# A Programmable Chemical Computer with Memory and Pattern Recognition

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# Structure of the Presentation

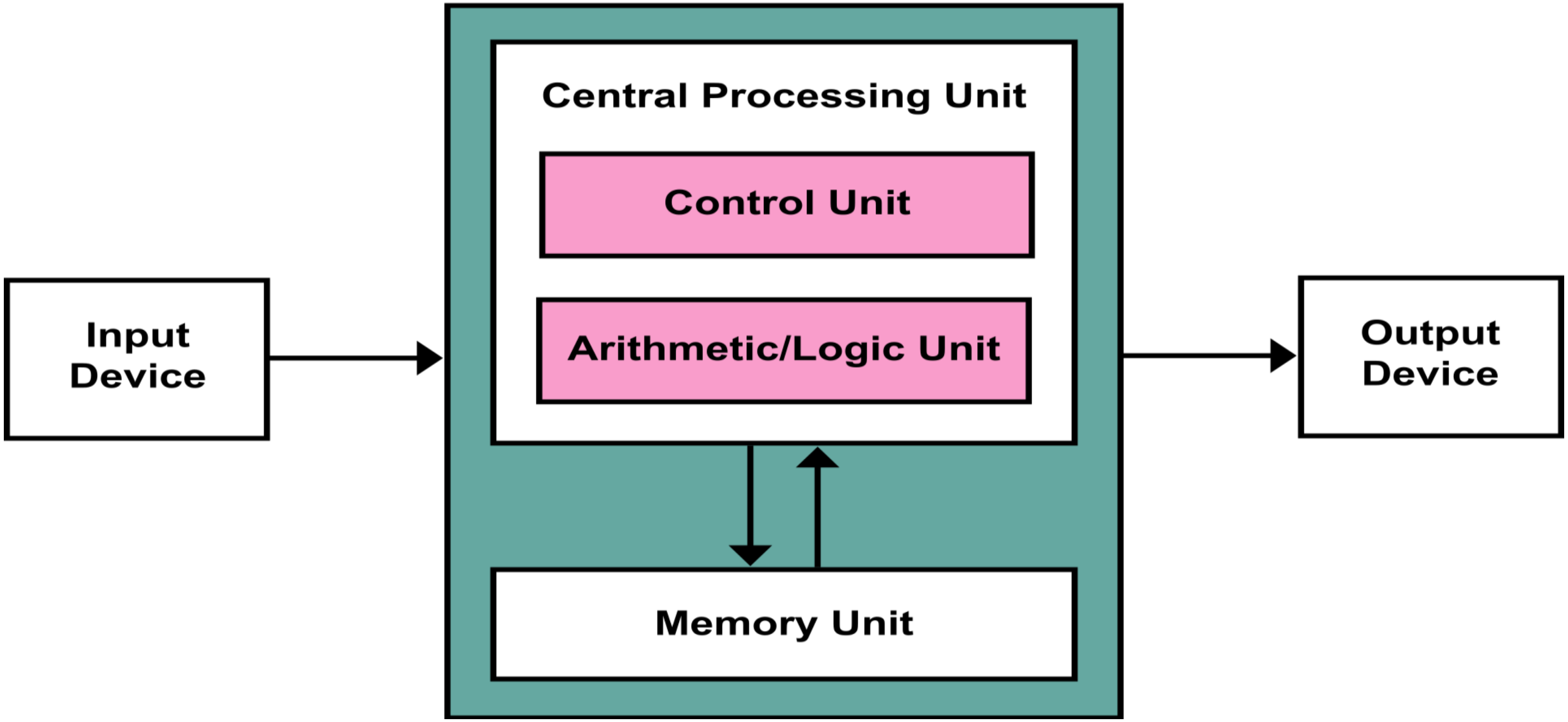
- Background, Problem & Goal
- Novelty
- Key Approach and Ideas
- Mechanisms (in some detail)
- Key Results: Methodology and Evaluation
- Summary
- Strengths
- Weaknesses
- Thoughts and Ideas
- Takeaways
- Open Discussion

Summary

Discussion

# Background, Problem & Goal

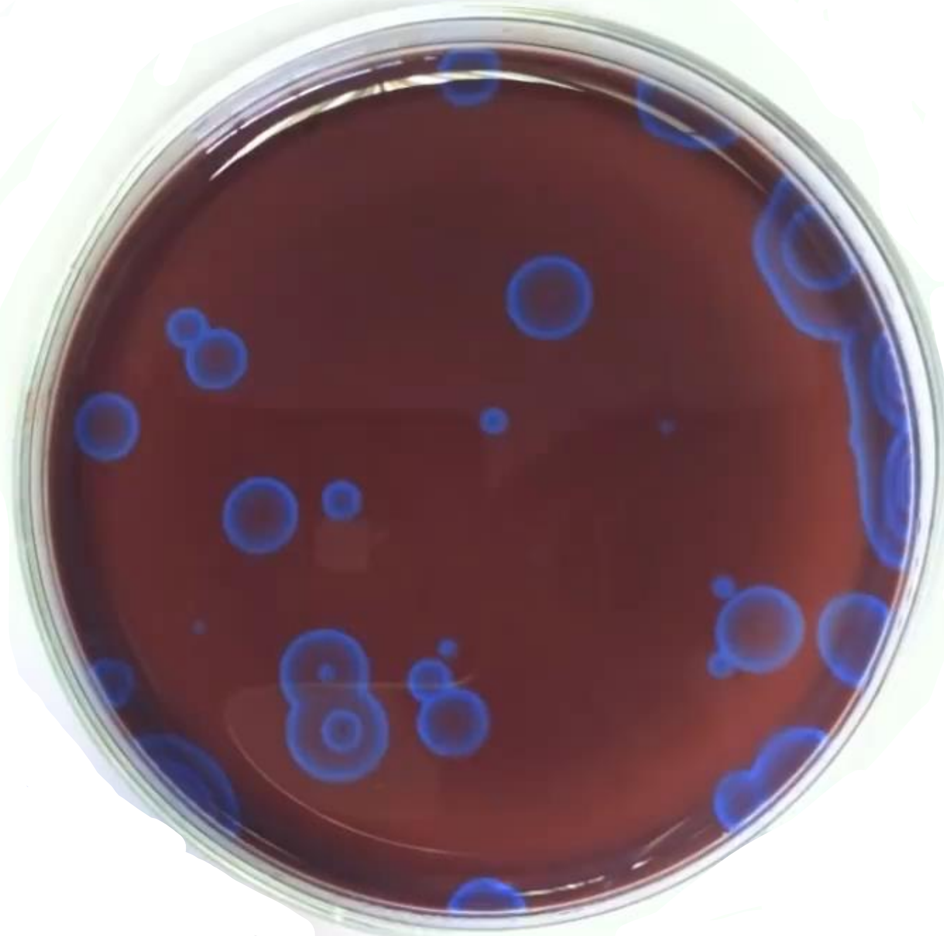
# Blessing and Curse:



# Short Introduction to Chemical Computing

- Based on oscillating chemical reactions
- Mainly utilizes Belousov-Zhabotinsky-Reaction
- First chemical computer from 1989 performed image processing

# Belousov-Zhabotinsky (BZ) reaction



# Executive Summary

- Motivation: Limitations of Von Neumann Model
- Problem: Chemical computers aren’t programmable, one architecture for one specific task
- Goal: Create a flexible, programmable, chemical computer
- BZ-Platform: flexible input through speed addressable stir bars
- Evaluation:

  Use BZ-platform as chemical encoder and decode with NN,

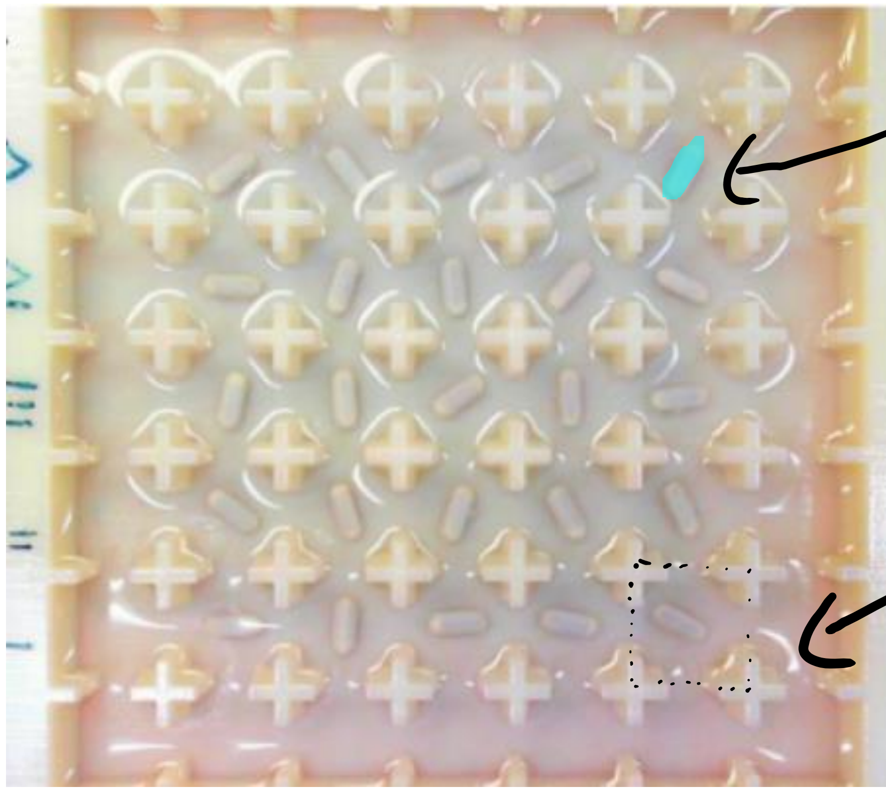
  92.5% accuracy,

  equivalent to 60M logic gates,

  1M gates per oscillation (~40s)

# Novelty

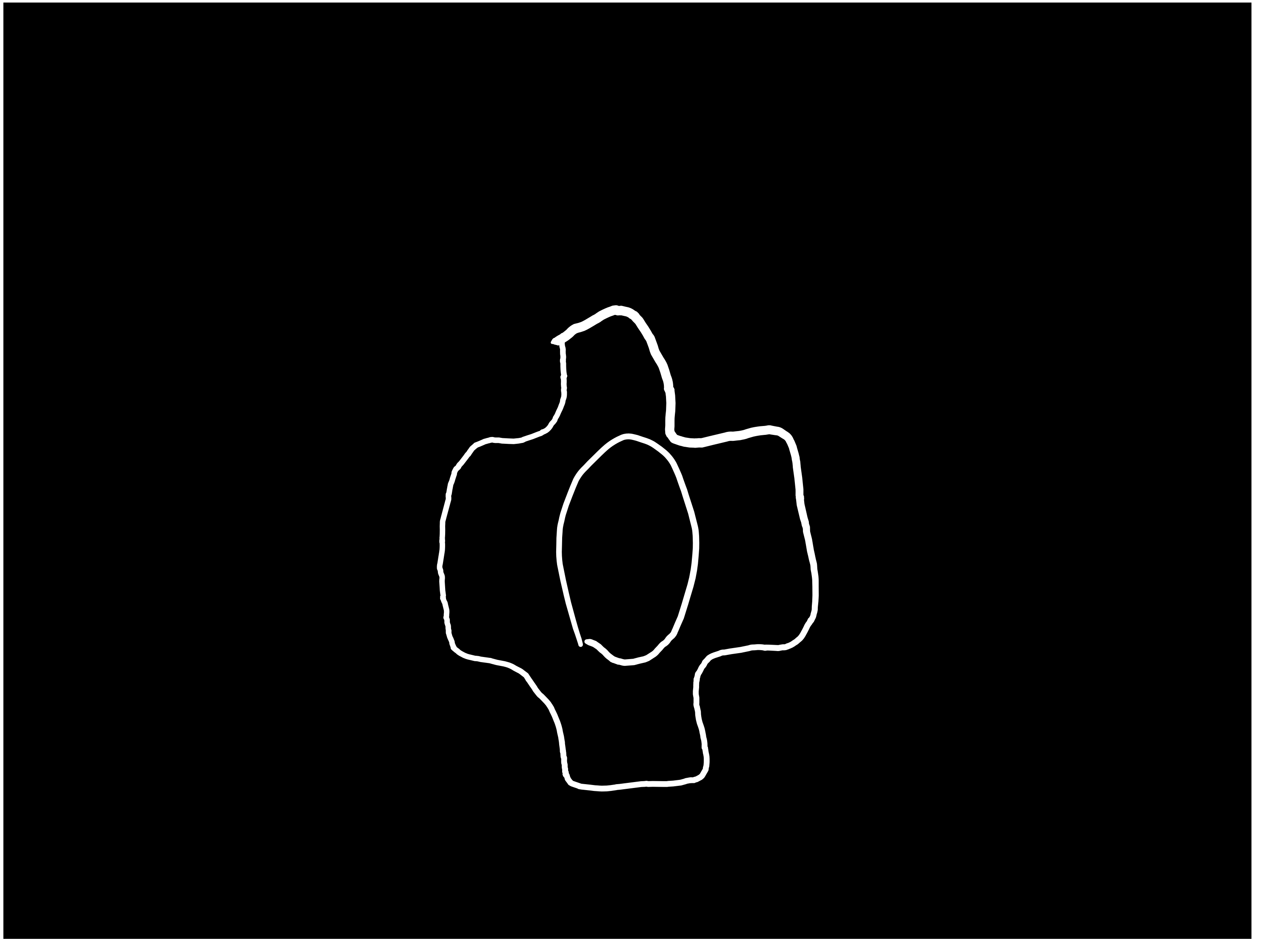
# BZ-Platform



# Key Approach and Ideas

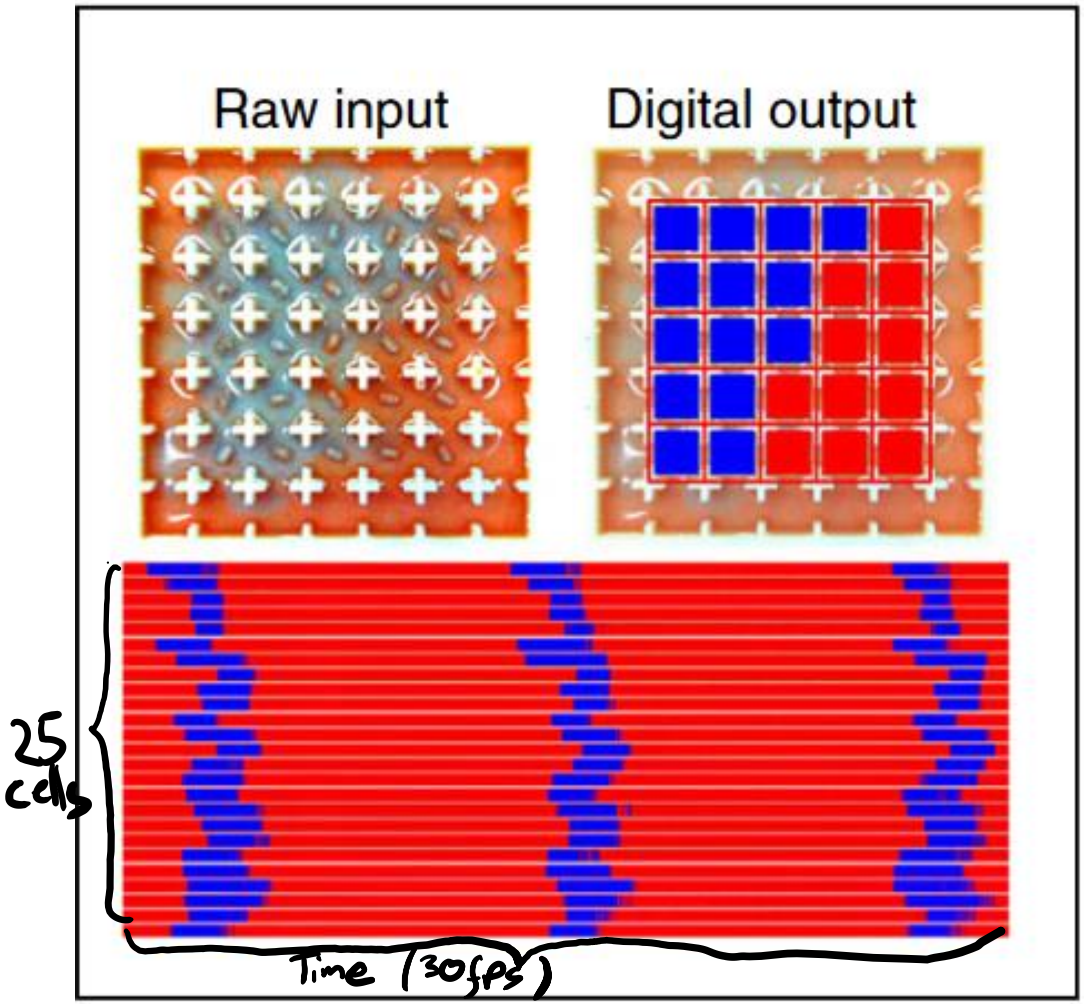
faster stirring =>
quicker oscillation & more coupling

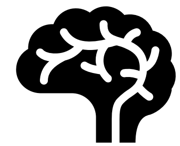
Reliable Patterns

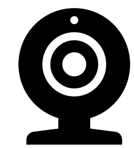


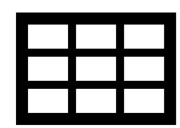
# Mechanisms (in some detail)

# Model Setup



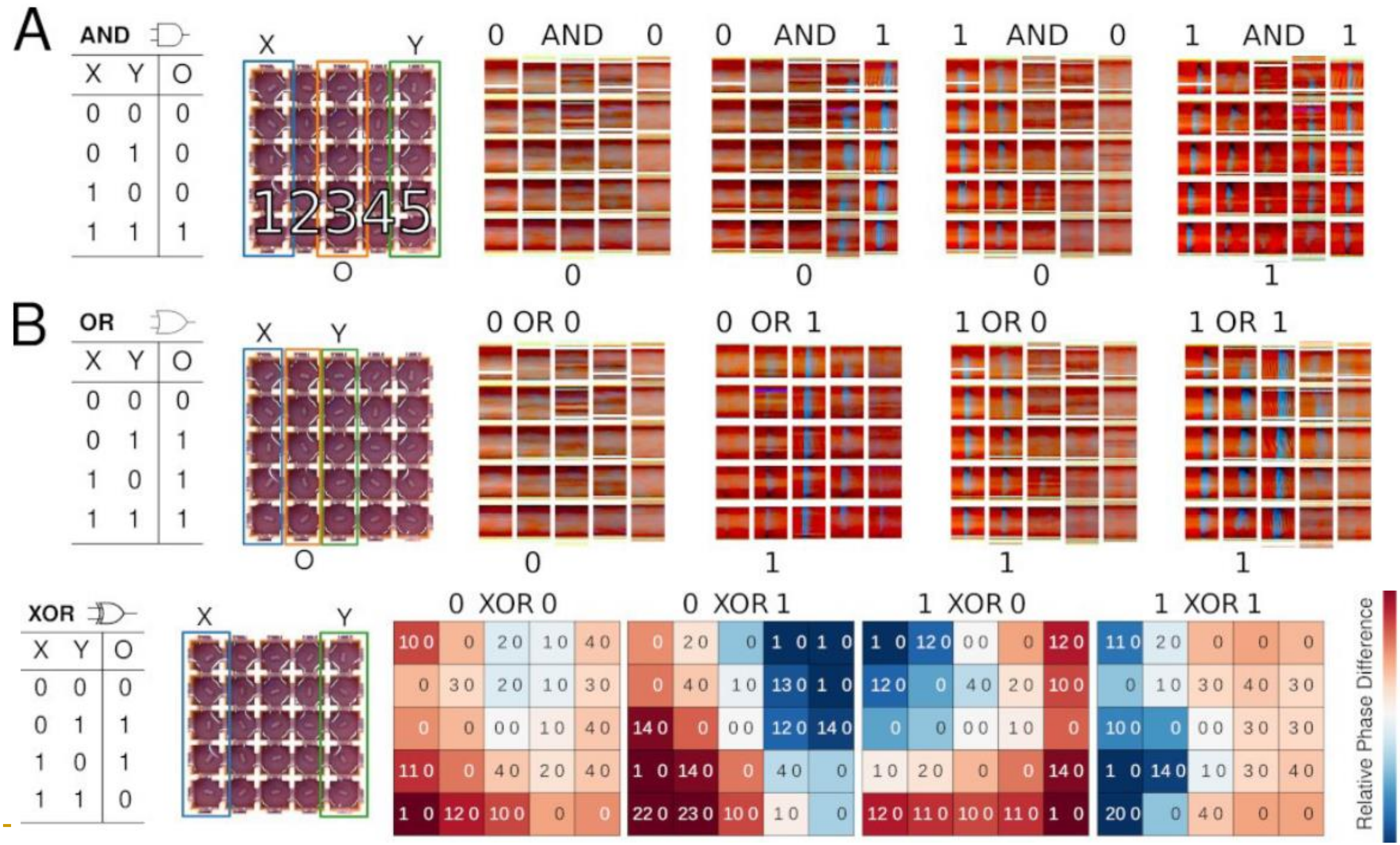




# $2.9 \times 10^{17}$ Programs?

- 5 speed choices per cell, 25 total cells
- $5^{25} \approx 2.9 \times 10^{17}$
- They count every combination as a program
- 3x3 Rubik's cube ca. $5 \times 10^{19}$

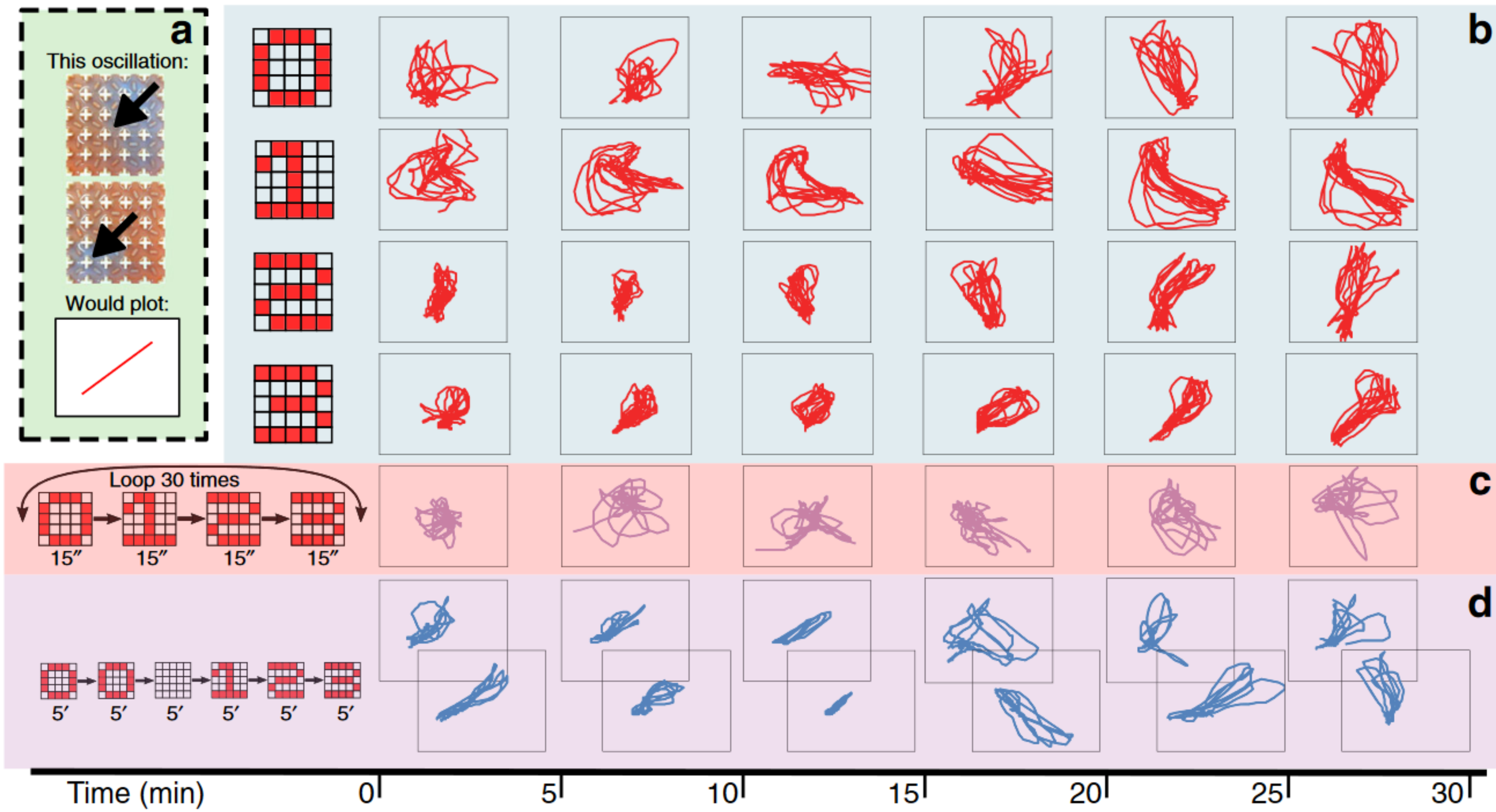
# Basic Logic Gate Emulation



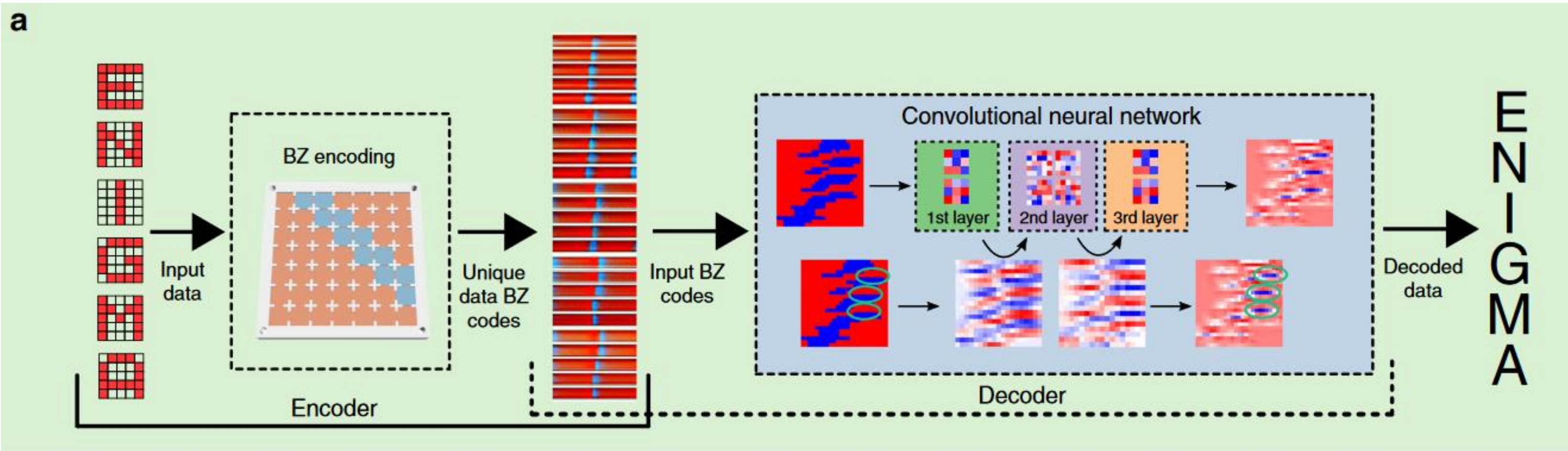
# Encoding and Decoding Data with BZ

# Key Results: Methodology and Evaluation

# Experiment for Pattern stability



# Encoding Results




- 92.5% accuracy
- BZ encoder equates 60,000,000 logic gates
- 1,000,000 gates per oscillation (40s)
- Obtained by size of the decoder
- Compared to Intel 8086: 29,000 transistors

# Summary

# Summary

- The authors use the oscillating Belousov-Zhabotinsky reaction to create a coupled oscillator system.
- The inputs are handled by individually addressable stir bars in each cell.
- 5 different speeds for the stir bars lead to varied coupling and different oscillation speeds.
- Architecture more flexible than any other chemical computer by being programmable through its inputs

Any Questions so far?

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# Strengths

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- Groundbreaking proof-of-concept, getting chemical computers much closer to being actually programmable
- Memory, input and computing happen in the same place, everything is parallel
- Built on top of other work, but comparatively cheaper and more stable than other coupled-oscillator systems
- Openness is applaudable, detailed guides, 3d models and even their codebase is completely open-source

# Weaknesses

# Weaknesses

- Workload and Metrics they used were questionable at best. Still have to show that it is actually programmable, and not just a reliable pattern generator.
- Number of potential programs meaningless for actual usability, their experiment also shows that the emerging patterns are not all that reliable
- Architecture limitations: Reliant on conventional computers, slow oscillation, only 30 minutes runtime, releases toxic gas (bromine and CO)
- Actual paper is 100 pages long, since paper is not understandable without their 80 pages of supplementary material.

# Thoughts and Ideas

# Thoughts and Ideas (and Discussion)

- Nothing stopping this from being scaled down
- Operation time? Oscillation speed?
- Extending the architecture?
- What types of algorithms do you think could benefit from such a computing model?

# Takeaways

# Takeaways

- Great proof of concept
- Innovation in a very slowly developing field

But:

- Still reliant on image-recognition AI to compute.
- Architecture maybe exceeds in very context based workloads like encoding a picture, but programmability as we understand it is not shown in this paper.

# Open Discussion

# Useful links

- - The preprint with a ton of extra info:
- https://chemrxiv.org/ndownloader/files/14357597
- - Their github, containing all the Arduino and NN code:
- https://github.com/croningp/BZ1