



Paper

What are "serial" tasks?

"9 women **CANNOT** make a baby in a month"

The Serial Scaling Hypothesis



Why diffusion models are not serial reasoners?

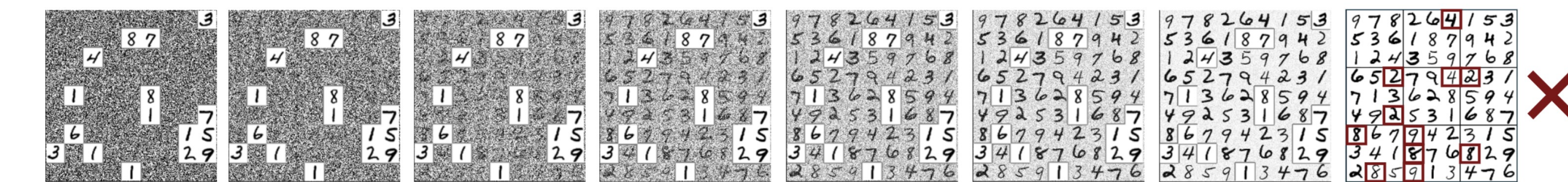
Yuxi Liu* Konpat Preechakul* Kananart Kuwarananchaoren† Yutong Bai

†Independent

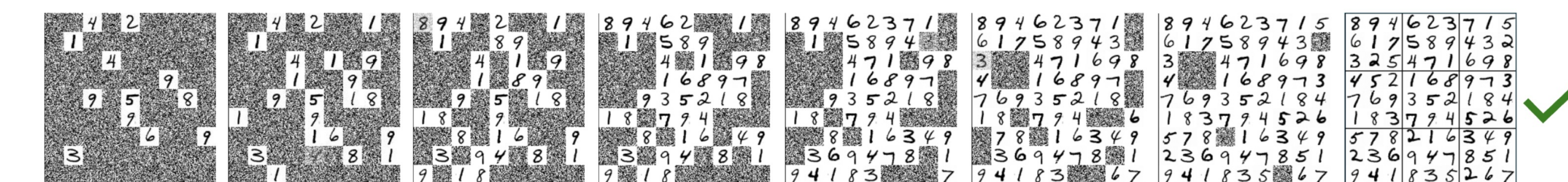
The Hypothesis

Problems involve reasoning, decision making, and dynamic systems need more **SERIAL** computation, not just **PARALLEL** ones.

Solving sudoku with diffusion



Solving sudoku with autoregressive

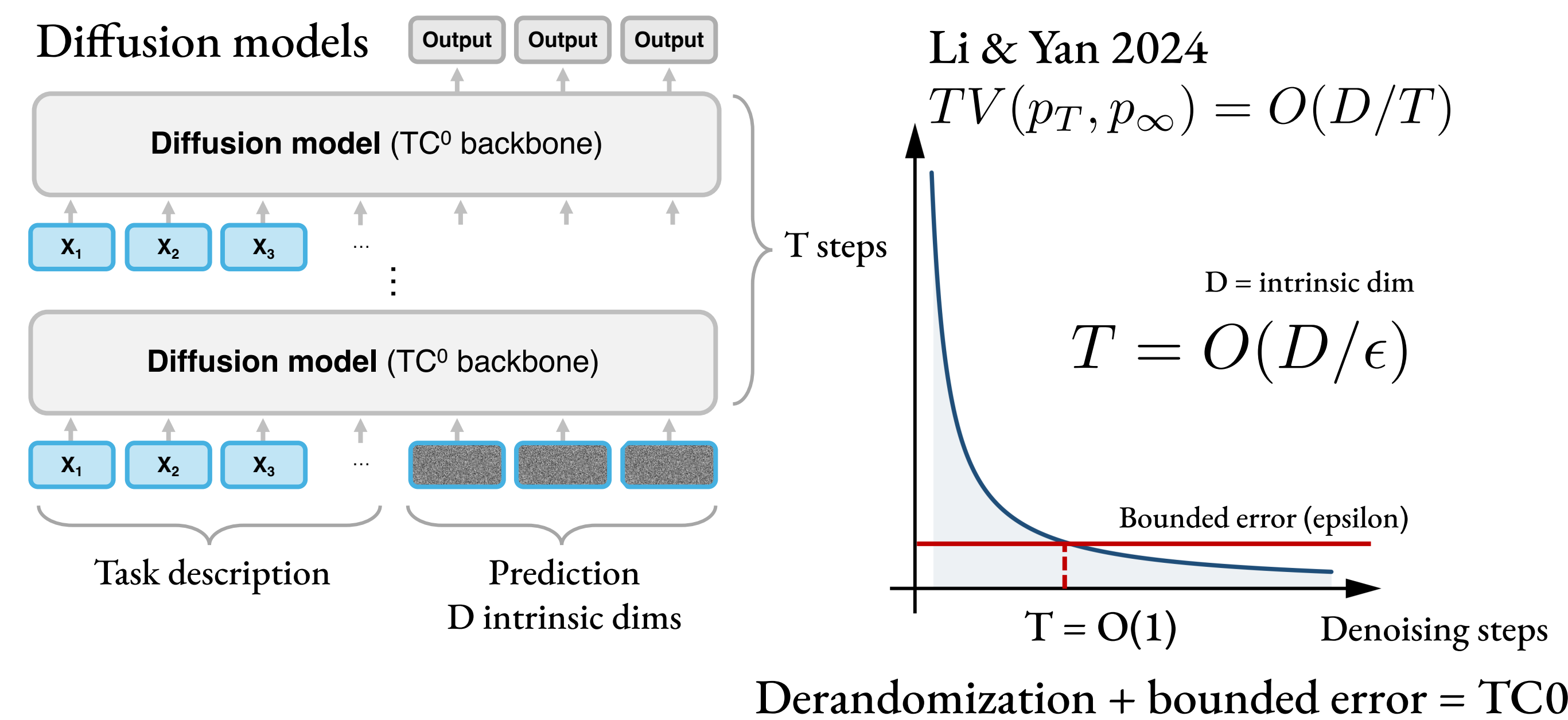


*Wewer 2025

Theorem (Informal)

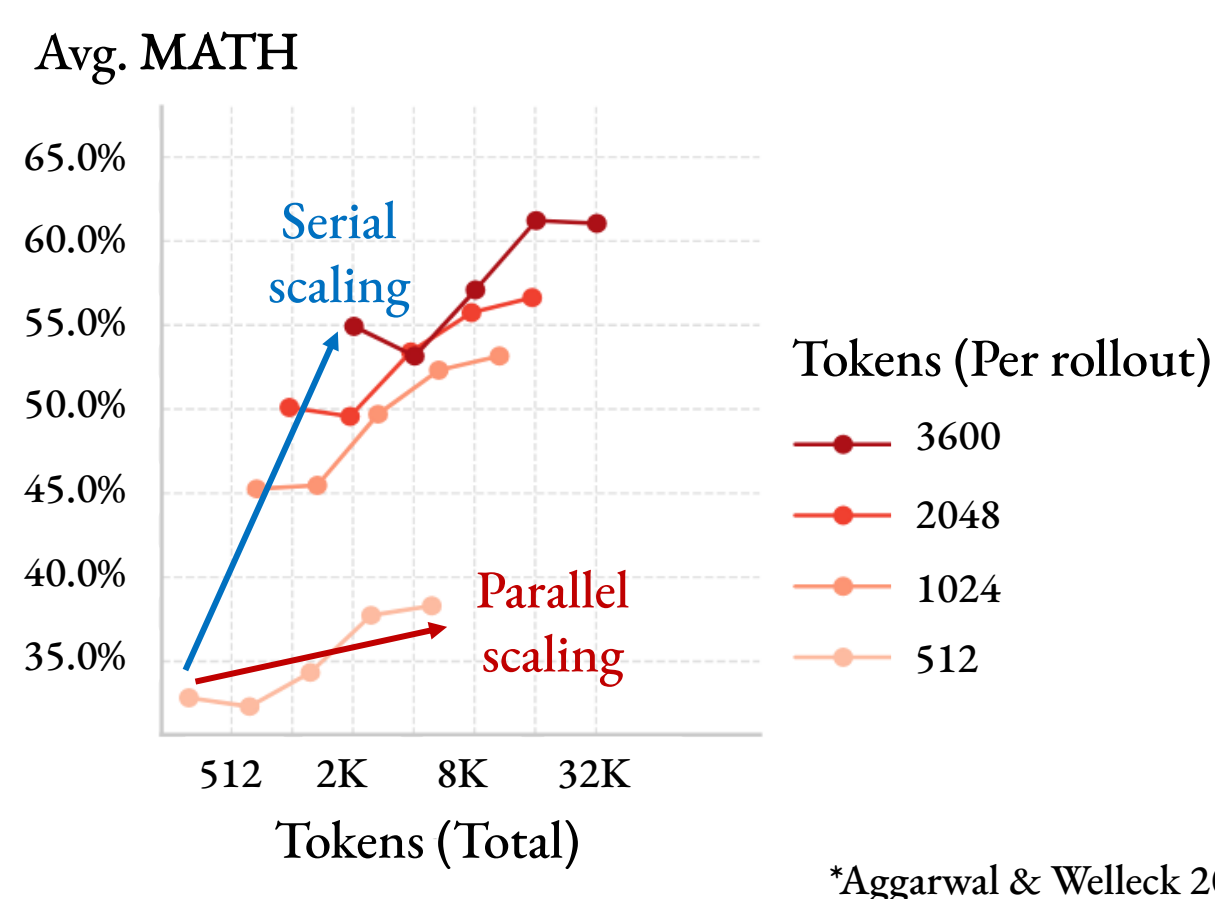
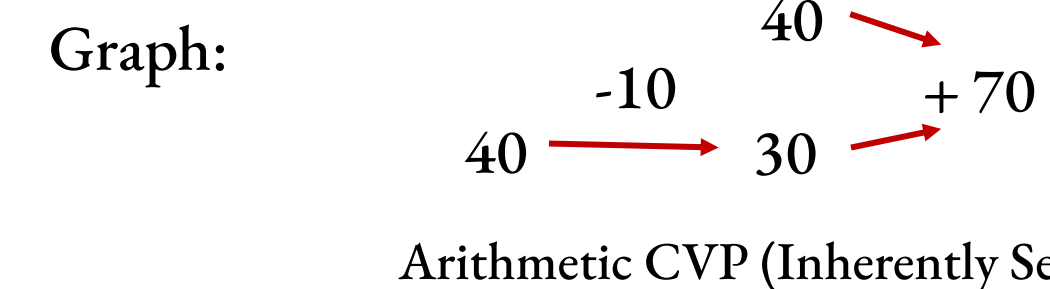
If a problem can be solved by a diffusion model with a TC0 backbone with high probability with infinite diffusion steps, the problem is in TC0.

TC0 ≈ fixed-depth network



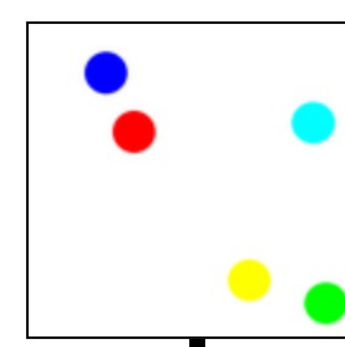
Math Q & A

GSM8K: James spends 40 years teaching. His partner has been teaching for 10 years less. How long is their combined experience?

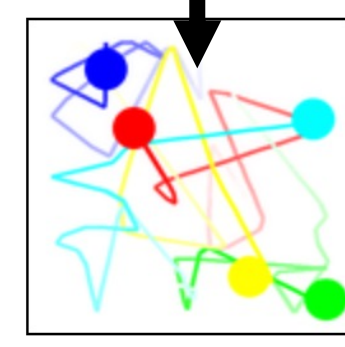


Many-body physics

Input (Initial state)

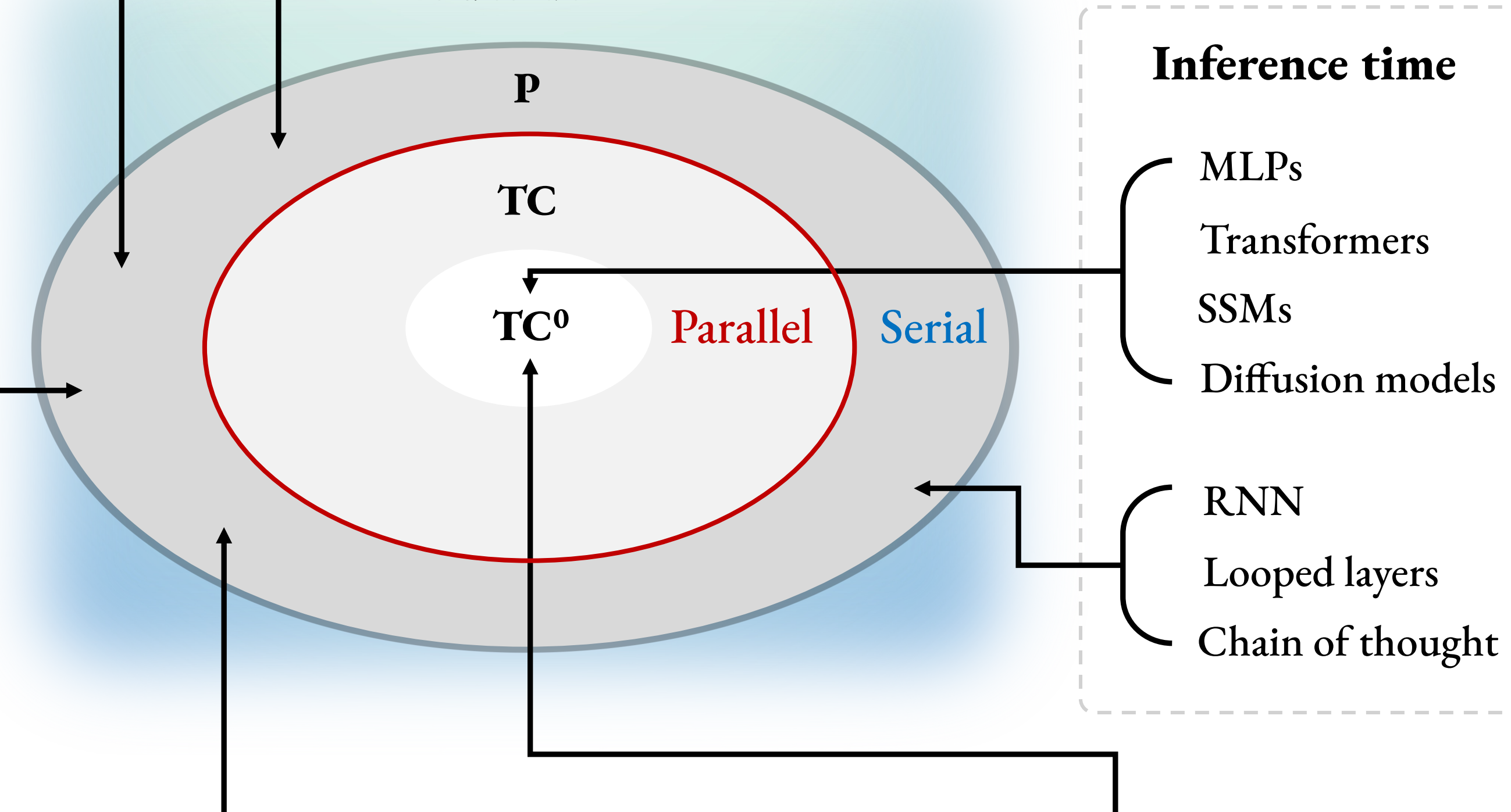


Output (State at T)



Inherently Serial (Fredkin & Toffoli 1982)

ALL PROBLEMS Outside P



What does it do?

- Deep learning Complexity theory
- Explains past successes

Why is it needed?

- 2017: We ditched RNN (serial) for Feed-forward Transformers (parallel)
- 2021: Scaling law doesn't make distinction serial vs. parallel
- 2024: Test-time scaling doesn't make distinction serial vs. parallel
- 2025: We use Diffusion models (parallel) to do reasoning

Past successes

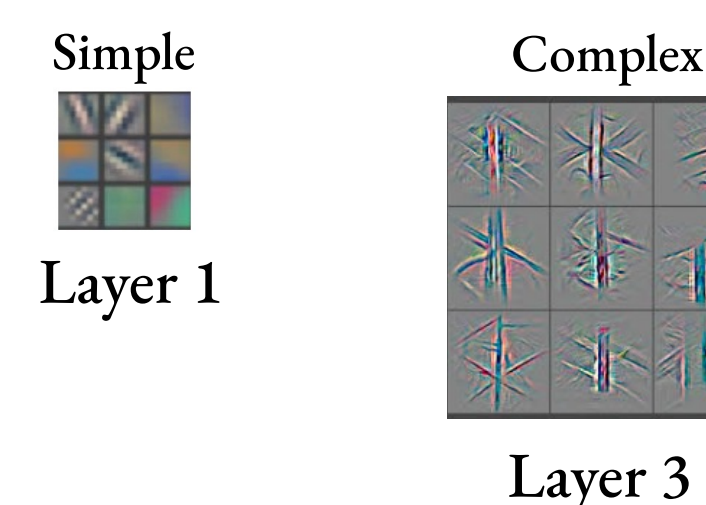
Scaling depth has been very successful. That's deep learning.

Chain-of-Thought improves LLMs because it's "deeper"

Li 2024, Merrill 2024

Deep features

Zeiler & Fergus 2014



Exponential depth-width trade-off

Prince 2023 (and many many others)

Shallower network needs to be exponentially wider to maintain expressivity

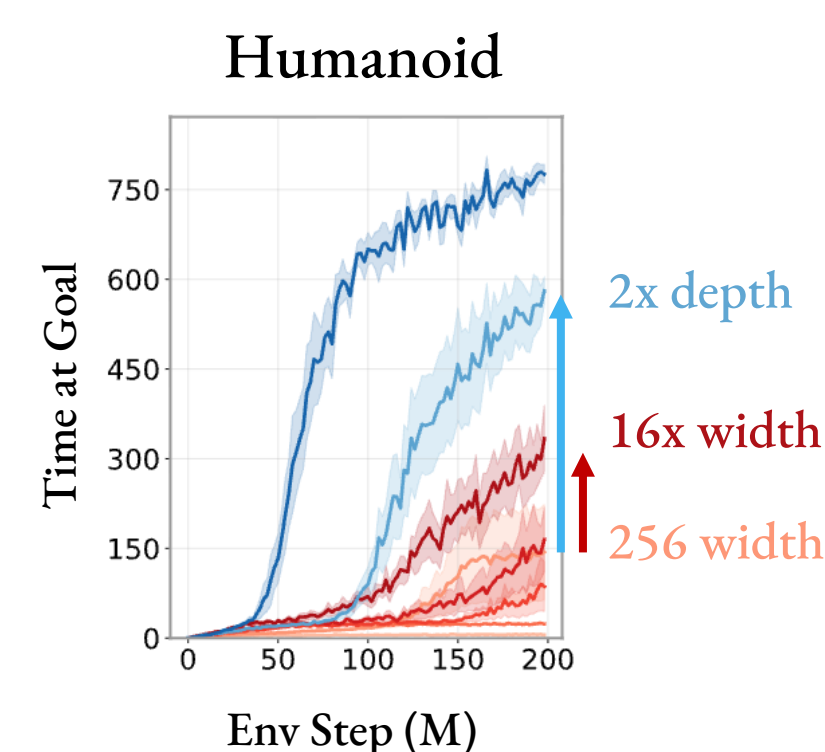
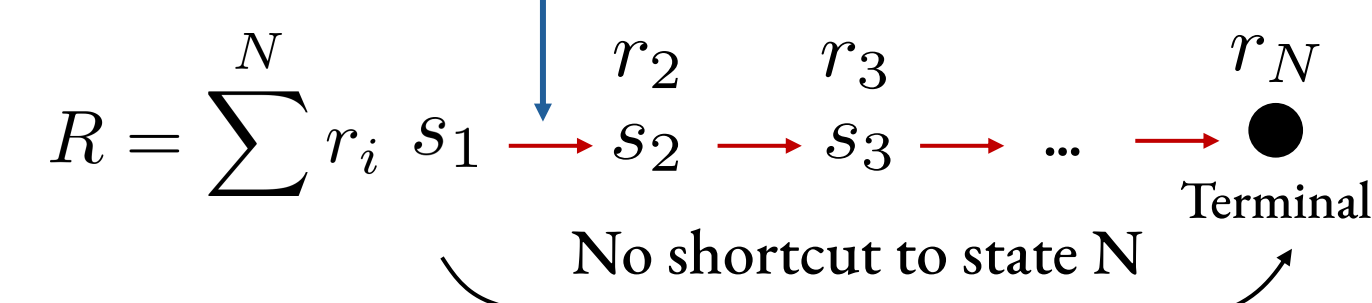
Intuitively: Shallow network memorizes. Deeper network generalizes.

Universal approximator: doesn't say about efficiency, how "wide" the network needs to be.

Reinforcement learning

Value function is a serial task

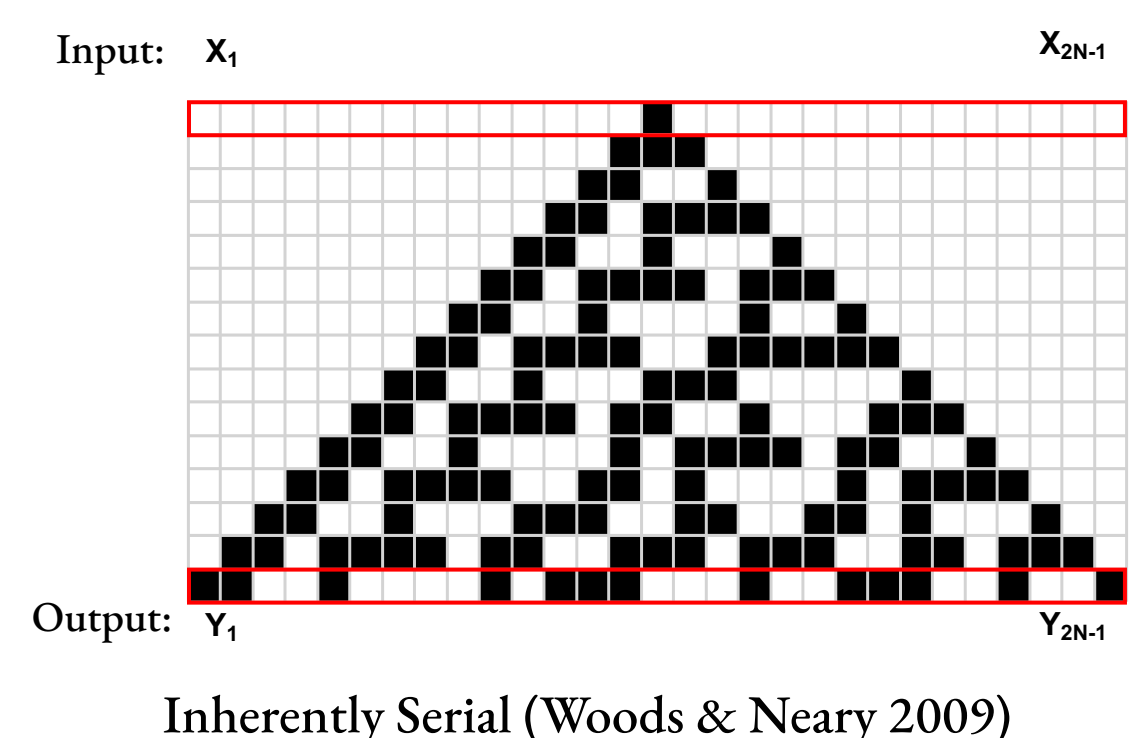
Transition = policy + environment



Deeper > Wider value & policy Kevin 2025

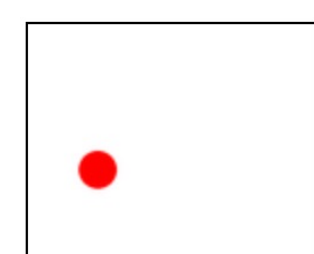
Model-based > Model-free Silver 2016

Cellular automata



Closed-form physics

Input (Initial state)



Output (State at T)

