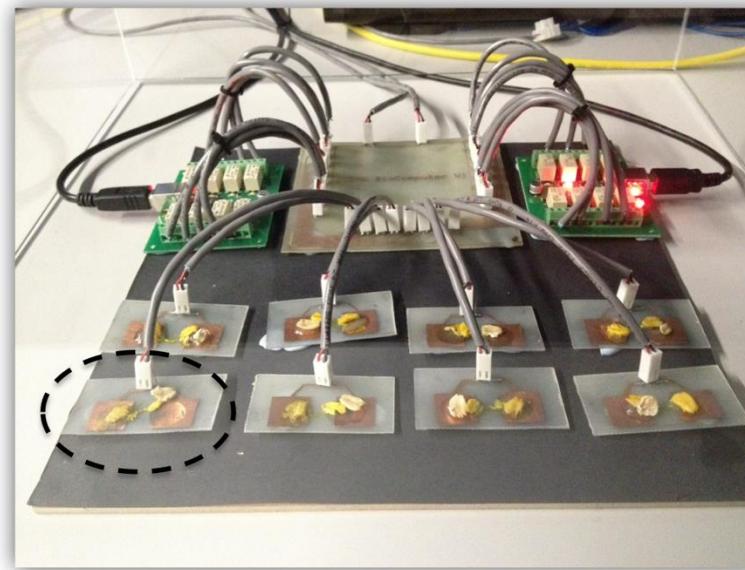


Integrated Circuits

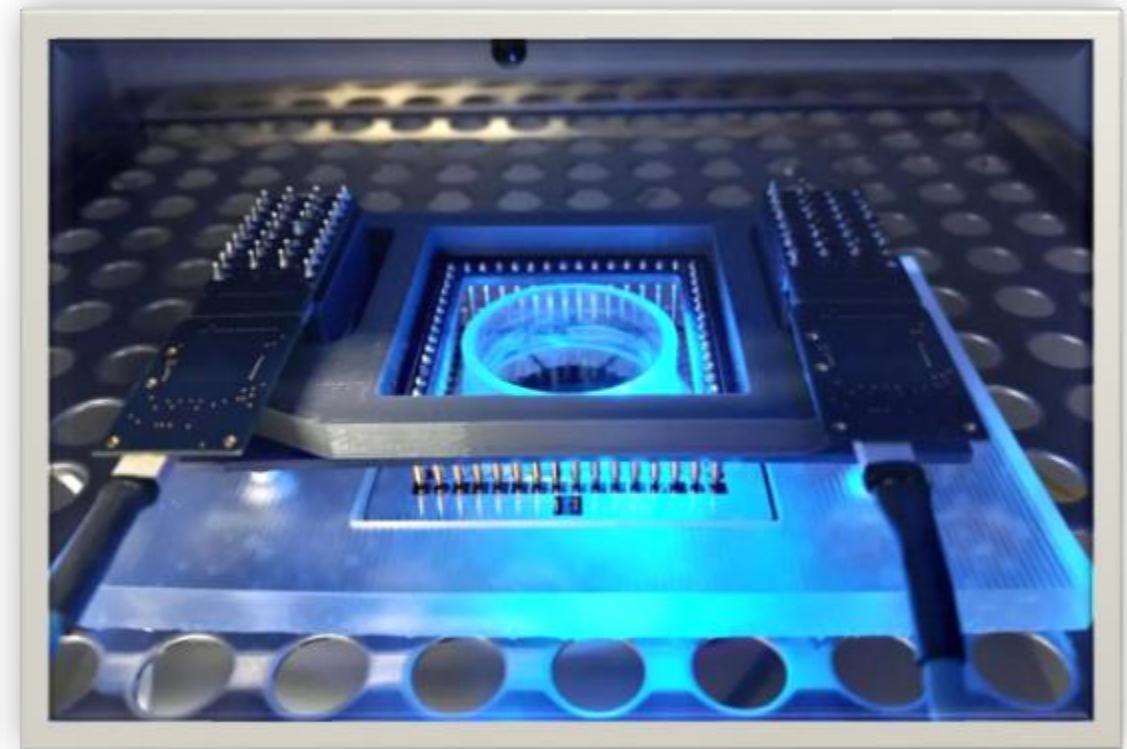
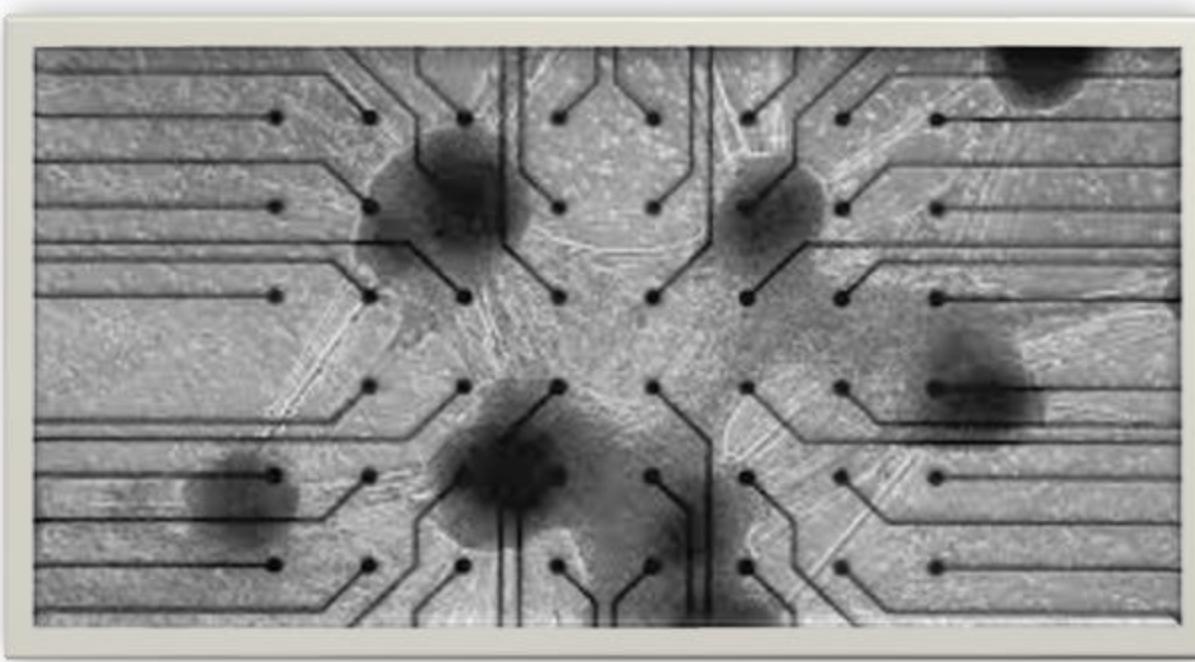
Represents 0 or 1 at a time

New kinds of hardware = New kinds of intelligence

Exploring bio-computers ...



Neurons living on a silicon chip



Biocomputer Rhythms

A one-piano duet between a pianist and the bio-computer.

The score for the pianist is fixed, but the responses generated by the bio-computer are unpredictable.

The musical score consists of three staves of piano music. Staff 1 (top) shows a bass clef, a key signature of one flat, and a tempo of 150 BPM. It includes instructions for the pianist: 'depress cluster silently' and 'at least 2 octaves, white keys'. The bio-computer is to play a 'gentle pedal work'. Staff 2 (middle) shows a bass clef, a key signature of one flat, and a tempo of 80 BPM. It includes instructions for the pianist: 'Ped' and 'at least 2 octaves, white keys'. The bio-computer is to play 'BIOSET 3' (downward arrow), 'BIOSET 4' (downward arrow), and 'BIOSET 4' (upward arrow). Staff 3 (bottom) shows a bass clef, a key signature of one flat, and a tempo of 80 BPM. It includes instructions for the pianist: 'Ped' and 'at least 2 octaves, black keys'. The bio-computer is to play 'BIOSET 5' (downward arrow), 'BIOSET 5' (upward arrow), and 'BIOSET 5' (downward arrow). The score is divided into sections: 5 secs., 30 secs., and 45 secs. The bio-computer's responses are triggered by the bio-set markers indicated by arrows on the staff.

Biocomputer Rhythms

This is “machine” intelligence that is far different from the pedestrian AI as we know it!

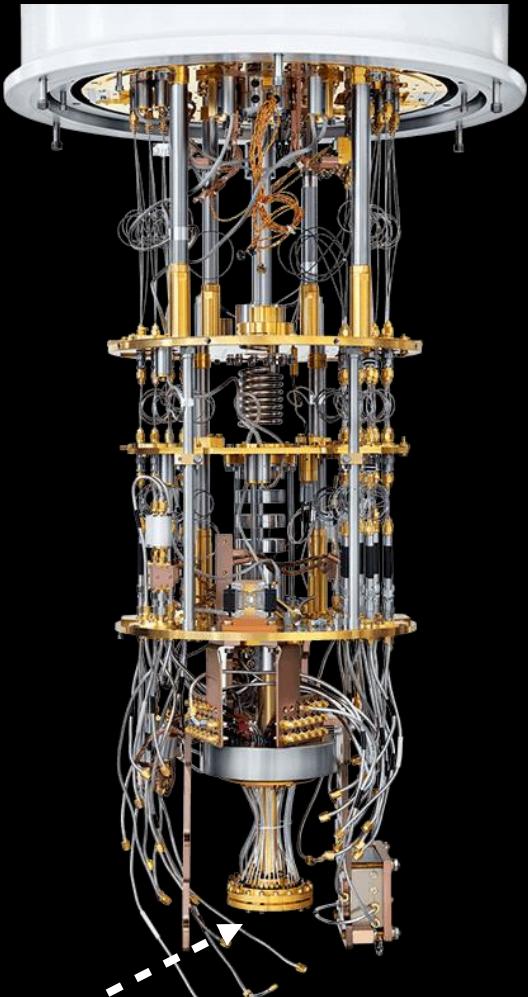
<https://youtu.be/fiOrhg1nKZs>



Quantum Computer

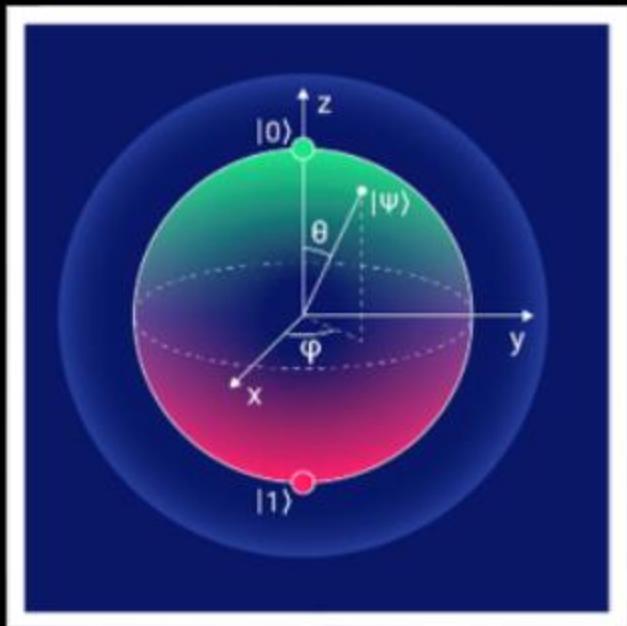


Rigetti



@ QuTech
Quantum Inspire

Is it be possible do design new kinds of AI with Quantum Computers?



- Using the principles of **quantum mechanics** to process information ...
- Using **quantum bits**, or **qubits**, to represent data ...
- Qubits can exist in a **superposition** of both 0 and 1 simultaneously
- Can be **entangled**: the state of one qubit can depend on the state of another.
- **Quantum interference**: Used to amplify correct results and cancel out incorrect ones. (Suitable for searching algorithms and logic problem solving.)

Bit
(Classical Computing)

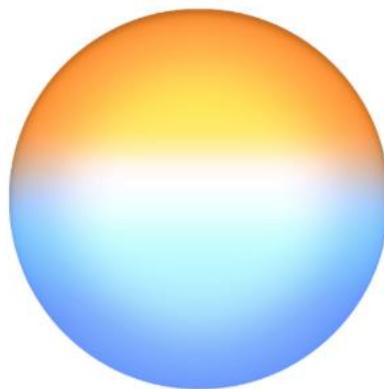
0



1

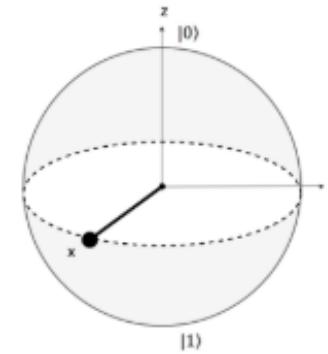
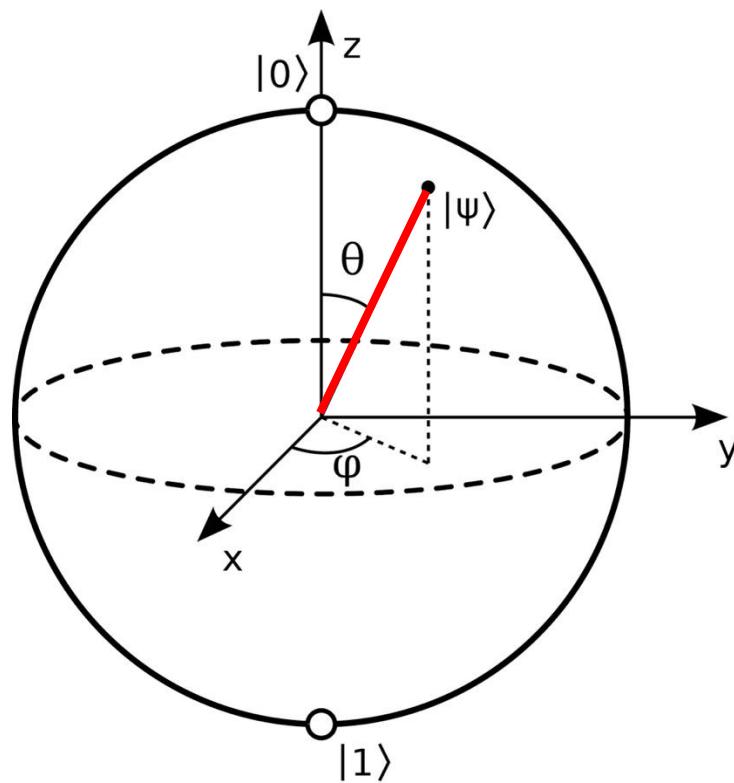
Qubit
(Quantum Computing)

0

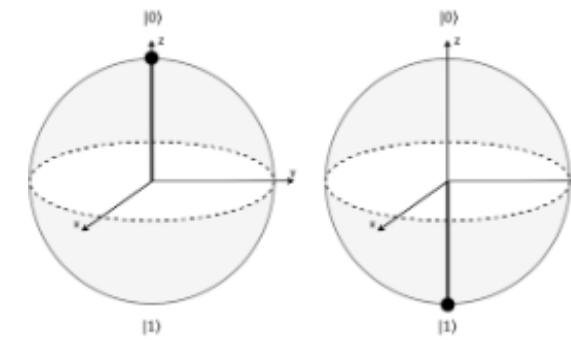


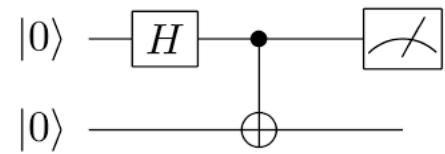
1

Quantum Superposition



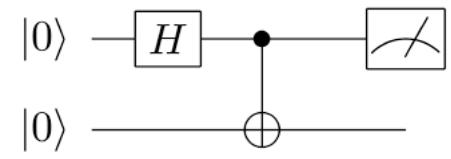
?





Quantum Entanglement





Quantum Entanglement

qubit 1



qubit 2

Science & Tech Behind the Concert

Quantum Loops, Broken Symmetries

Dec. 3, 2025 6:00 PM – 7:00 PM, Salen, ZEB , Oslo

Read the programme notes here: <https://www.uio.no/ritmo/english/news-and-events/events/artistic-performances/2025/quantum-music/>

Scan the QR below for peer-reviewed papers detailing the quantum computing systems used in the compositions



Composition entitled: *Heisenberg's Hammer*

Quantum live-coding

```
// MIDT
// q1: s1 notes. q2: s2 notes. q3: s3 notes. q4: s4 notes. cc3: bpm
// cc5: s2 notes. cc6: s4 notes. cc7: s5 notes

clear()
midi()

z.s = 8
z.bpm.midicc(3,11,0.5).mtr(8,240) // cc3 device = 11 (Fighter)

// Circuit -----
q0.fb()
q1.fb()
q2.fb()
q3.rx($midicc(0,12,0.5)) // cc0 device = 12
  .cx(2,3)
q4.rx($midicc(1,12,0.5)) // cc1 device = 12
  .cx(0).x().cx(1).ccx([3,1],1).x().ccx([3,0]).x().ccx([3,2])

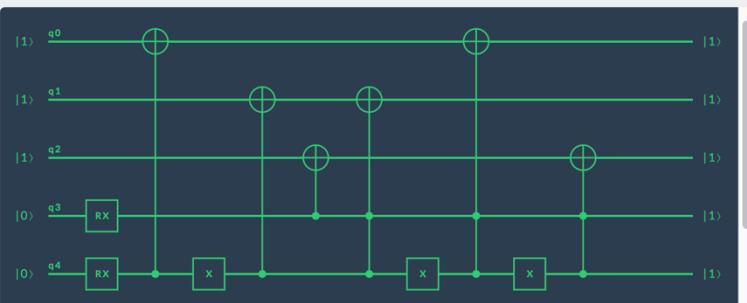
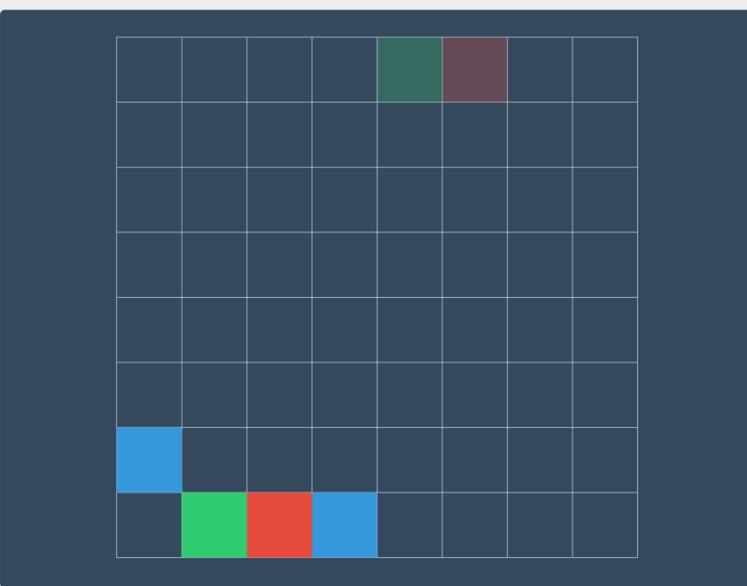
// Dice -----
let diceQubits = $qms().fn(arr => arr.slice(3,5))
  .fn(arr => parseInt(arr.join(''), 2))

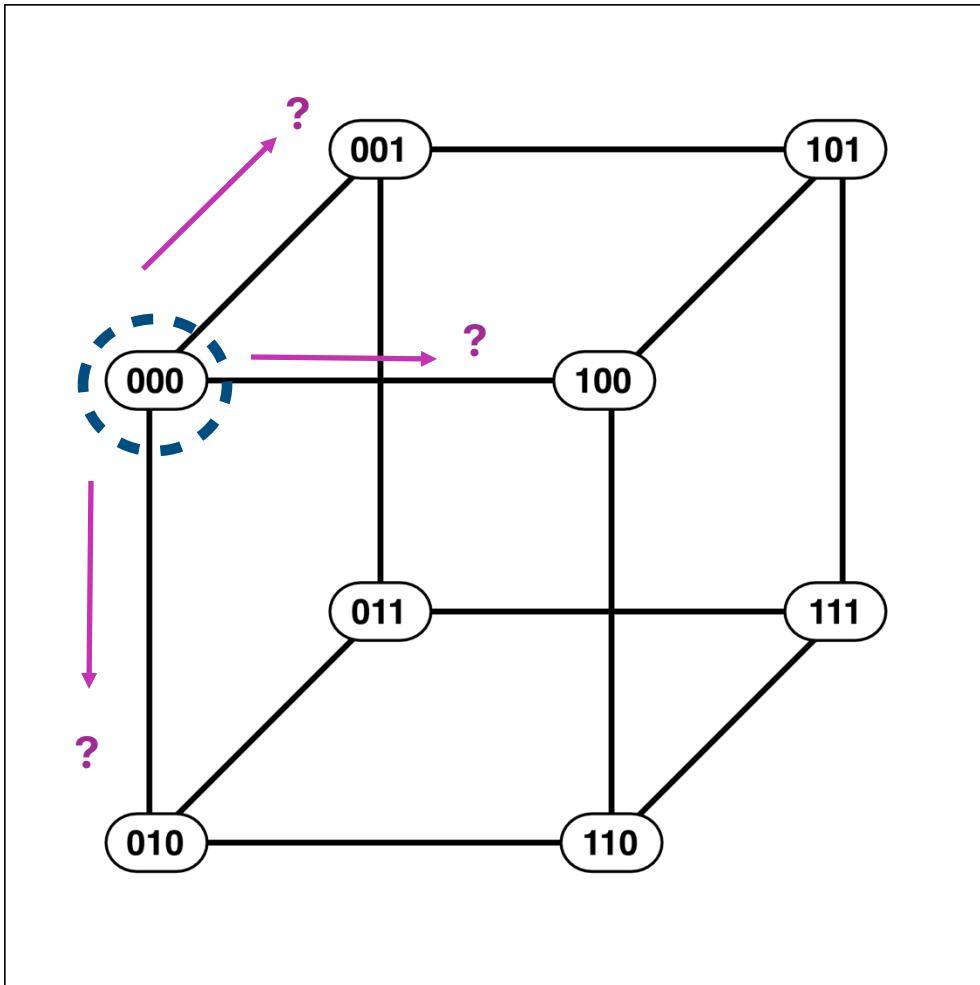
let dice = $io(
  $set(diceQubits).eq(0),
  $set(diceQubits).eq(3)
)

s0.y.set(diceQubits).mtr(0,1,0,4)
s0.e.set(1)

// Sections -----
let sectionA = $not(dice)
let sectionB = dice
```

```
» 4: IAC port1,  
» 5: IAC port2,  
» 6: IAC port3,  
» 7: IAC port4,  
» 8: IAC port5,  
» 9: IAC SWAM Double Bass,  
» 10: IAC Bus 5 SWAM,  
» 11: IAC Emergency Plan B,  
»
```





```

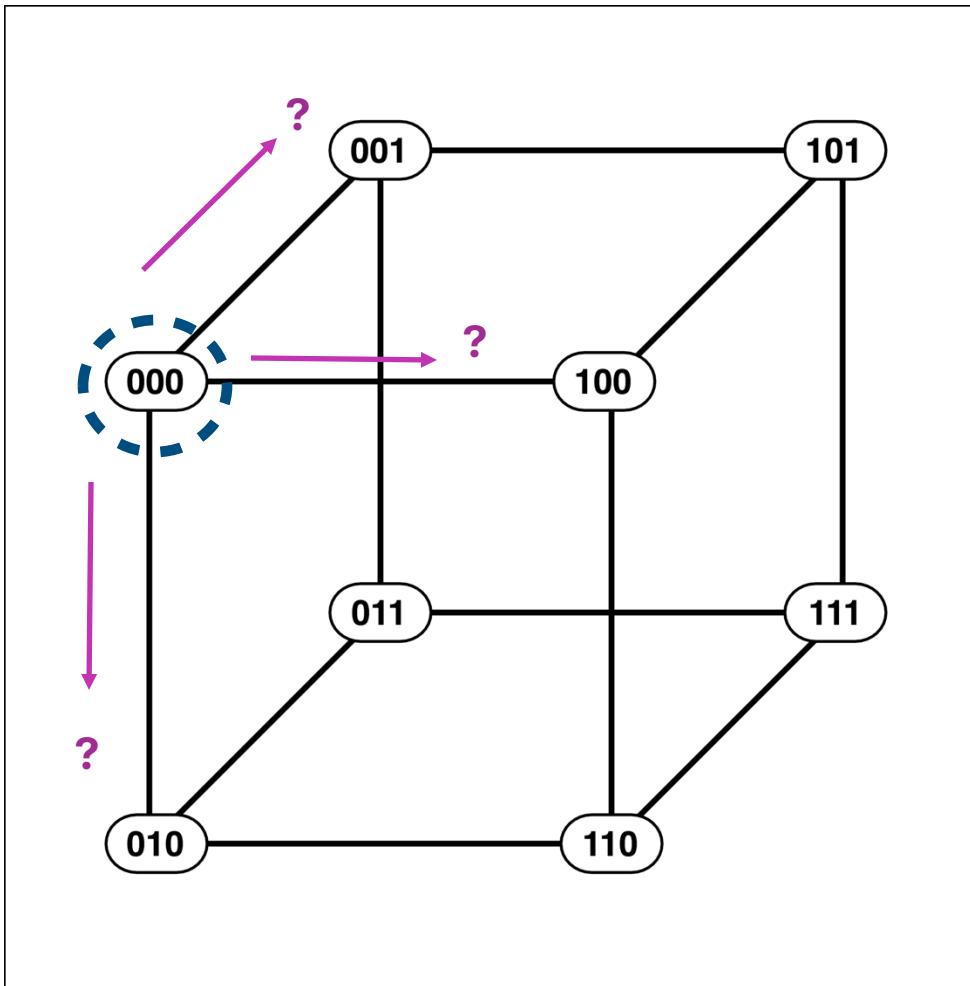
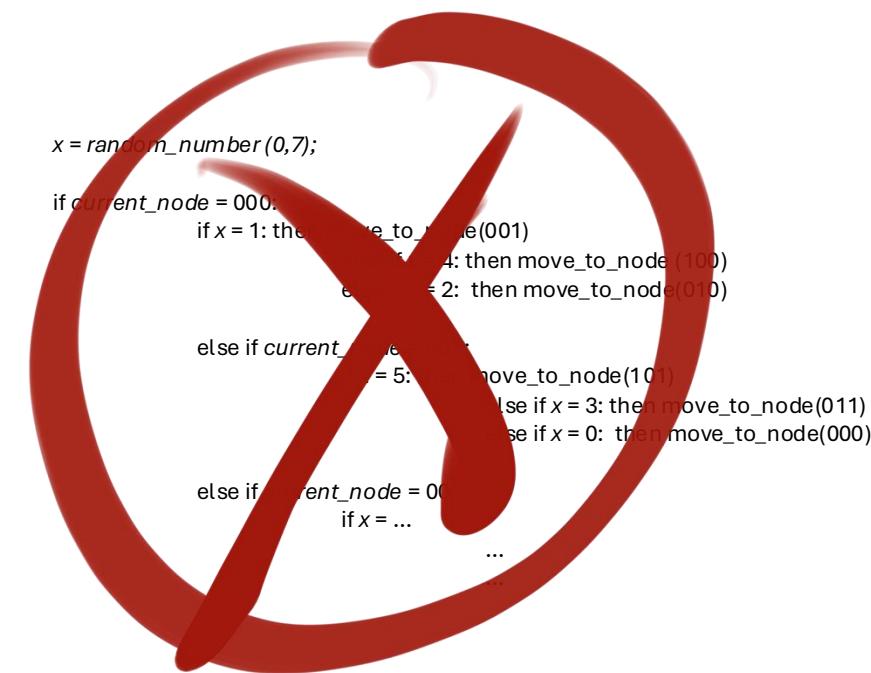
x = random_number(0,7);

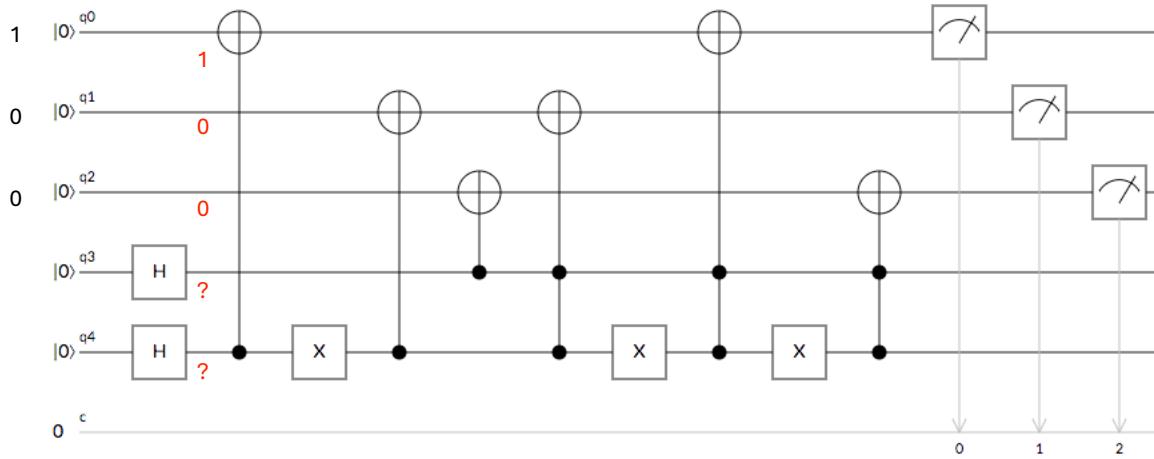
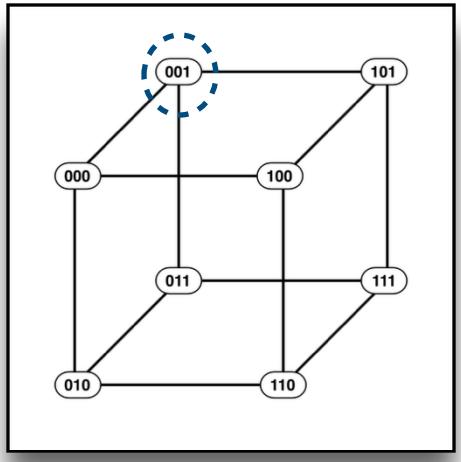
if current_node = 000:
    if x = 1: then move_to_node(001)
    else if x = 4: then move_to_node(100)
    else if x = 2: then move_to_node(010)

    else if current_node = 001:
        if x = 5: then move_to_node(101)
        else if x = 3: then move_to_node(011)
        else if x = 0: then move_to_node(000)

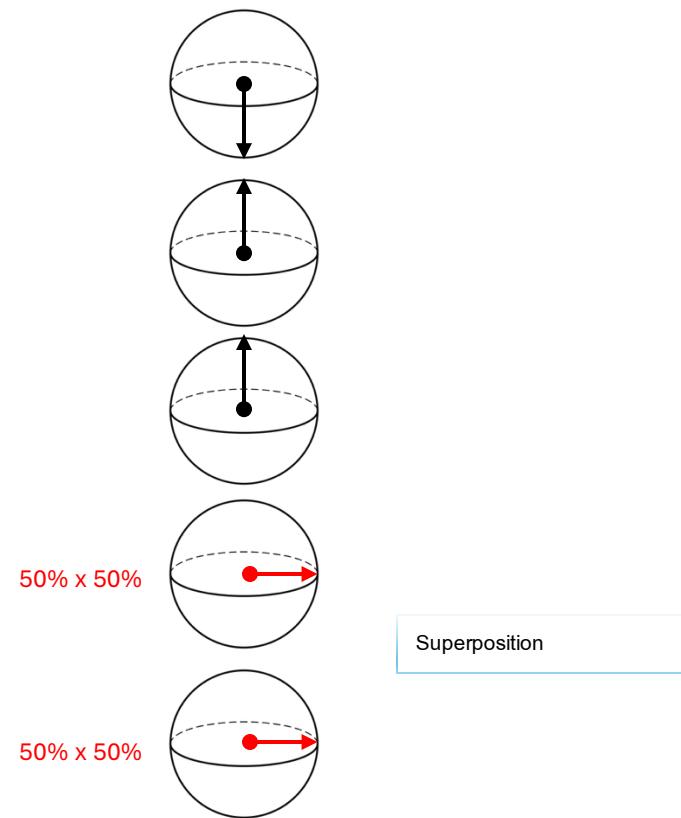
    else if current_node = 001:
        if x = ...
            ...
            ...
  
```

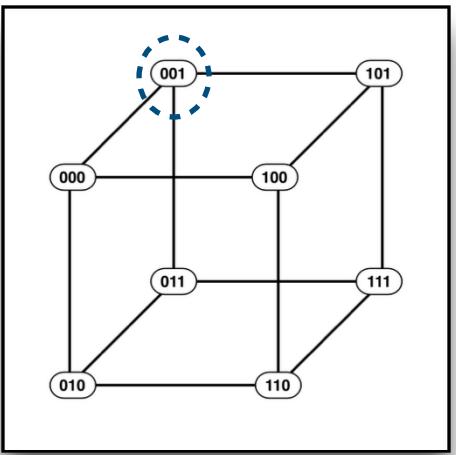
Standard sequential digital computing:



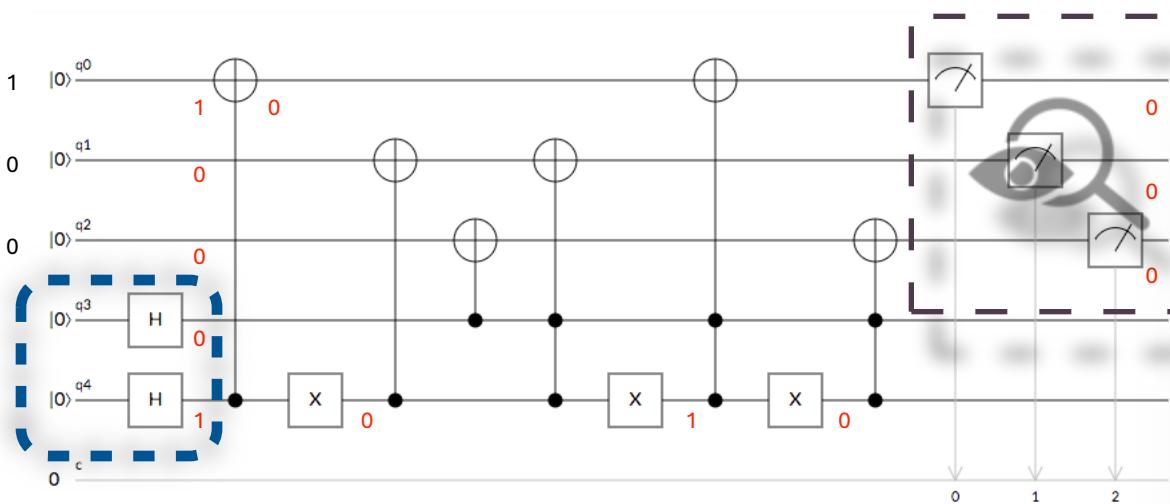


Quantum computing

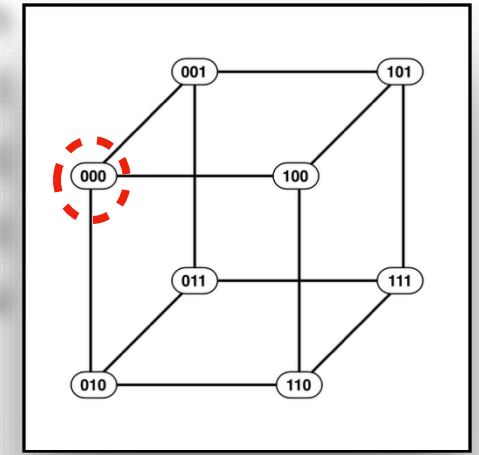




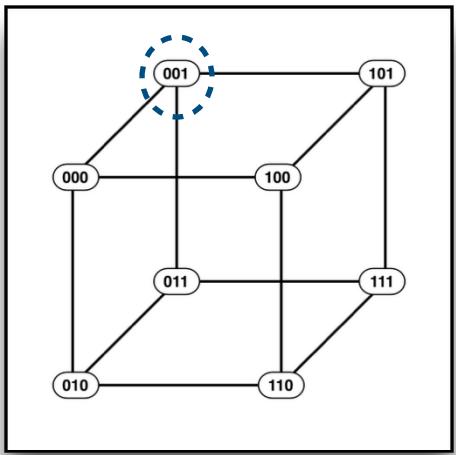
PROBLEM RULES



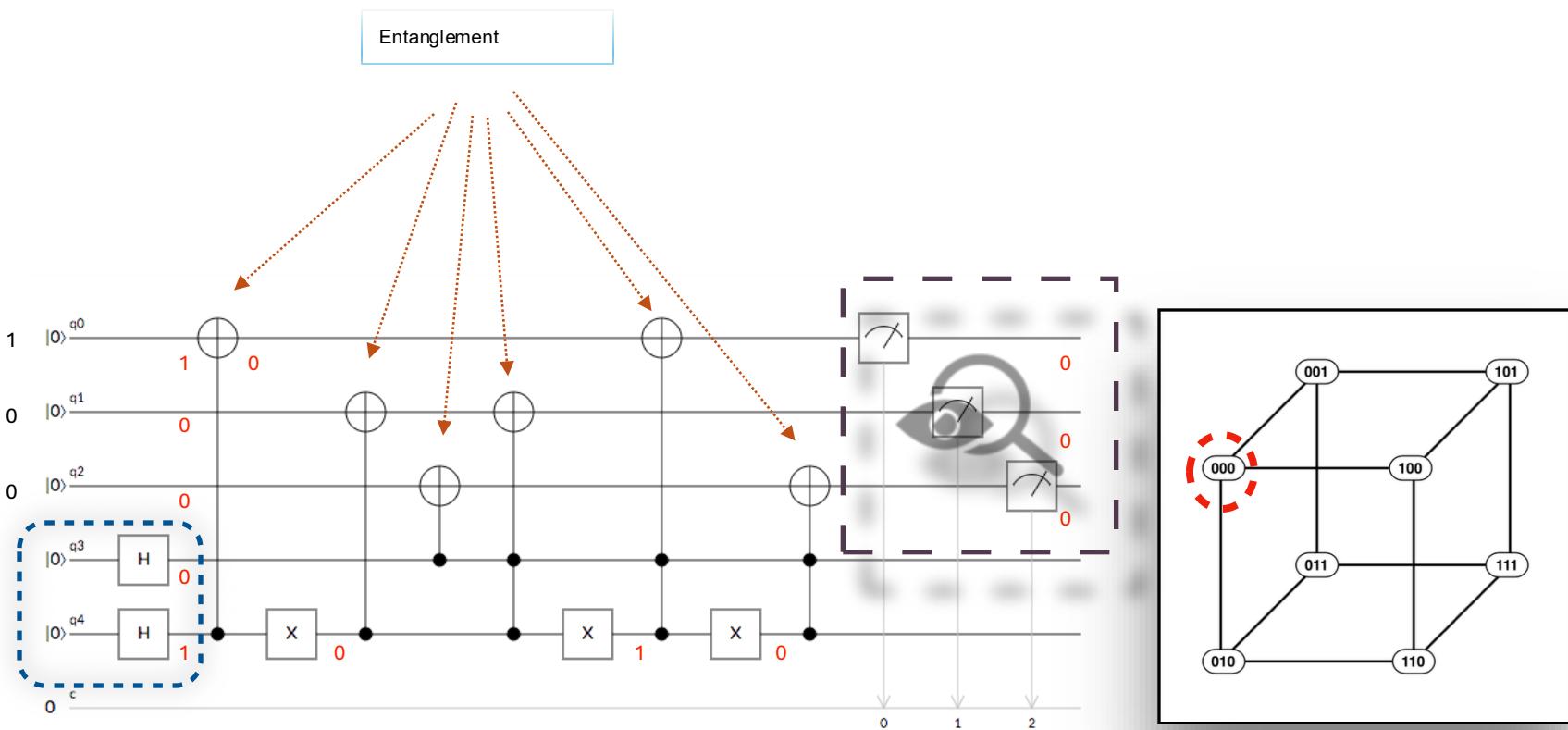
ENCODING FOR QUANTUM PROCESSING



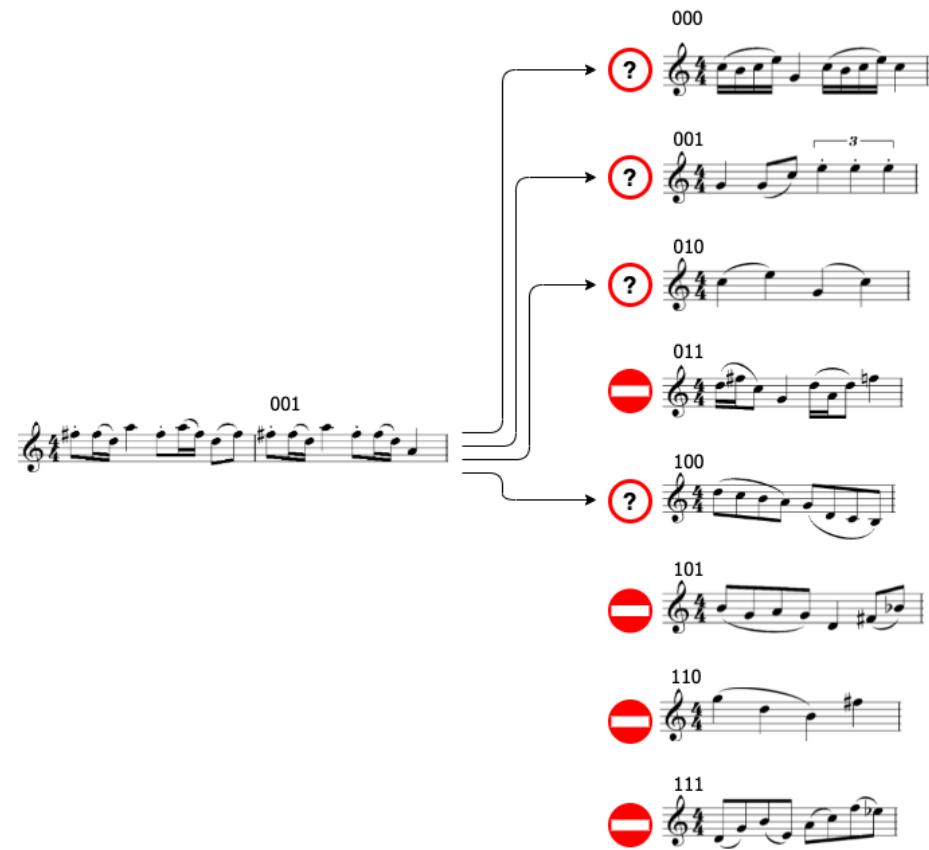
RESULT



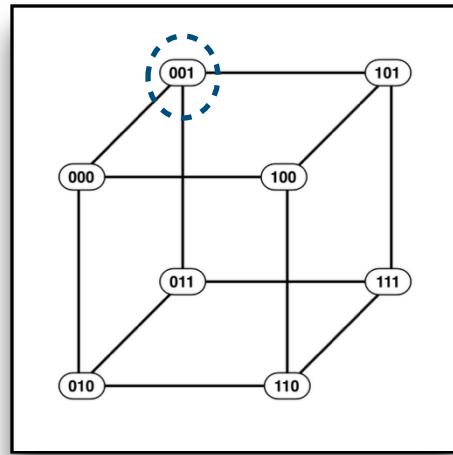
PROBLEM RULES



RESULT



MUSIC RULES



000

001

010

011

100

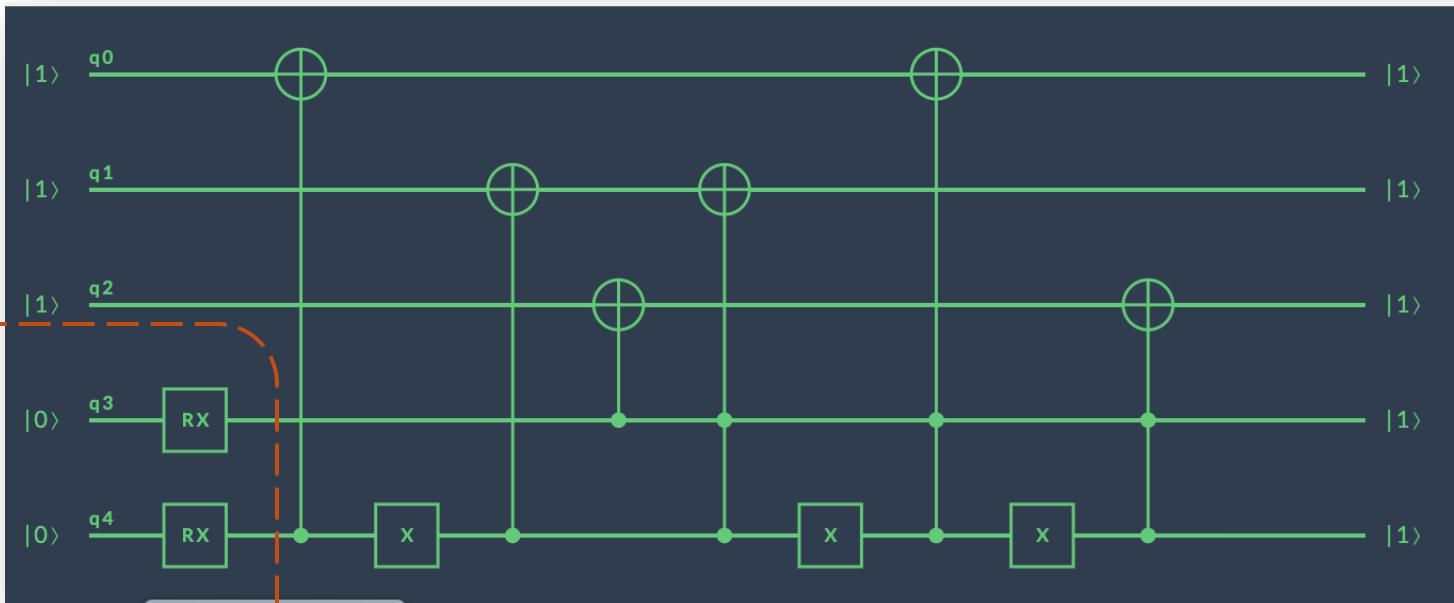
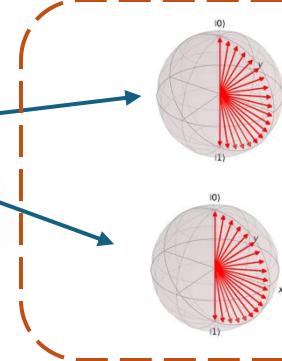
101

110

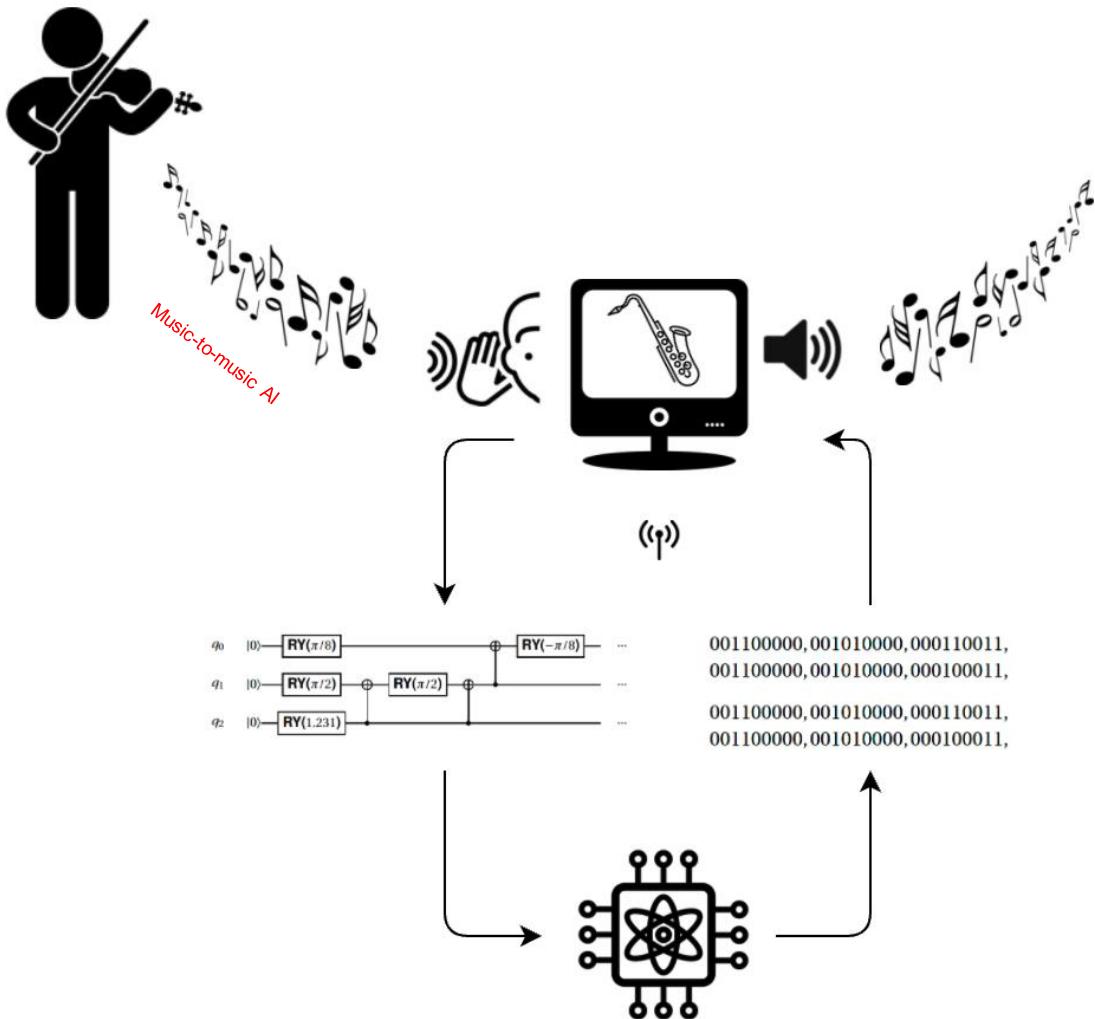
111



“Interfering” with Interference



Composition entitled: I don't know how, but I will find a way



7-qubit superconducting quantum machine @ QuTech, TU Delft, The Netherlands

$C_3 \implies D_3(25\%) \vee G\sharp_3(25\%) \vee C_4(25\%) \vee D_4(25\%)$

$D_3 \implies C_3(30\%) \vee E_3(70\%)$

$E_3 \implies D_3(25\%) \vee F\sharp_3(25\%) \vee A\sharp_3(25\%) \vee C_4(5\%) \vee D_4(20\%)$

$F\sharp_3 \implies E_3(100\%)$

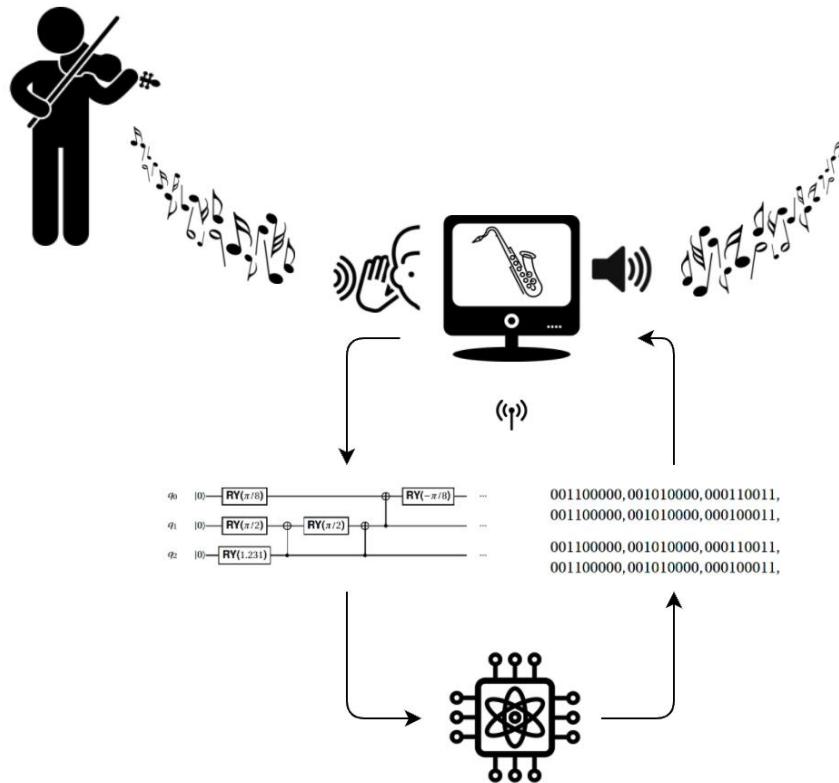
$G\sharp_3 \implies C_3(30\%) \vee A\sharp_3(70\%)$

$A\sharp_3 \implies E_3(33\%) \vee G\sharp_3(33\%) \vee C_4(34\%)$

$C_4 \implies C_3(30\%) \vee A\sharp_3(70\%)$

$D_4 \implies C_3(20\%) \vee E_3(80\%)$

MUSIC RULES



$$C_3 \implies D_3(25\%) \vee G_{\#3}(25\%) \vee C_4(25\%) \vee D_4(25\%)$$

$$D_3 \Rightarrow C_3(30\%) \vee E_3(70\%)$$

$$E_3 \implies D_3(25\%) \vee F_{\#3}(25\%) \vee A_{\#3}(25\%) \vee C_4(5\%) \vee D_4(20\%)$$

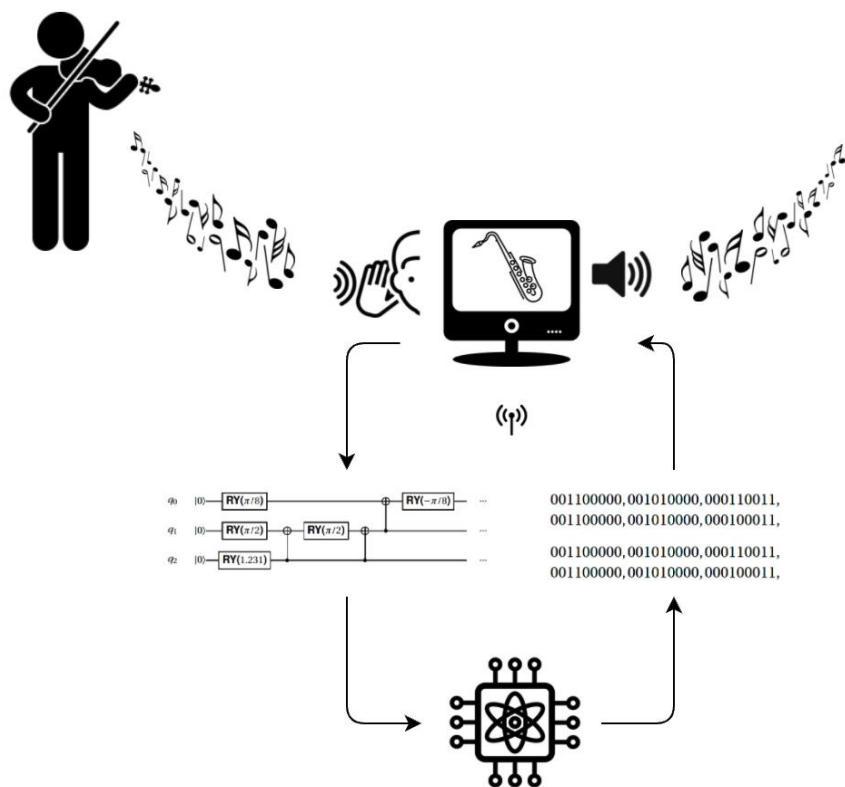
$F_{\#3} \Rightarrow E_3(100\%)$

$$G_{\#3} \Rightarrow C_3(30\%) \vee A_{\#3}(70\%)$$

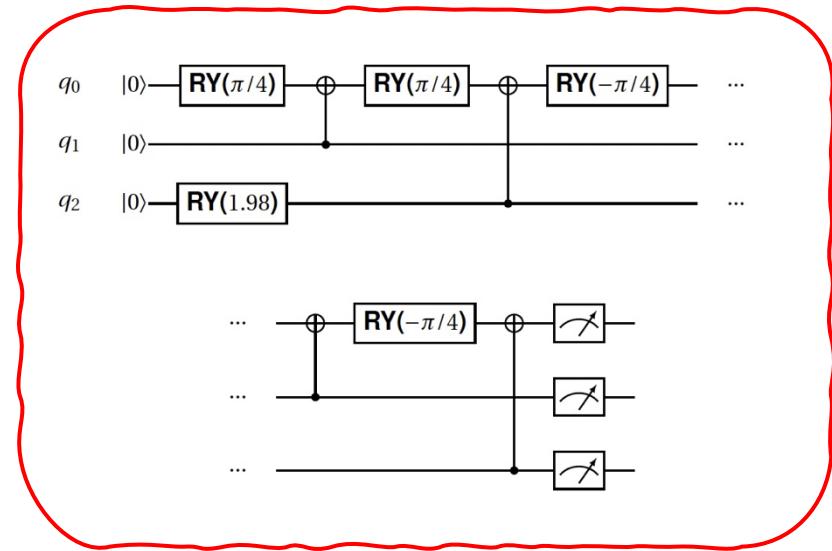
$$A_{\#3} \implies E_3(33\%) \vee G_{\#3}(33\%) \vee C_4(34\%)$$

$$C_4 \Rightarrow C_3(30\%) \vee A_{\#3}(70\%)$$

$$D_4 \implies C_3(20\%) \vee E_3(80\%)$$



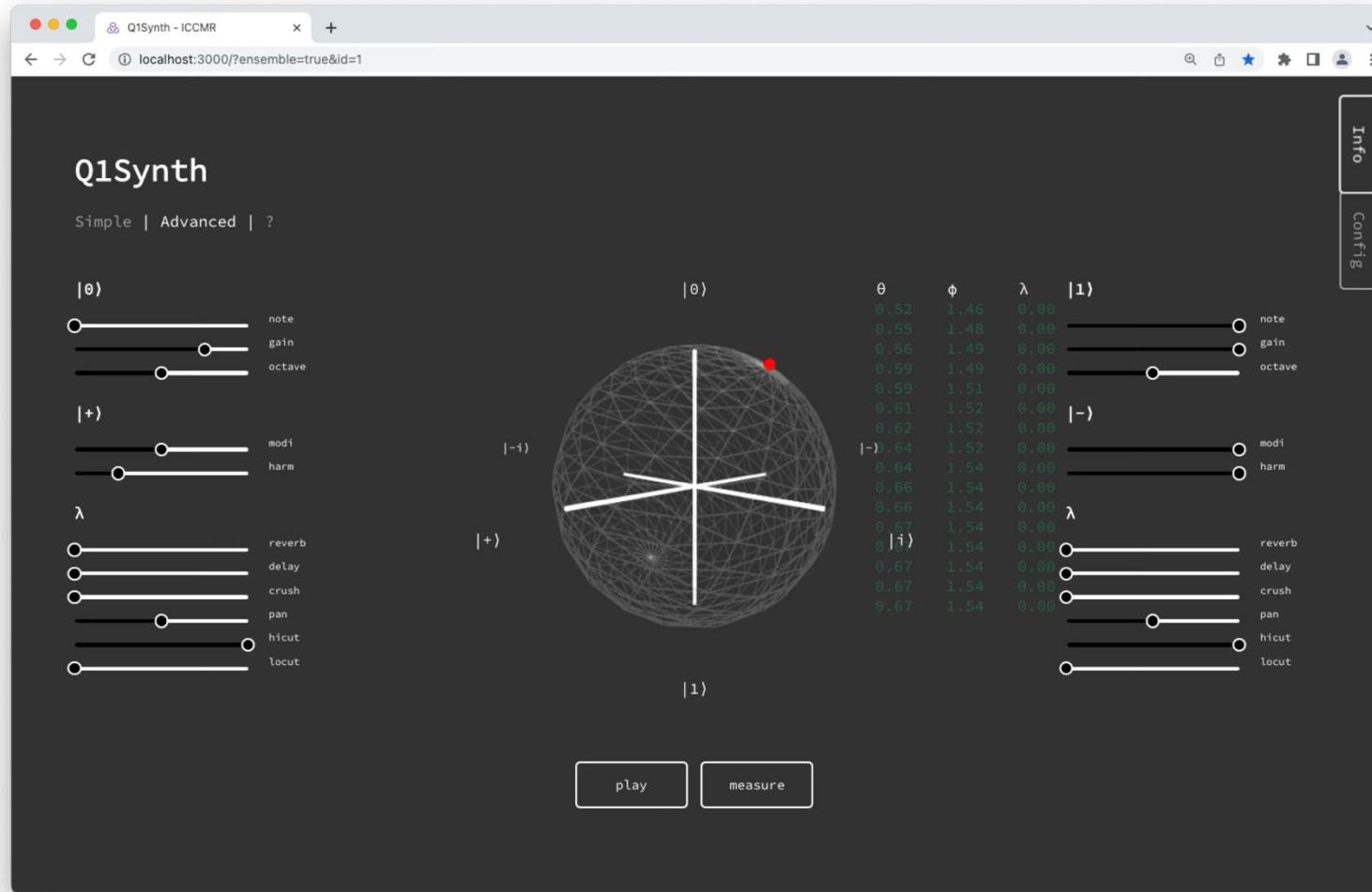
ENCODING FOR QUANTUM PROCESSING



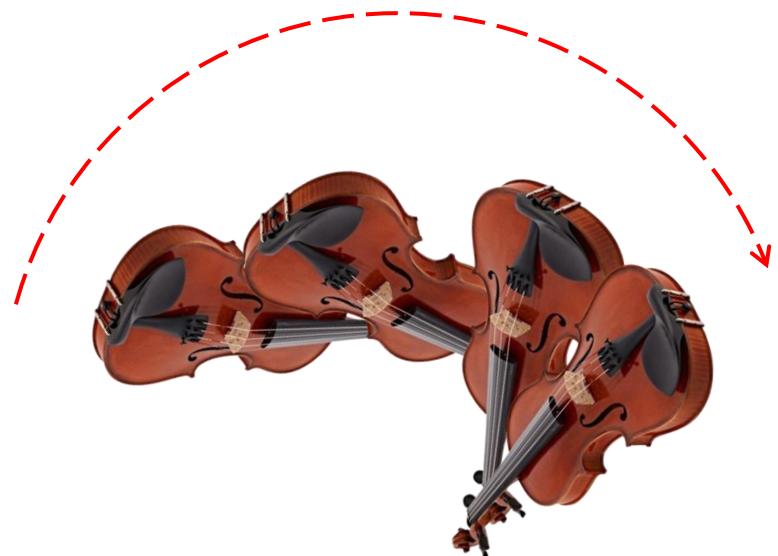


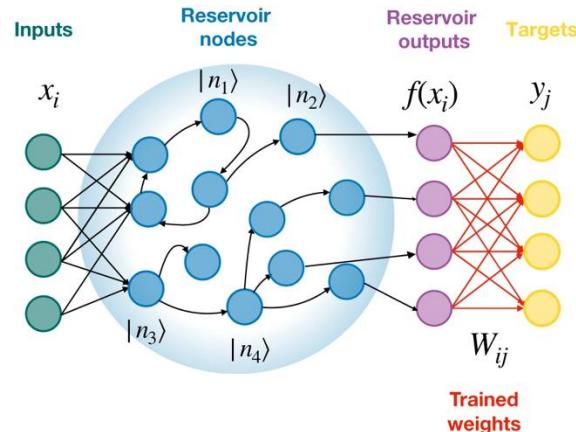
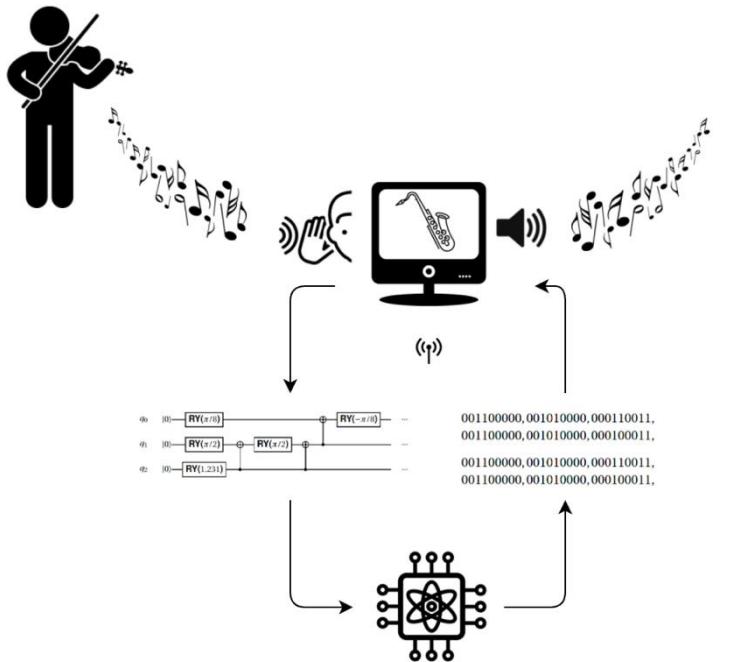
of quantum mechanics
to process data for me, to generate data,

<https://www.youtube.com/watch?v=DW9hgFQLeeE>



<https://iccmr-q1synth-proto.cephasteom.co.uk/>





Credit: <https://doi.org/10.1038/s41534-023-00734-4>

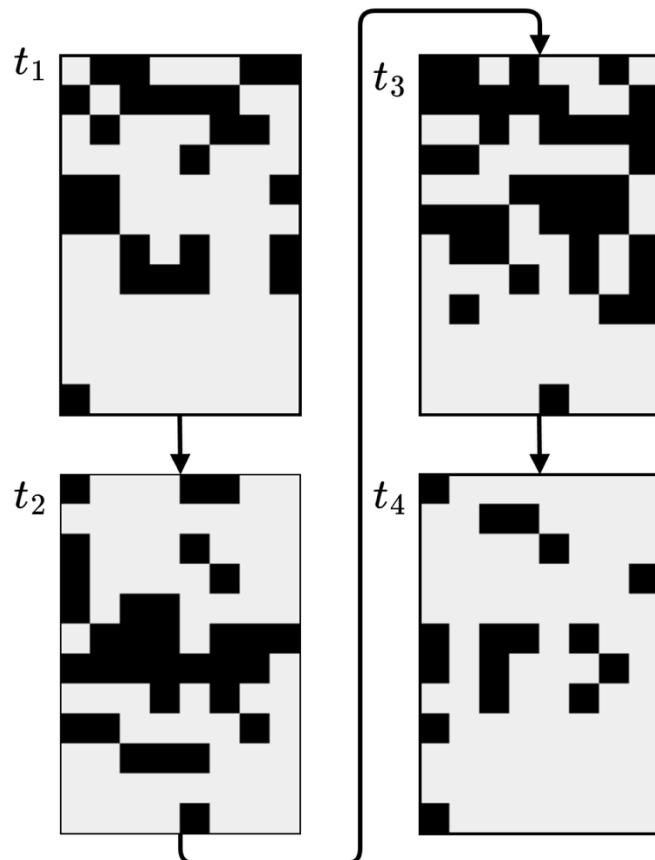
Composition entitled: Moment States

Quantum AI Method: Reservoir Computing

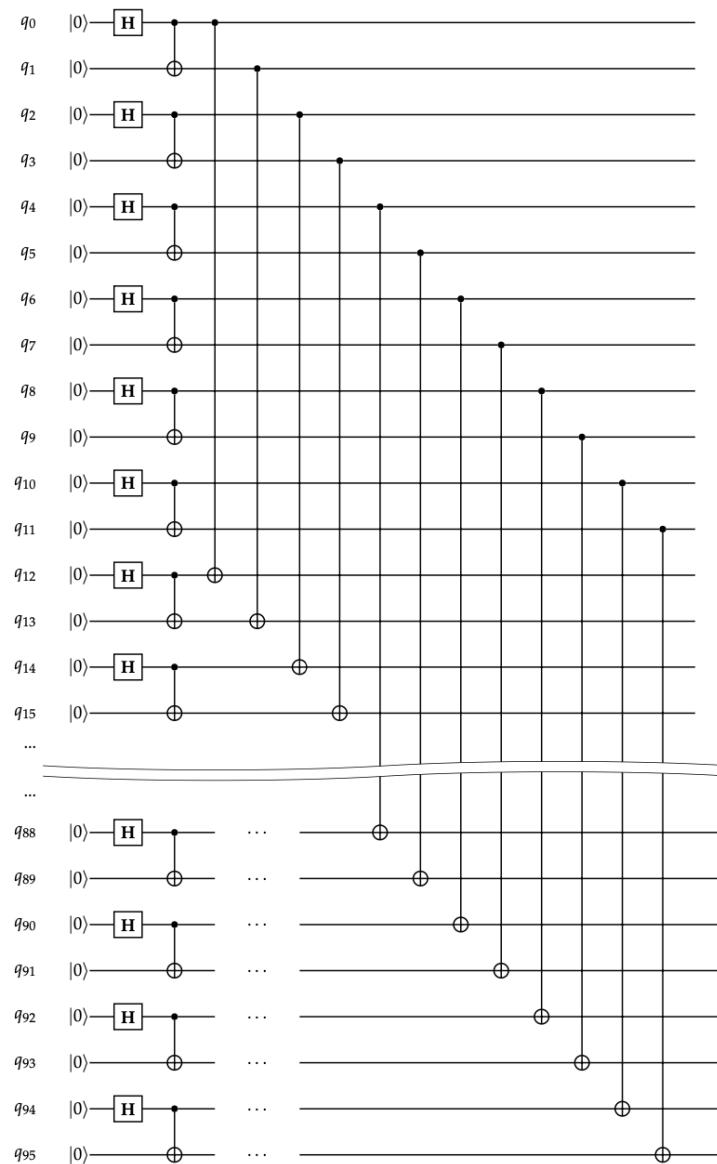
- Off-line batch processing with my own music for training the model (alter ego).
- On-line real-time interaction with the model for performing.
- Technically superior to the so-called RNN deep learning.
- Not convinced. It produced good results, albeit in a rather convoluted fashion.

Procedural Generation with Partitioned Quantum Cellular Automata

8 x 12 cells = 96 qubits



Ran for 50 cycles, 80,000 shots per cycle on IBM hardware.



References: 12-tone series and transformation rows

The image displays four staves of musical notation, each representing a 12-tone series or transformation row. The staves are arranged vertically, each with a treble clef and a key signature of one sharp (F#). The first staff is labeled '00' above the staff line. The second staff is labeled '01'. The third staff is labeled '10'. The fourth staff is labeled '11'. Each staff contains 12 notes, represented by black dots on the five-line staff. The notes are distributed across the octaves, with some notes being higher or lower than the previous one, illustrating the unique ordering of the 12 notes in each row.

Raw outputs ...

2 6 3 4

5

4

1

2

3

3

... composed score

$\text{J} = 120$ A

Vlns 1

Vlns 2

Vlas

Cellos

DBas

2

5 scratch

6

1 pizz. 3

3

4 pizz. 5

fff

pizz. 6

fff

pizz. 4

fff

pizz. 5

fff

THE FIRST QUANTUM COMPUTER MUSIC RELEASE!



<https://www.51beats.net/51vin005-miranda-qubism/>

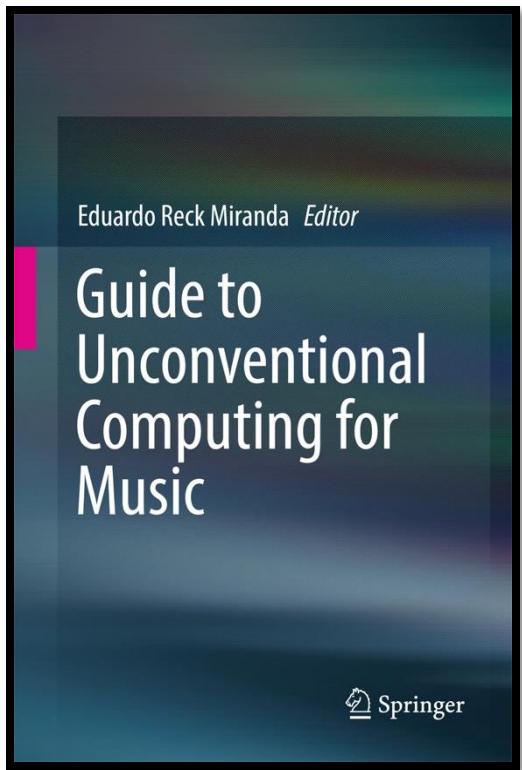
 **51 BEATS**
AN ELECTRONIC EXPERIENCE



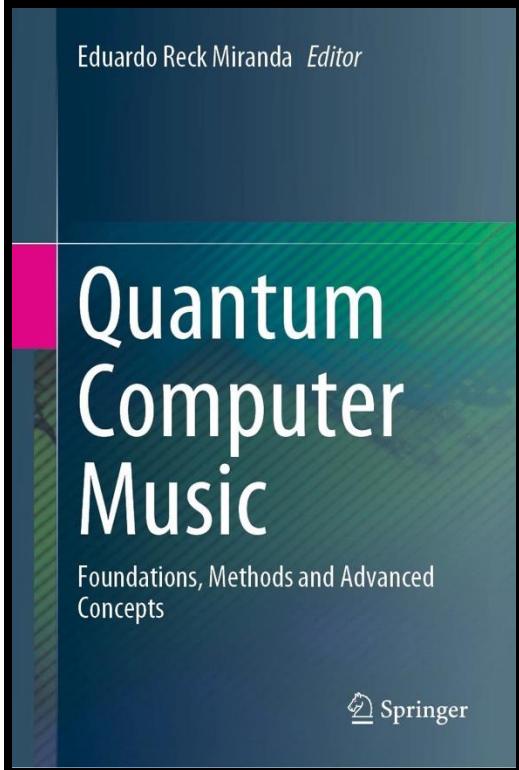
More on Science & Tech & Philosophy Behind the Music

Where you will find chapters penned by other presenters in this workshop (as indicated below)

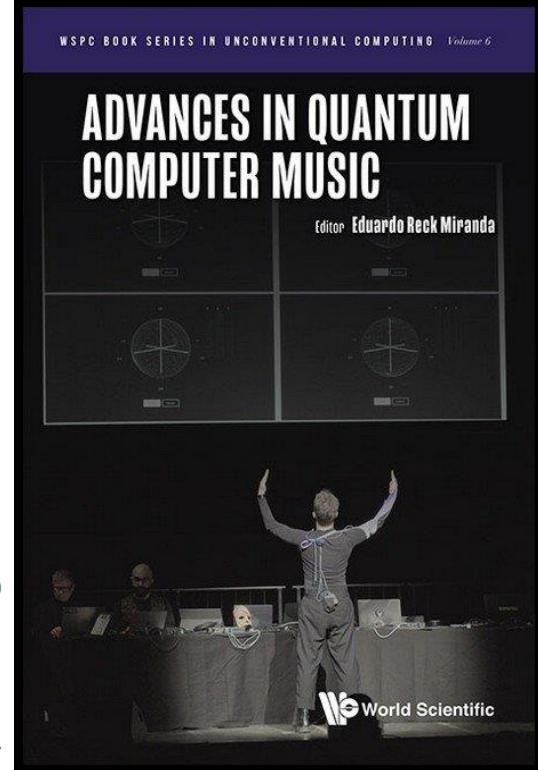
<https://link.springer.com/book/10.1007/978-3-319-49881-2>



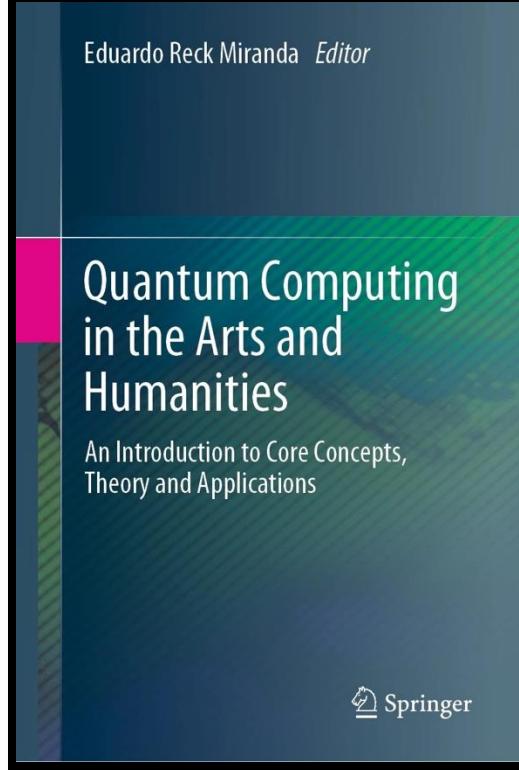
<https://link.springer.com/book/10.1007/978-3-031-13909-3>



<https://doi.org/10.1142/14025>



<https://link.springer.com/book/10.1007/978-3-030-95538-0>



M. Mannone

M. Mannone

M. Mannone
M. Cuffaro
R. Quehenberger

School of Art, Design and Architecture

PhD Quantum Computing in the Arts, Music and Humanities

Duration **Full time: 2-4 years**
Part time: 4-8 years

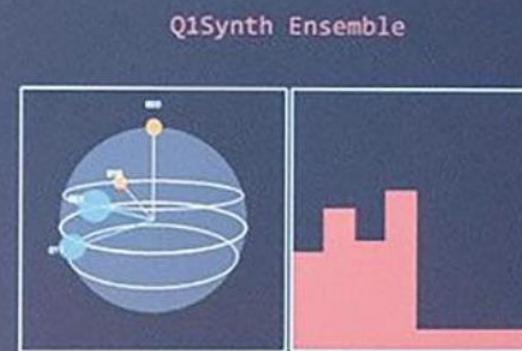
Course type **Full-time, Part-time route available**

Study location **Plymouth**

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"job is actively running "



Thank you!



UNIVERSITY OF
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www.plymouth.ac.uk/research/iccmr