Research Overview

Inria Paris, 19/11/2021

Mischa Woods

- Now: ETH Zurich, Switzerland → (In 2022) Inria Grenoble (QInfo Team)

ETH zürich

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- Now: ETH Zurich, Switzerland → (In 2022) Inria Grenoble (QInfo Team)

- Resource quantification for channel implementation
- Novel approaches to quantum error correction

Co-authors: Yuxiang Yang, Yin Mo, Joseph M. Renes, Giulio Chiribella, Shishir Khandelwal, Maximilian P.E. Lock, Costantino Budroni, Giuseppe Vitagliano, Ralph Silva, Gilles Pütz, Sandra Stupar, Renato Renner, Álvaro M. Alhambra, Michał Horodecki, Jonathan Oppenheim, Paul Erker, Mark T. Mitchison, Nicolas Brunner, Marcus Huber.

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Resource quantification for channel implementation

- Quantum channel applied at time t_0: $\rho_{\mathrm{A}}(t_0) \to \rho_{\mathrm{A}}(t_1)$

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"clock"

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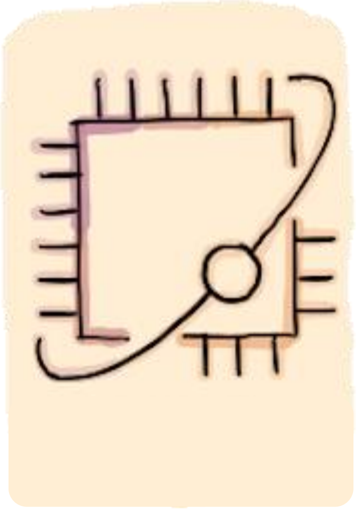
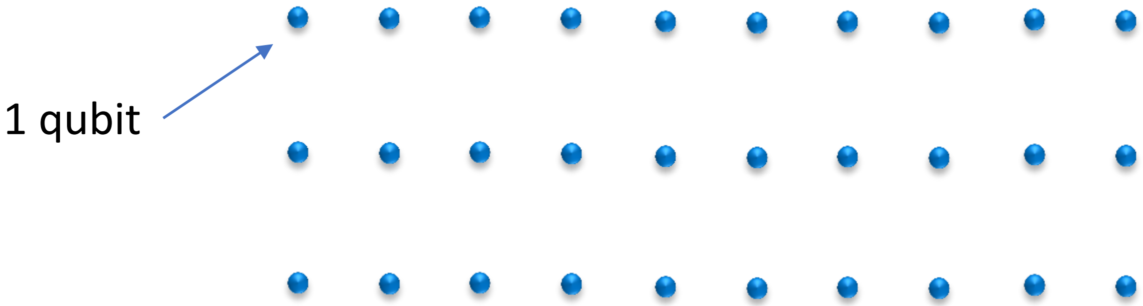
"clock"

- ➢ No-go theorem: equality only possible with "infinite energy clock"
- ➢ Two main research directions:
  1) Cost of channels with catalysts — [1912.05562, Phys. Rev. X (to appear) (2021)] [1607.04591, Annales Henri Poincaré (2019)]
  2) Cost of implementing a clock — [1609.06704, Phys. Rev X (2015)] [2005.04628, Quantum (2021)] [arXiv:1806.00491]

Novel approaches to quantum error correction



- The problem of errors:



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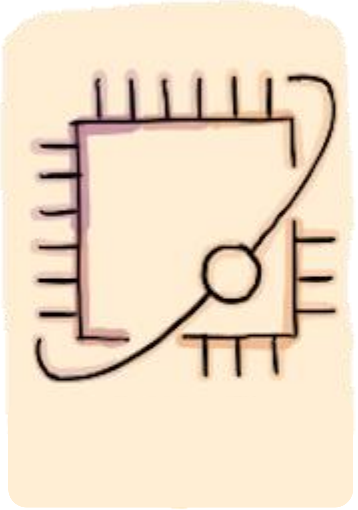

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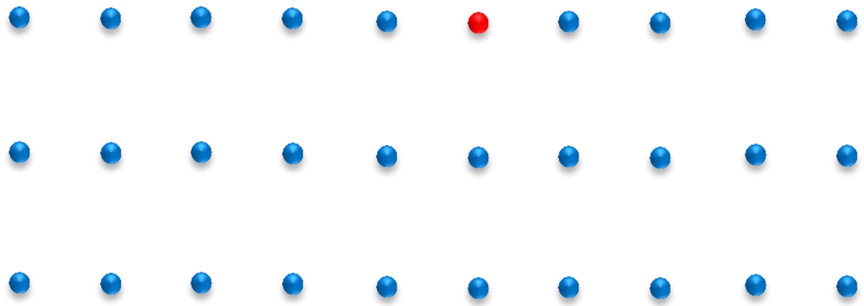

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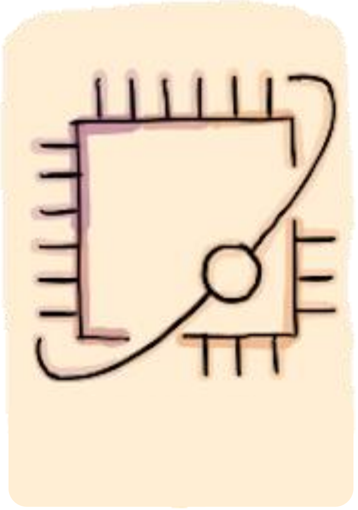

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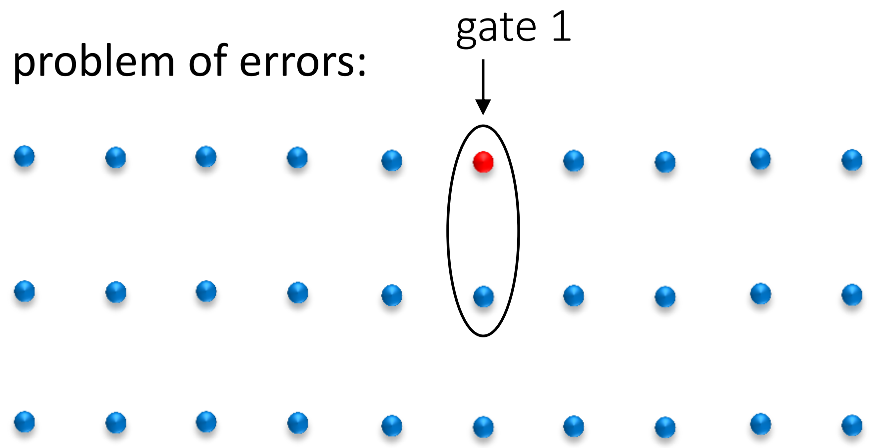

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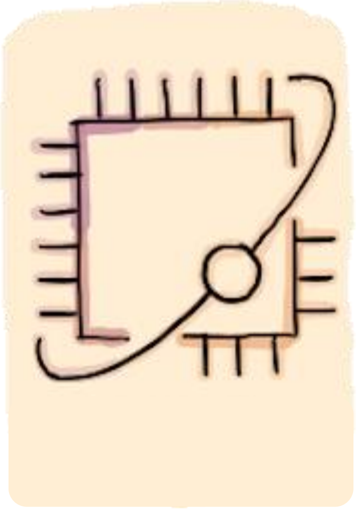

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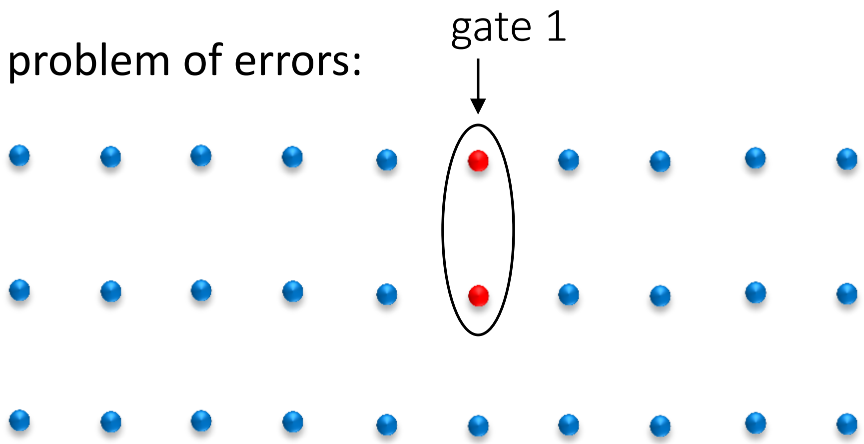

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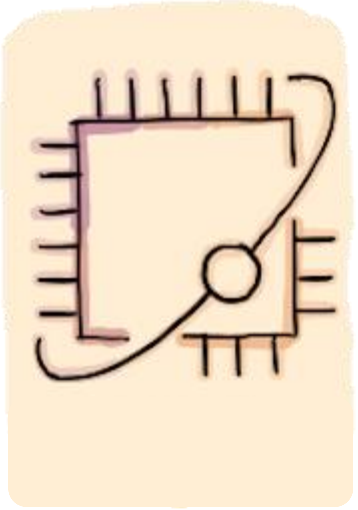

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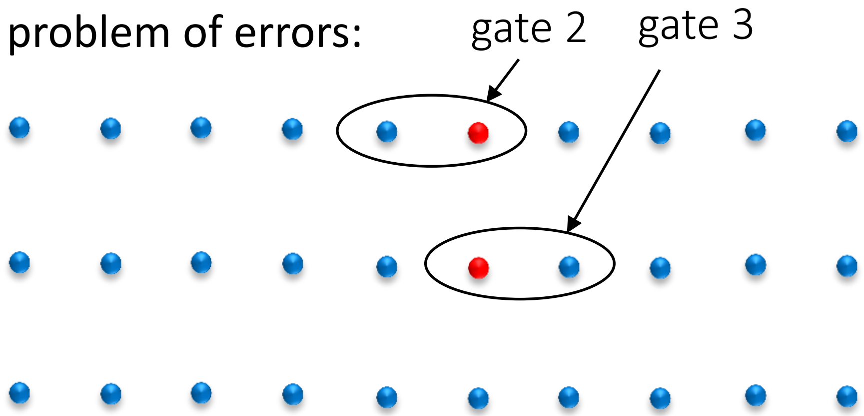

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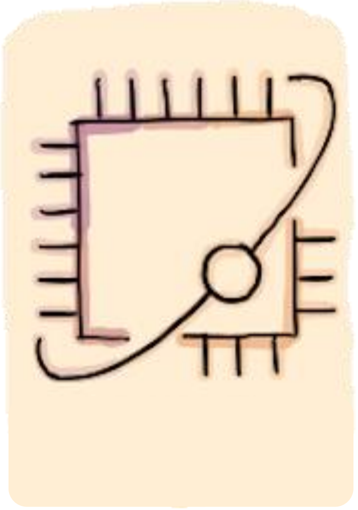

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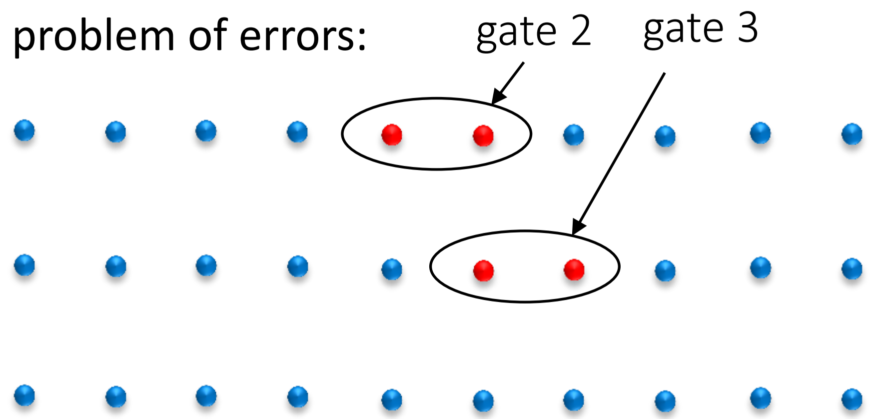

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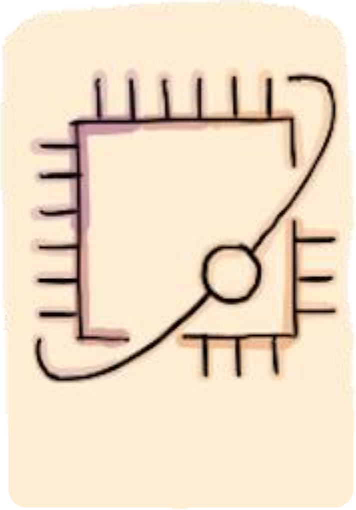

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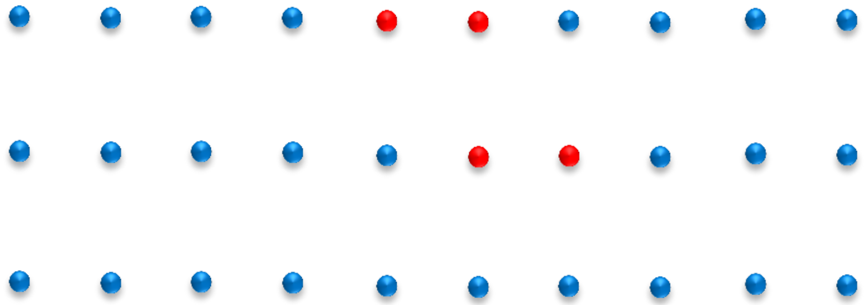

- A small local error propagates into a large error!

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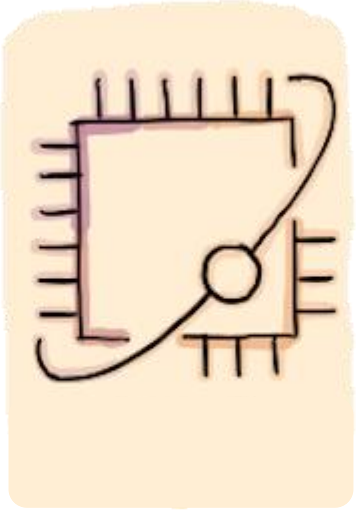

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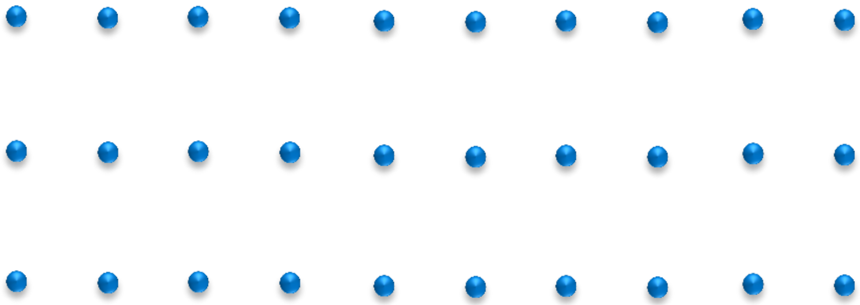

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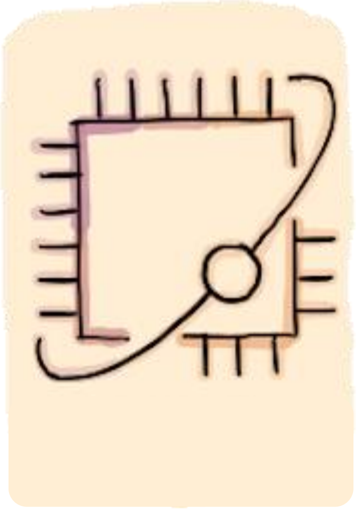

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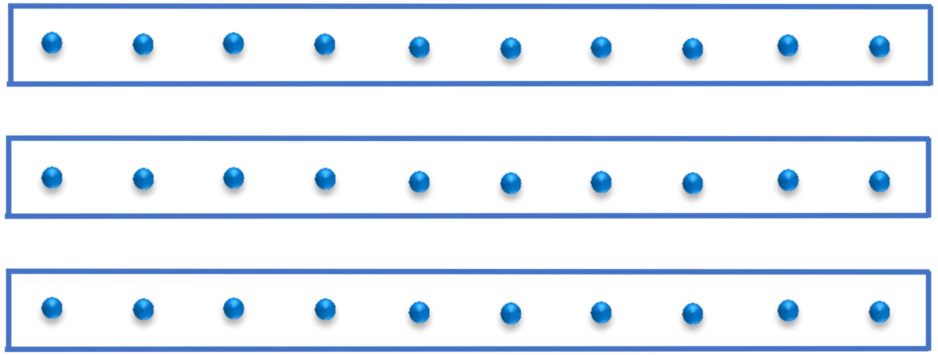

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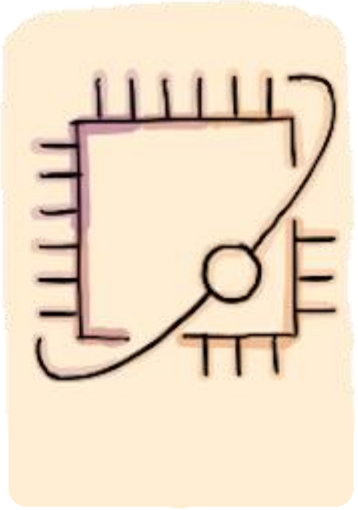

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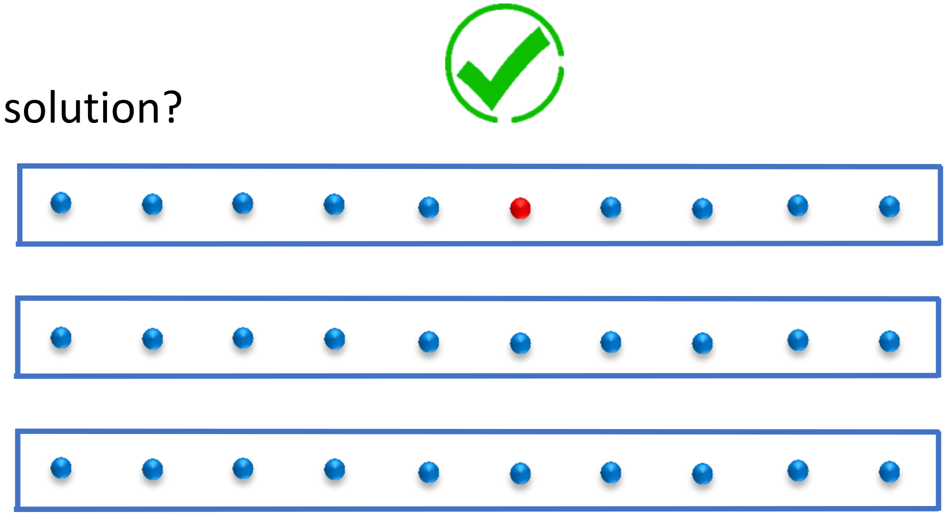

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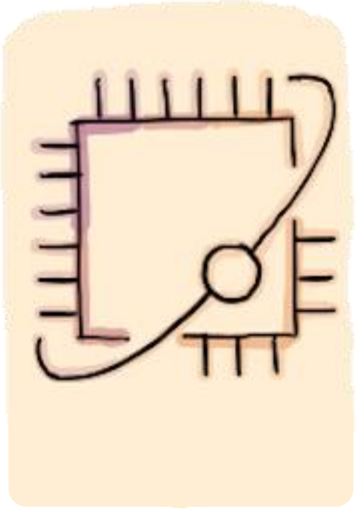

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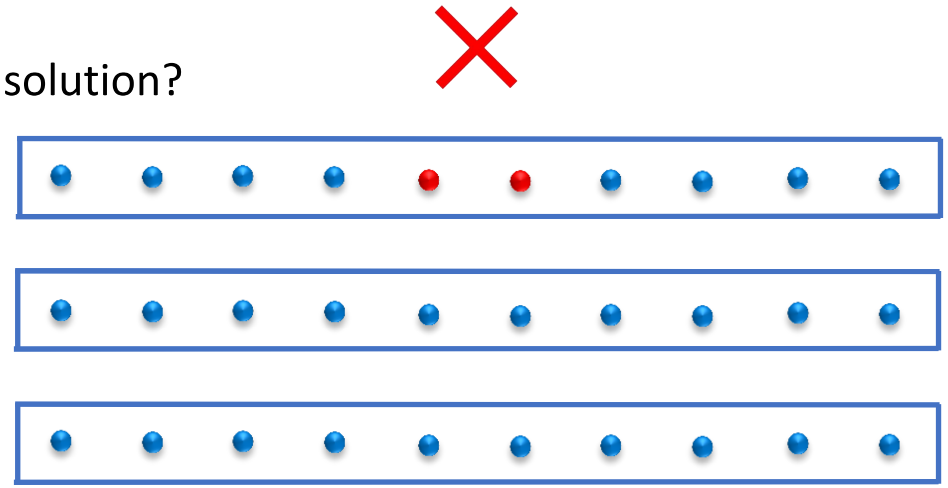

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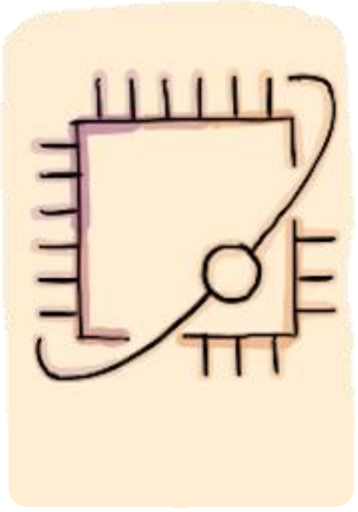

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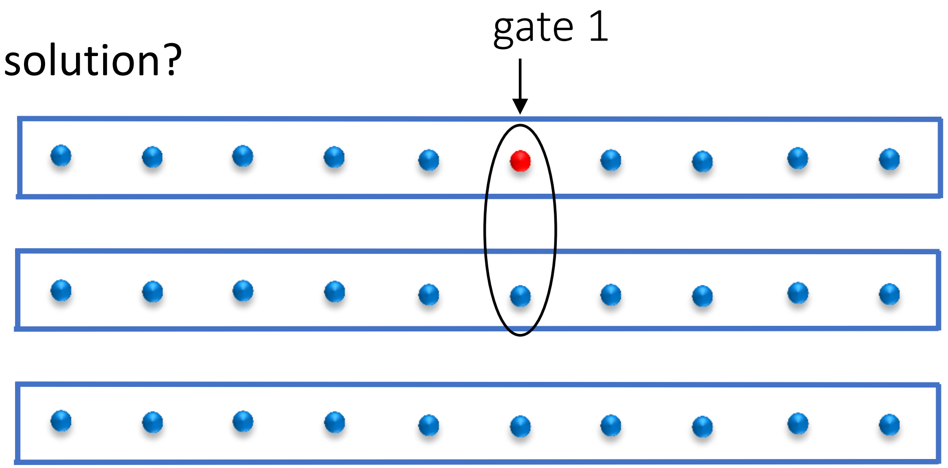

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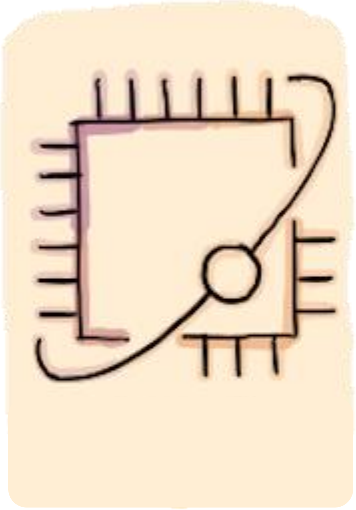

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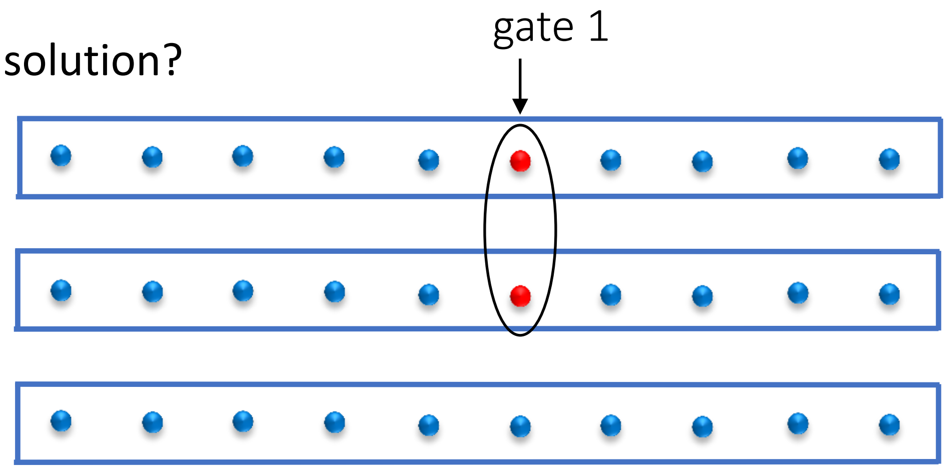

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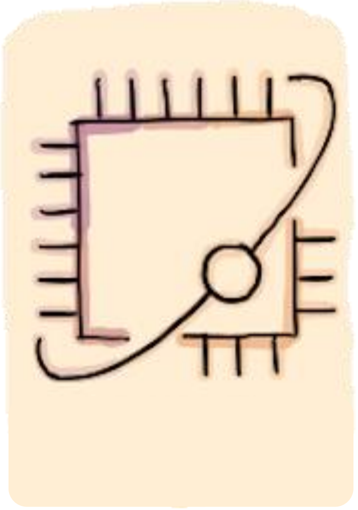

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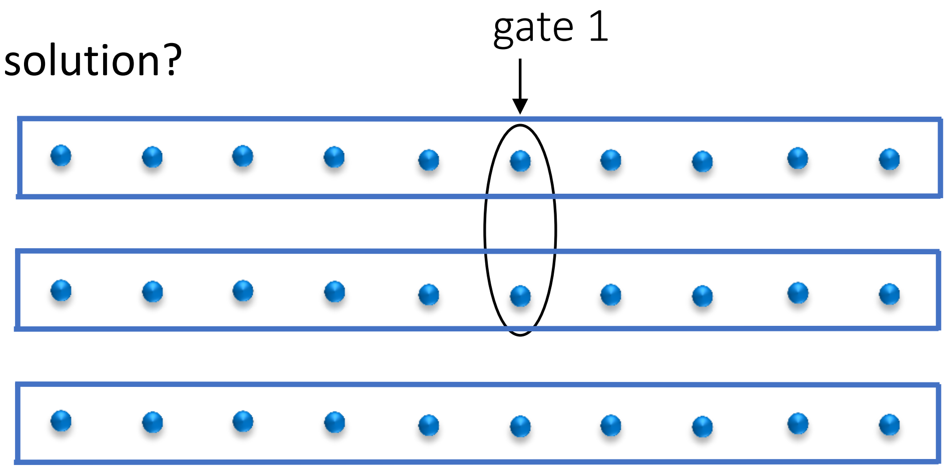

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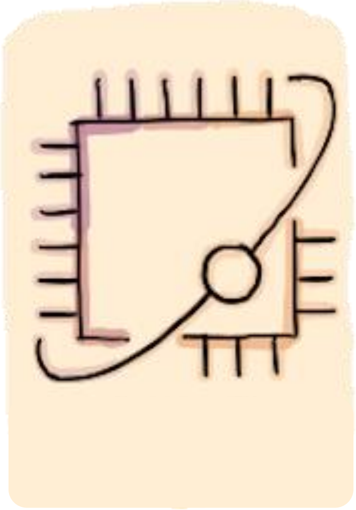

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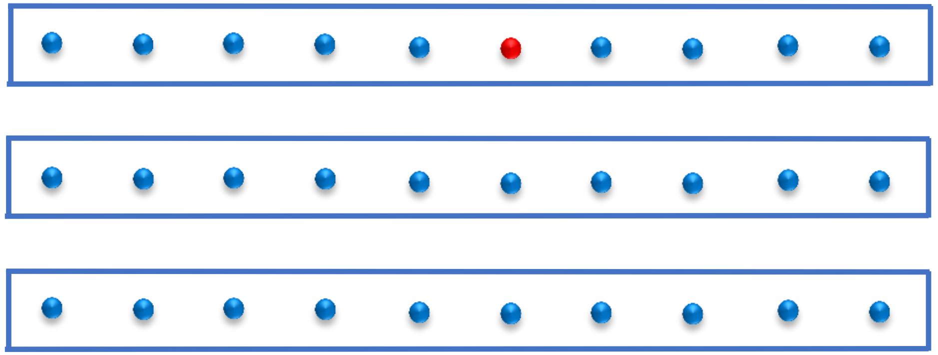

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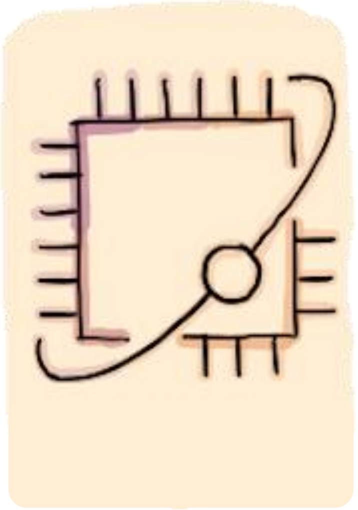

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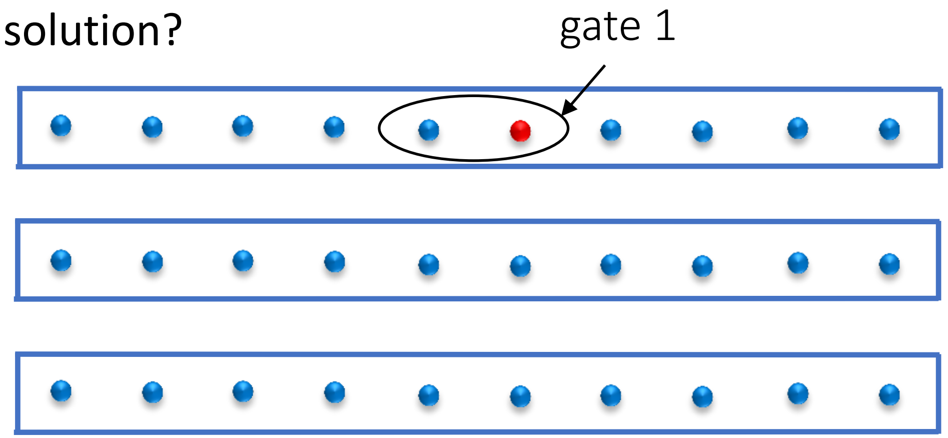

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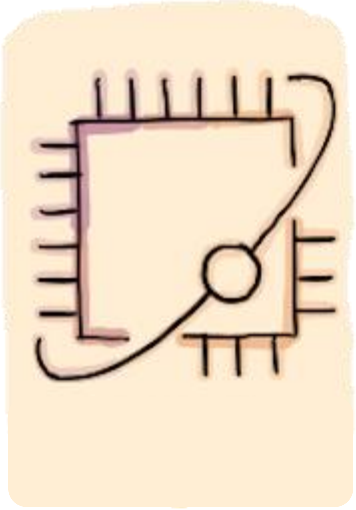

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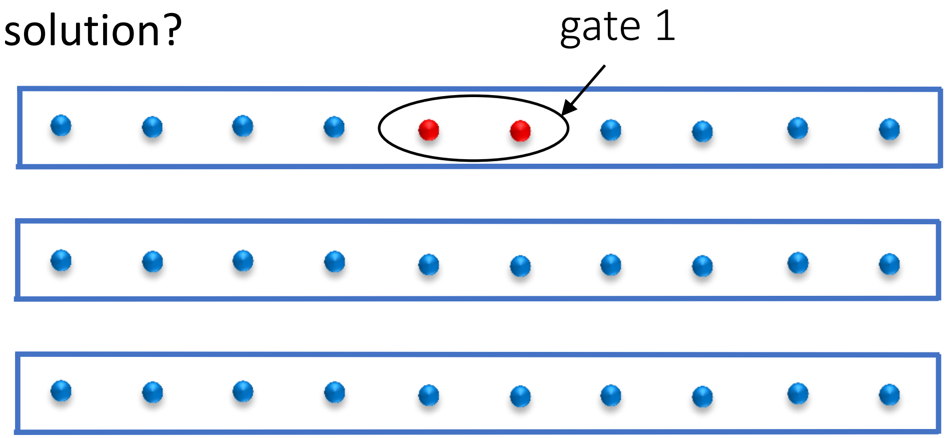

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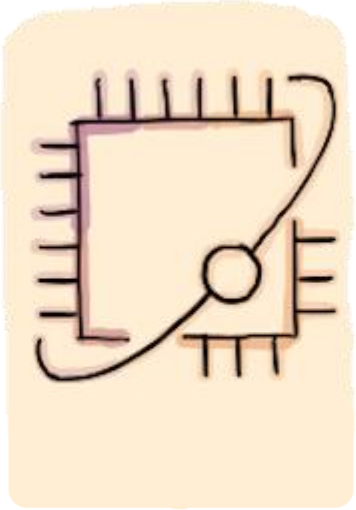

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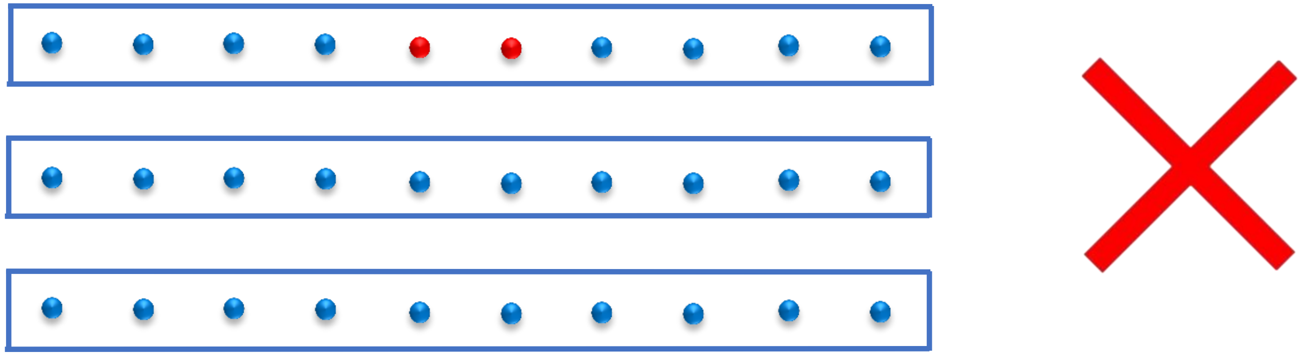

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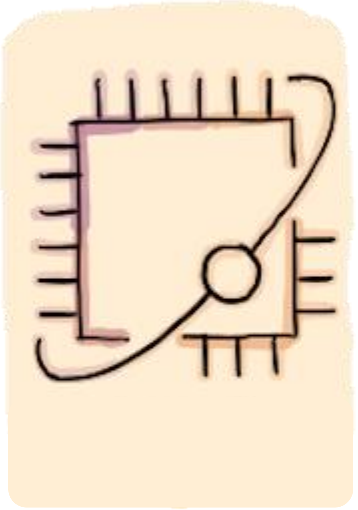

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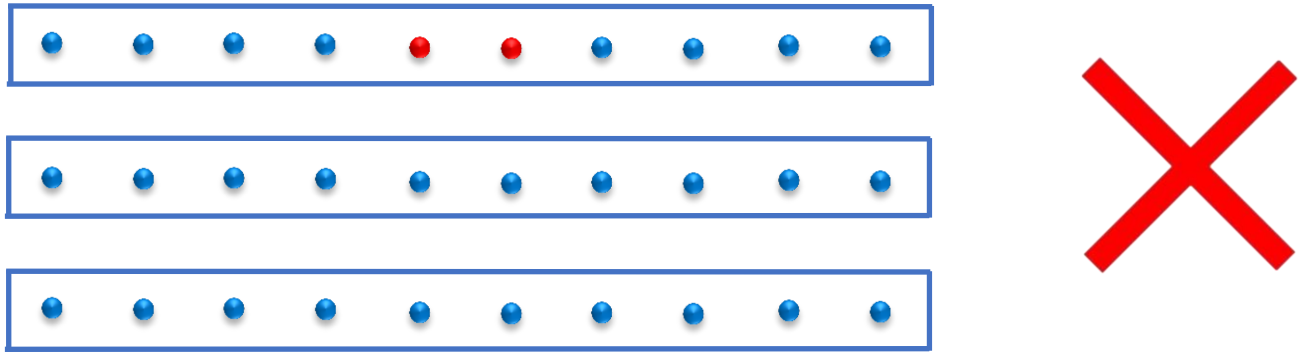
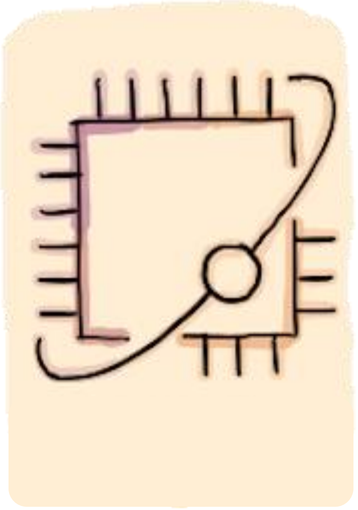
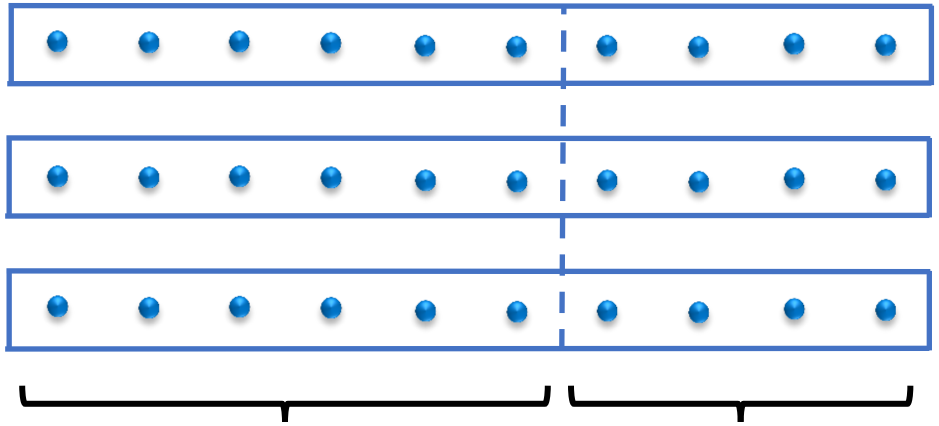


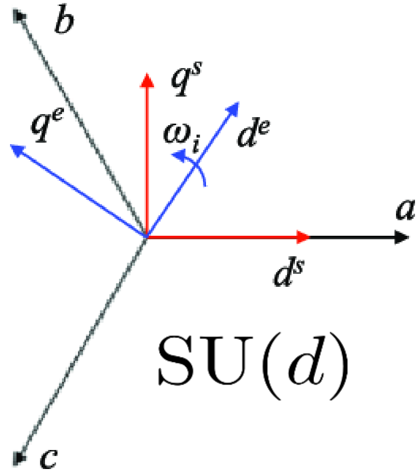
- Eastin-Knill theorem: No, we cannot! ☹

Novel approaches to quantum error correction



- My work: new solution via reference frames:
  - Observe: problematic gates $\equiv$ forbidden symmetries
  - Reference frames can be used to “lift” forbidden symmetries
  - Therefore: reserve some qubits to use as reference frames





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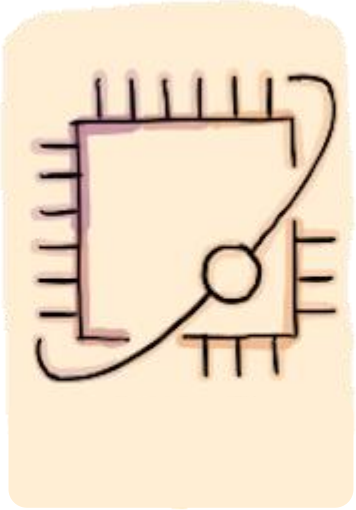

- My solution:
  - Can now perform all computations with simple error correction
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  [1902.07725, Quantum (2019)]
  [ArXiv: 2007.09154, (2021)]

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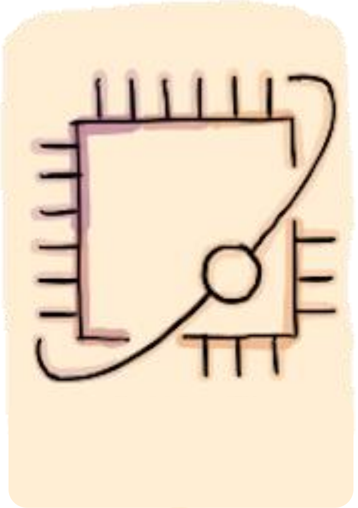

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[P. Faist, S. Nezami, et al. PRX (2020)] [P. Hayden, S. Nezami, et al. PRXQ (2021)]

- Follow up papers by other authors:

[A. Kubica, et al. ArXiv: 2004.11893 (2020)]
[D. Wang, et al. Phys. Rev. Research (2020)]
[S. Zhou, et al. ArXiv: 2005.11918 (2020)]
[L. Kong, et al. ArXiv: 2102.11835 (2021)]
[Zi-Wen Liu et al. ArXiv: 2111.06355 (2021)]
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Near term future directions

- Fully develop my approach to quantum error correction
- Other problems involving, clocks, control, and foundations

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➢ Online video resources:

see AHP Award Ceremony 2021, Geneva [My work on control]

see QIP Plenary talk 2020 and TQC 2021 talk [My work on QEC]