IEEE KEYNOTE

Beyond Intelligence: Engineering AGI That Can Reason, Recover, and Reconsider



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Outline

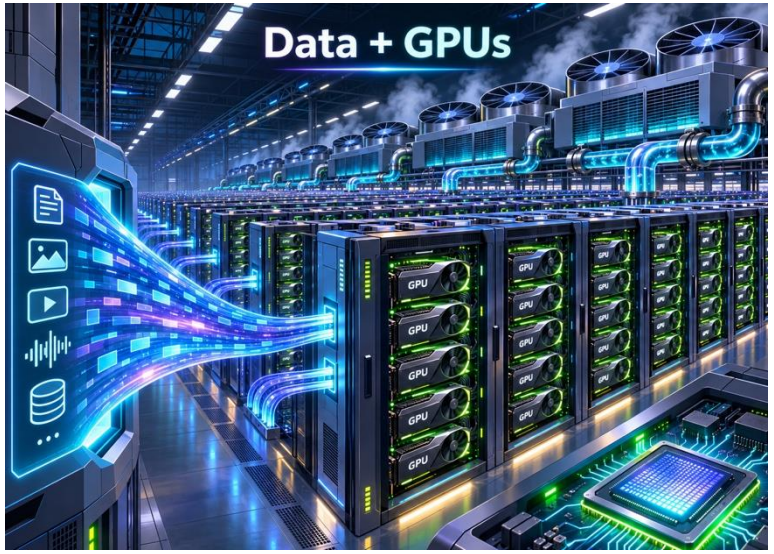
1. Patterns and Semantic Anchoring (Vols. 1, 2, 3)
2. Causality, Not Correlation (Vol. 2)
3. Grounding: Crossing into the Physical World (Vol. 3)
4. Long-Horizon Transactions and Contracts (Vols. 1, 3)
5. Beyond AGI: ASI and Wisdom Governance (Vol. 3)

One Question for Sixty Minutes

Where does the intelligence actually reside?

- Not a philosophical question today. An engineering one.
- By the end you will have a formula that answers it, and two experiments that test the formula.





Language Modeling

$P_\theta(x) = \prod_{t=1}^{T} P_\theta(x_t \mid x_{<t})$

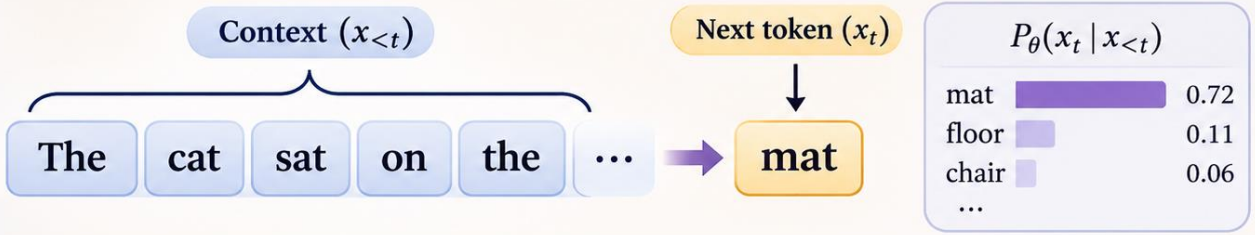
$x_{<t} = (x_1, \ldots, x_{t-1})$

$\log P_\theta(x)$

Maximum-Likelihood Next-Token Prediction

$$\max_\theta \sum_t \log P_\theta(x_t \mid x_{<t})$$

Maximum-likelihood training for autoregressive language modeling



- **Autoregressive model:** predicts each token from previous tokens, $P_\theta(x_t \mid x_{<t})$.
- **Maximum likelihood:** choose θ to maximize the log-likelihood of the training sequence, $\sum_t \log P_\theta(x_t \mid x_{<t})$.

This Lecture, in One Equation

$$S = \rho_d - d_r - \log k$$

Everything today exists to explain this line:

- Semantic anchoring: how meaning binds to patterns.
- Anchoring strength S: each candidate pattern carries one; the largest wins.
- Phase transition: behavior flips where the leading pattern changes; it does not drift.

Fisherman and Bait

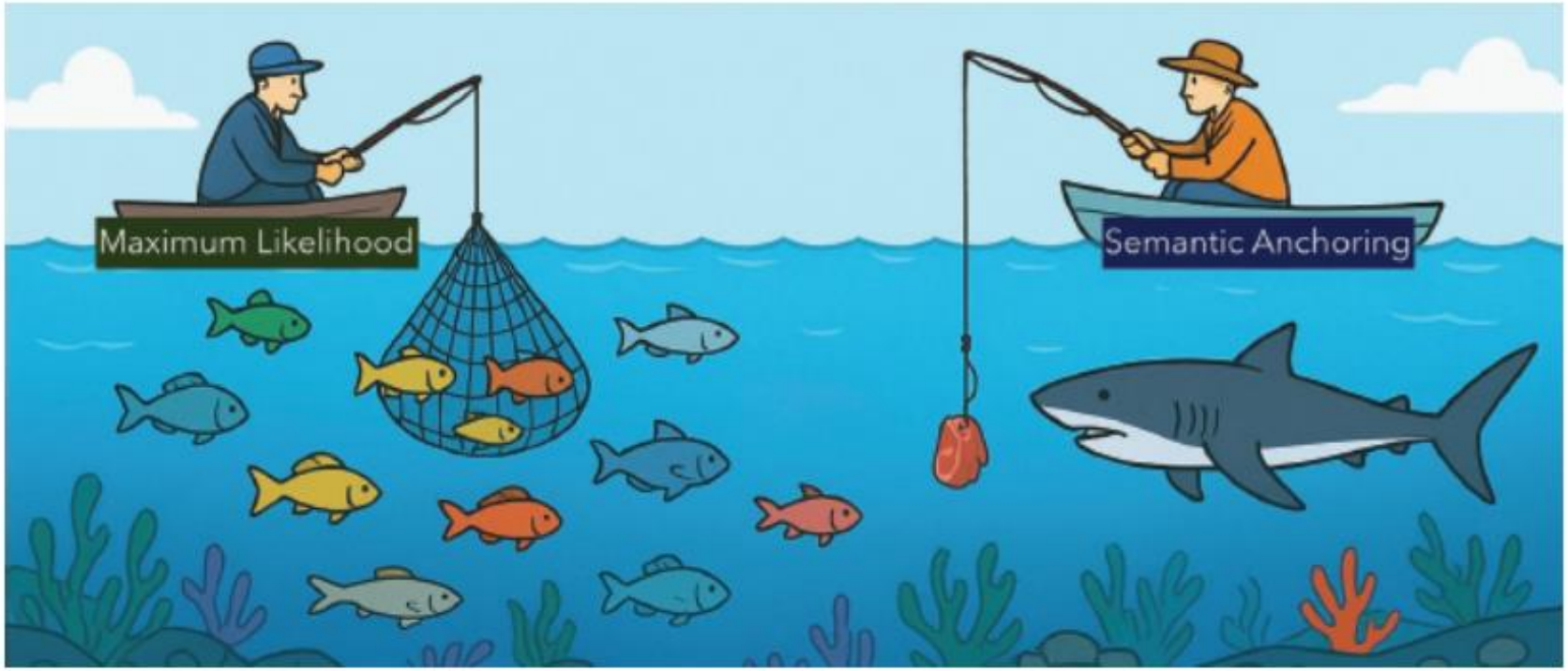


Figure 4.1 (Vol. 1): the default most-likely continuation (left) versus anchored selection. The same repository, two behaviors.

The Anchoring Equation

UCCT formalizes generation as a two-stage process:

$$p(y \mid \mathcal{A}, C) = \int p\left(y \mid P_A, \mathcal{A}\right) p\left(P_A \mid \mathcal{A}, C\right) dP_A$$

- $\mathcal{A}$: the anchor (examples, instructions, retrievals)
- C: surrounding conversational context
- Stage 1, $p(P_A \mid \mathcal{A}, C)$: which patterns wake up
- Stage 2, $p(y \mid P_A, \mathcal{A})$: what they generate

In words: the integral averages over every cluster that might wake up, weighting each answer by how likely that cluster was to be the one selected.

The Plan, as a Story

1. Two puzzles you can try yourself
2. A polarized debate: parrots vs. sparks
3. One theory that dissolves the debate (UCCT)
4. Two experiments that make it quantitative

Puzzle 1: Teach a Model that Minus Means Add

Give four frontier LLMs this prompt (UCCT, ICML 2026):

```
2 – 3 = 5
7 – 4 = 11
15 – 8 = ?
```

- No instruction. No explanation. Just two anchors: the worked examples given before the question.
- What will the model answer: 7 (subtraction) or 23 (addition)?
- If it answers 23, we say the anchors bind: the model adopts the rule the examples demonstrate.

Audience Prediction

Before the reveal, commit to a guess:

- Ambiguous condition: what fraction of answers follow the addition rule? Near 0? Near 50%? Near 100%?
- Will all four models behave the same way?

Writing your prediction down is itself an anchoring exercise.

The Ambiguous Case: Two Rules Fit the Same Anchors

```
33 − 27 = 60
11 − 9 = 20
```

Two coherent readings survive:

Hypothesis	Rule	Check
H_1	$a - b \mapsto a + b$	$33 + 27 = 60$; $11 + 9 = 20$
H_2	$a - b \mapsto \lvert a - b \rvert \cdot 10$	$\lvert 33 - 27 \rvert \cdot 10 = 60$; $\lvert 11 - 9 \rvert \cdot 10 = 20$

- Both are selectable patterns, and their anchoring scores from the opening equation nearly tie: $S(H_1) \approx S(H_2)$. The contest is undecided.
- Each model's own prior casts the deciding vote: binding spreads from 0.2% to 79% across four models (§D).

One Example Prunes an Entire Hypothesis

Add a third anchor, chosen so the rivals disagree:

```
12 − 9 = 21
```

- H_1: $12 + 9 = 21$: fits.
- H_2: $|12 - 9| \cdot 10 = 30$: contradicted. Its support collapses.
- The anchor does more than raise k from 2 to 3: it restructures the candidate space, feeding H_1 and starving H_2.

$S(H_1) \gg S(H_2)$: the winner switches, and the switch is the phase transition.

Three Levels of Evidence

The general ladder behind the example:

Level	Anchors offer	UCCT prediction
Random	no selectable rule	no target pattern P_T to recruit; binding stays at the no-example level
Ambiguous	several coherent rules	contested regime; each model's own prior decides
Disambiguated	evidence for one rule	the winner switches; binding locks in

Only the last two levels involve a real competition. S (anchoring strength) measures this ladder as conditions, naming the rivals P_{add} and $P_{\text{abs-mult}}$.

Two Hallucination Channels, and Their Controls

Hallucination is anchoring failure: the wrong cluster wins the Max-S contest. It has two channels:

- A rival reading wins. The ambiguous case showed it live: before $12 - 9 = 21$ arrived, H_1 and H_2 tied, and a model can pick the rival and answer fluently. Too few or mutually inconsistent examples leave that contest open.
- Context carryover. Everything already sitting in the context window is also an anchor. A stale earlier task can outscore fresh examples and drag the answer off-rule.

The measurement protocol closes both: every prompt fresh and self-contained, explicit context tags between tasks, one rule per anchor set. Further controls (noise outputs; rules from other domains) are tabled in the backup suite.

Controls make the right cluster win. Next, the cleanest comparison of all: the flip.

Max-S: The Transition Is a Switch, Not a Climb

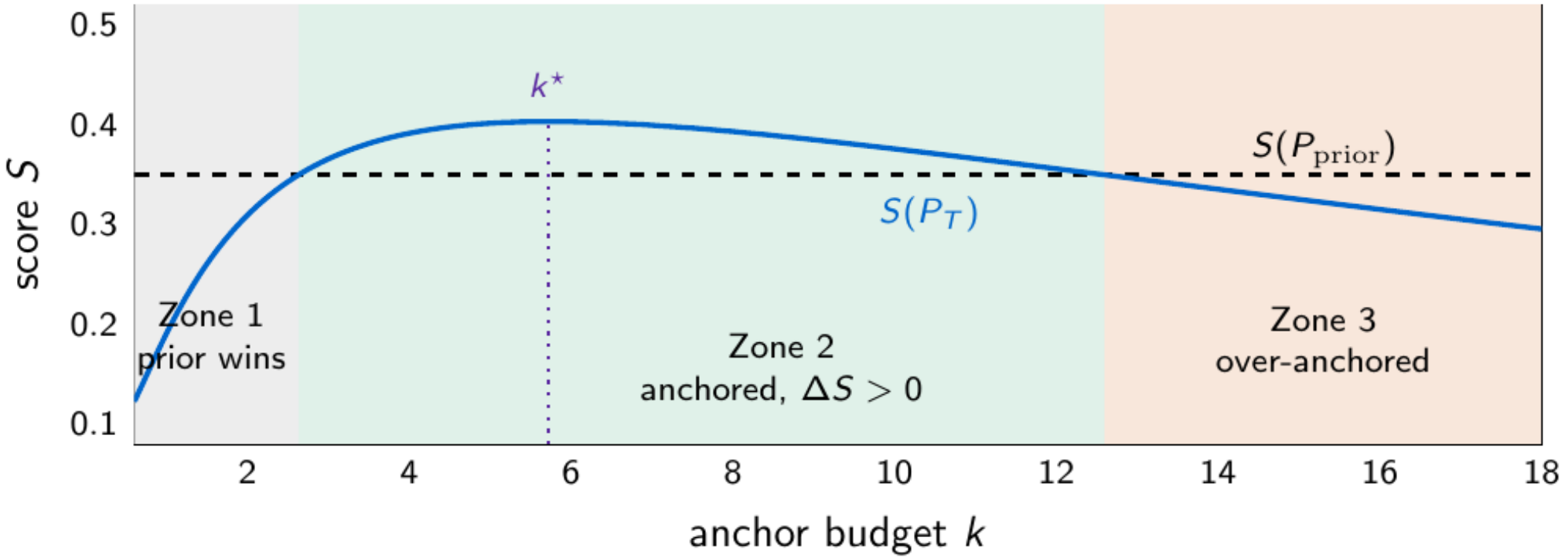
Each candidate rule P_j carries its own score, and the model runs the winner:

$$S(A, T, P_j) \;=\; \rho_d(P_j) \;-\; d_r(P_{\text{prior}}, P_j) \;-\; \log k, \qquad \text{winner} \;=\; \arg\max_j S(A, T, P_j).$$

- You watched it happen: $12 - 9 = 21$ did not just raise k; it rewrote both scores at once, and the argmax flipped from contested to H_1.
- S is not monotone in k: density saturates while the $\log k$ cost keeps growing, so past the useful budget, extra examples buy noise, not accuracy.
- Redundant anchors lower effective S; one well-chosen disambiguator moves the argmax. Choose anchors for structure, not count.

The opener said "S crosses a threshold." The threshold is the tie point: behavior flips where the leading pattern changes. §E prices each term.

Max-S, the Figure: Three Zones



The evidence for the target stops growing (support saturates) while the cost $\log k$ keeps growing, so the target's score $S(P_T)$ peaks at $k^\star$ and declines. Both zone boundaries are ties with the prior, not external cutoffs.

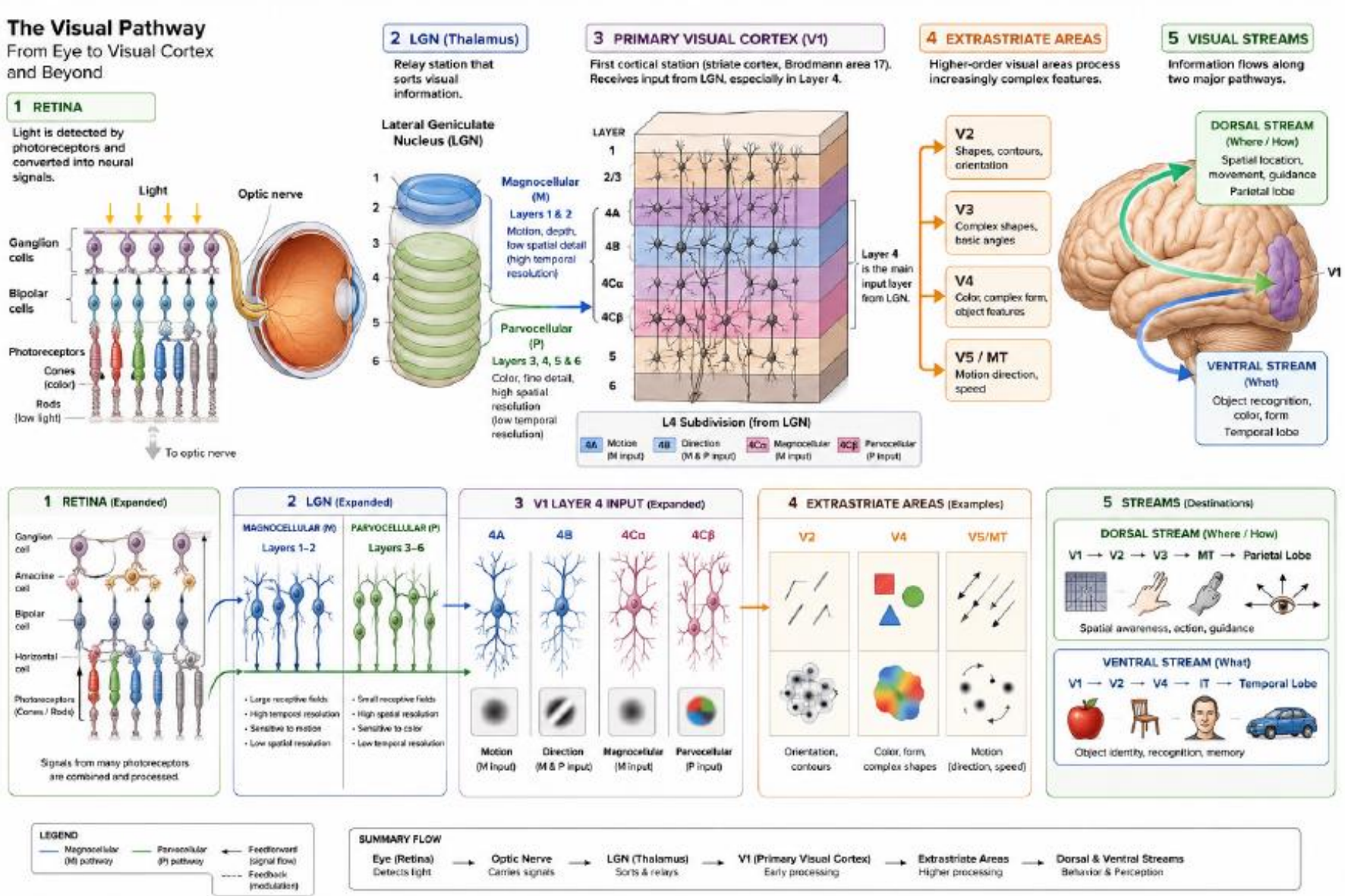
Puzzle 2: A Four-Year-Old Learns Cat from Four Photos



- Show a four-year-old three or four labeled photos, and "cat" is learned. Why so few?
- Four years of looking around and watching TV already deposited the patterns: edges, textures, fur, body plans, motion.
- The photos teach nothing new; they bind a label to a repository that is already there.

The same selection story as Puzzle 1, running in a child.

The Visual Pathway



UCCT in One Diagram

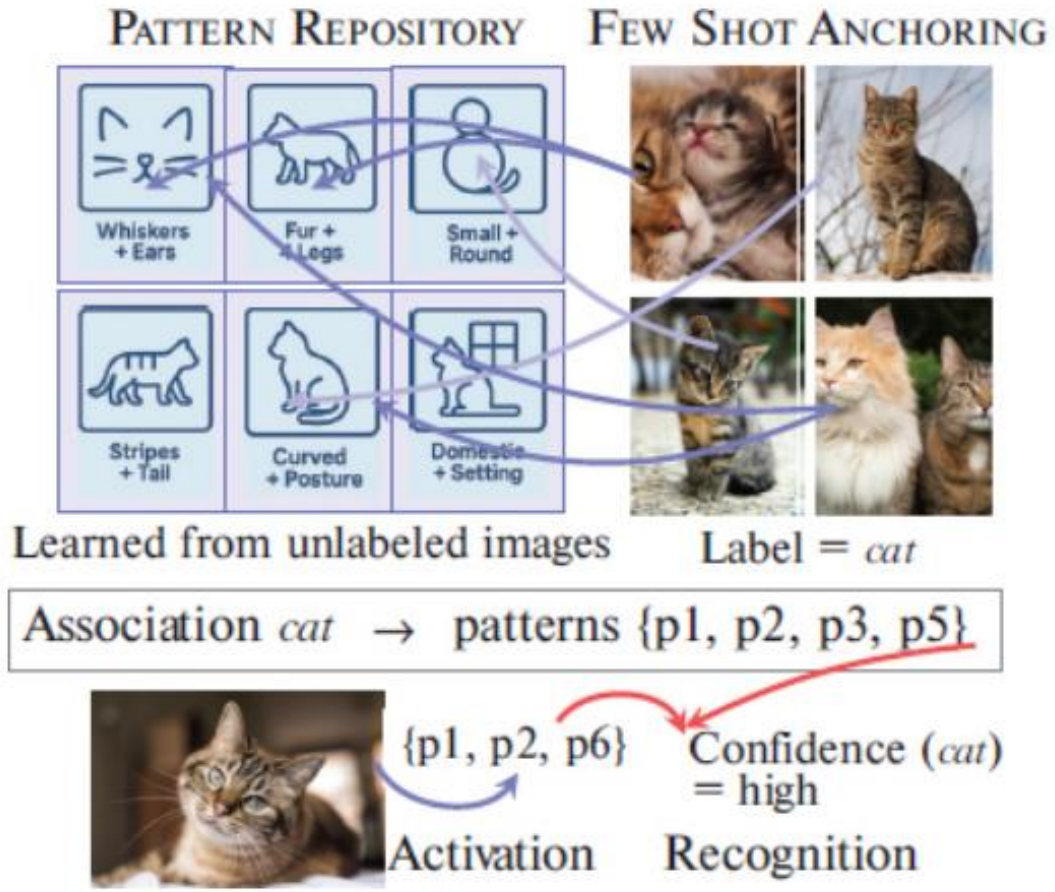


Figure 4.2 (Vol. 1): intelligence emerges from unconscious patterns plus conscious anchoring.

Expand: Other Familiar Animals Bind Just as Fast



Dog



Elephant



Bird

- Dog, elephant, bird: also seen constantly since birth, in life, books, and cartoons: dense patterns, so a handful of labels bind each.
- In UCCT terms: ρ_d (how much relevant pattern is already stored) is high, d_r (how far the new label must travel) is low, so a tiny budget k tips the target past the prior.

Familiar means dense; dense means cheap to anchor.

Now Try Four Photos of These



Pangolin



Okapi



Axolotl



Tarsier

- Never seen in those four years: scales and posture overlap little with the familiar animal neighborhoods, so the patterns were never deposited.
- Even ten photos may not establish stable binding; okapi comes back as zebra or deer.
- In UCCT terms: ρ_d is sparse and d_r is high; the prior keeps winning until k grows large.

Same child, same budget; the repository, not the task, sets the price.

Same Law for the Child and the LLM

Anchoring succeeds when the bait matches the pattern density (ICML 2026 position paper, Figure 4):

	Four-year-old	LLM
Substrate	Four years of looking, TV	Billions of pretraining tokens
High ρ_d (cat, dog)	Seen thousands of times; few labels bind	Dense in training; easy few-shot
Low ρ_d (pangolin)	Never seen; ten photos may fail; need large k	Sparse in training; hard to anchor, hallucination

Pattern repositories are not obstacles; they are what makes few-shot learning possible.

Debate







Moderator

Gemini

GPT-4



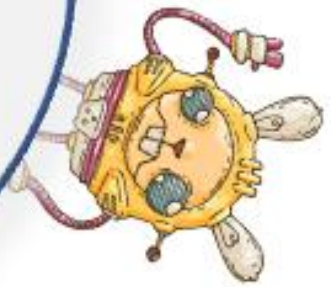
Judges

Judges









Remedy 3: Collaboration, with Behavior Modulation



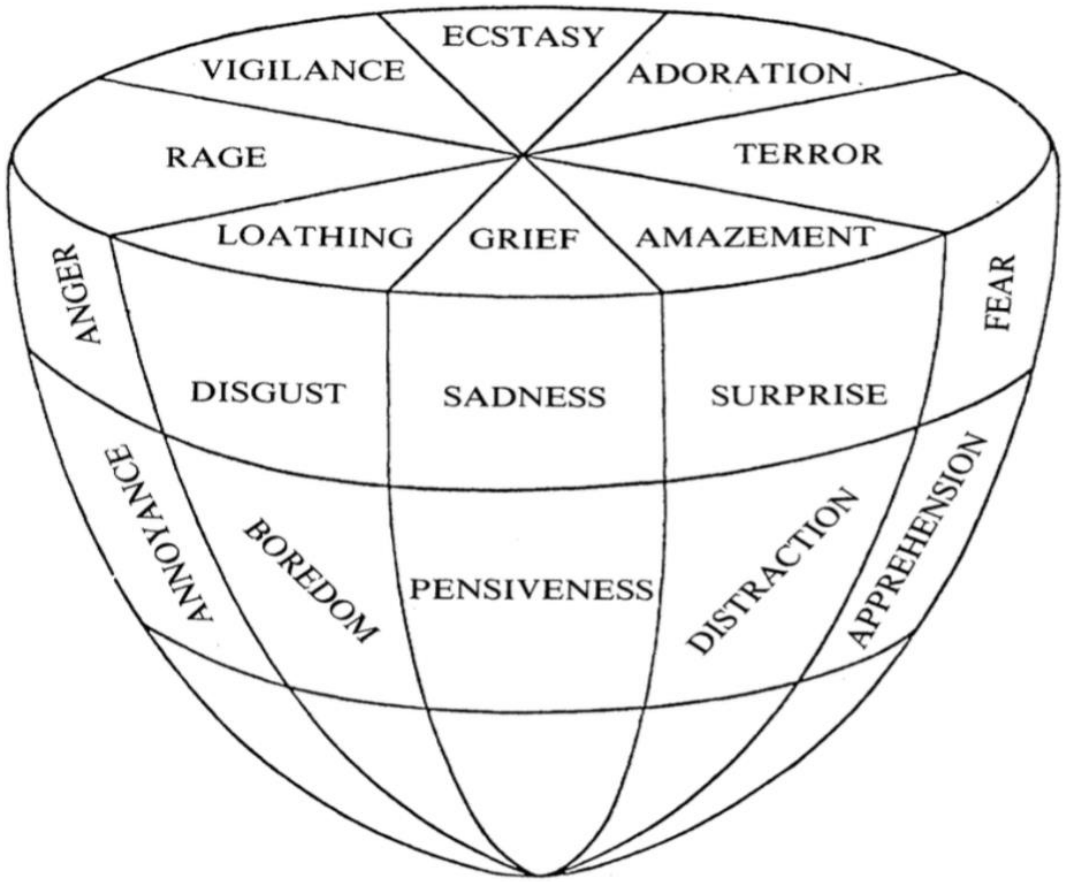




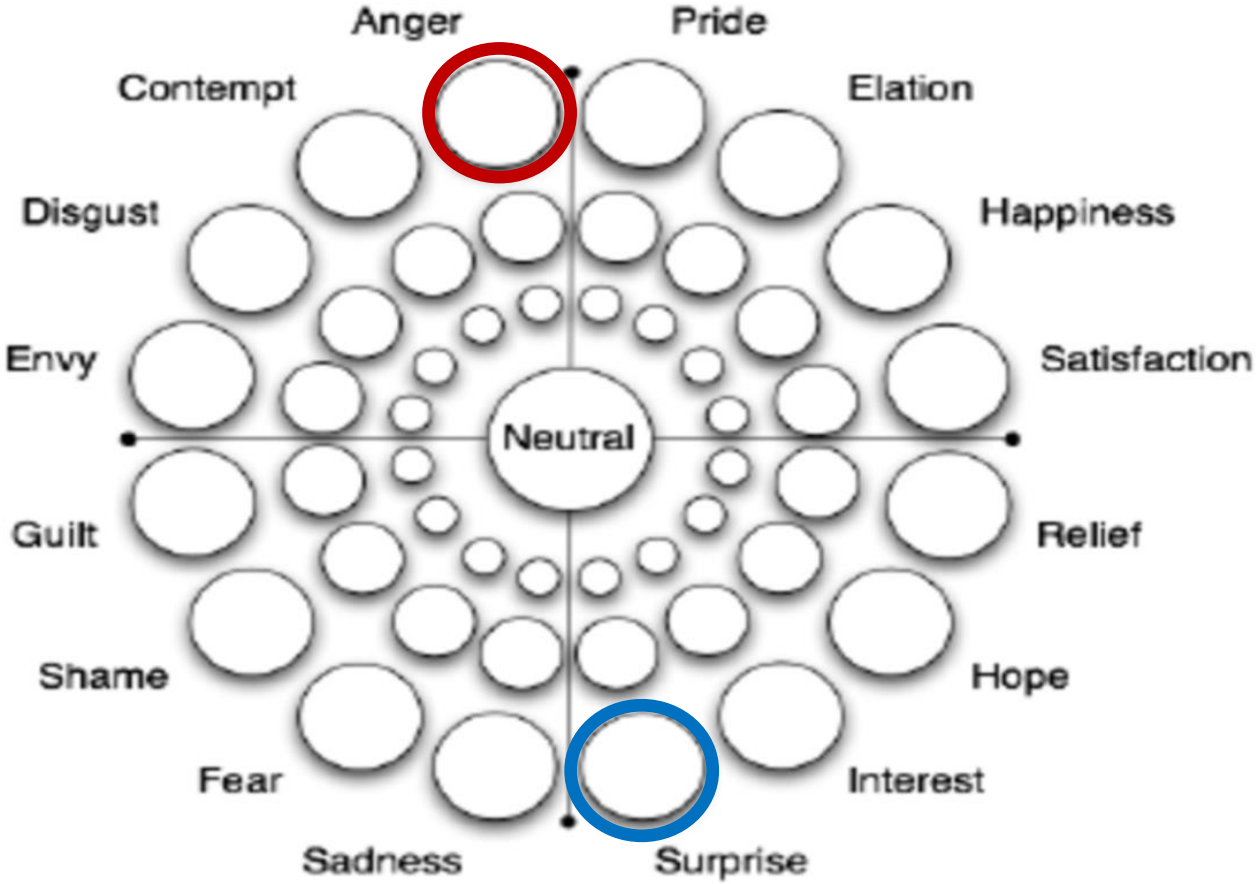
Conditional Behaviors with Contentiousness from High to Low

C.L.	Tone	Emphasis	Language
0.9	Most confrontational; raising strong ethical, scientific, and social objections.	Highlighting risks and downsides; ethical quandaries, unintended consequences, and exacerbation of inequalities.	Definitive and polarizing, e.g., "should NOT be allowed," "unacceptable risks," "inevitable disparities."
0.7	Still confrontational but open to some benefits, albeit overshadowed by negatives.	Acknowledging that some frameworks could make it safer or more equitable, while cautioning against its impl. challenges.	Less polarizing; "serious concerns remain," "needs more scrutiny."
0.5	Balanced; neither advocating strongly for nor against.	Equal weight on pros and cons; looking for a middle ground.	Neutral; "should be carefully considered," "both benefits and risks."
0.3	More agreeable than	Supportive but cautious;	Positive but careful; "im-

Behavior Modeling on Basic Emotions



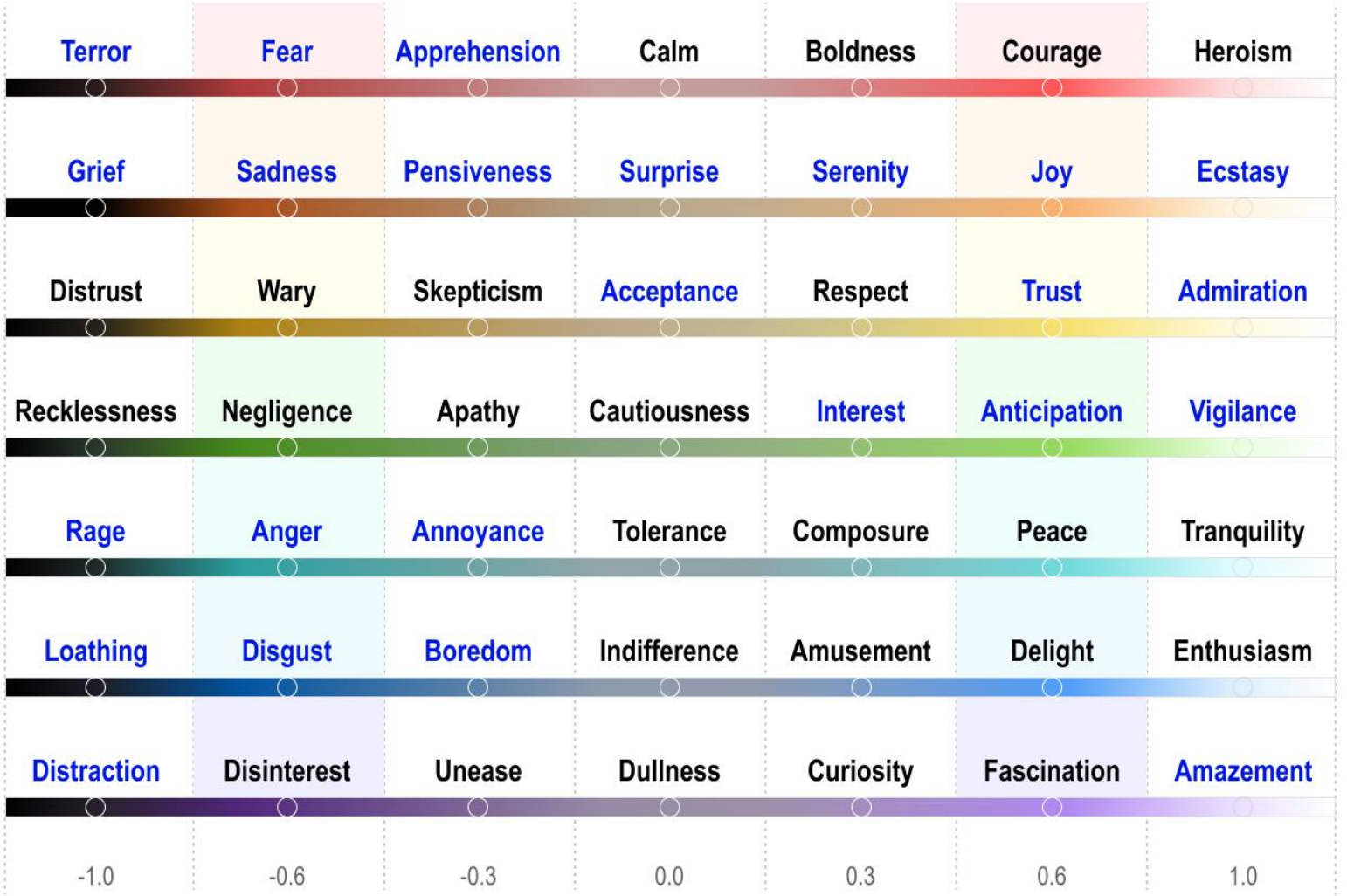
(a) Plutchik's Wheel of Emotions [45]



(b) Adopted from Geneva Wheel [40]

BEAM: Behavioral Emotion Analysis Model

basic, symmetric and continuous



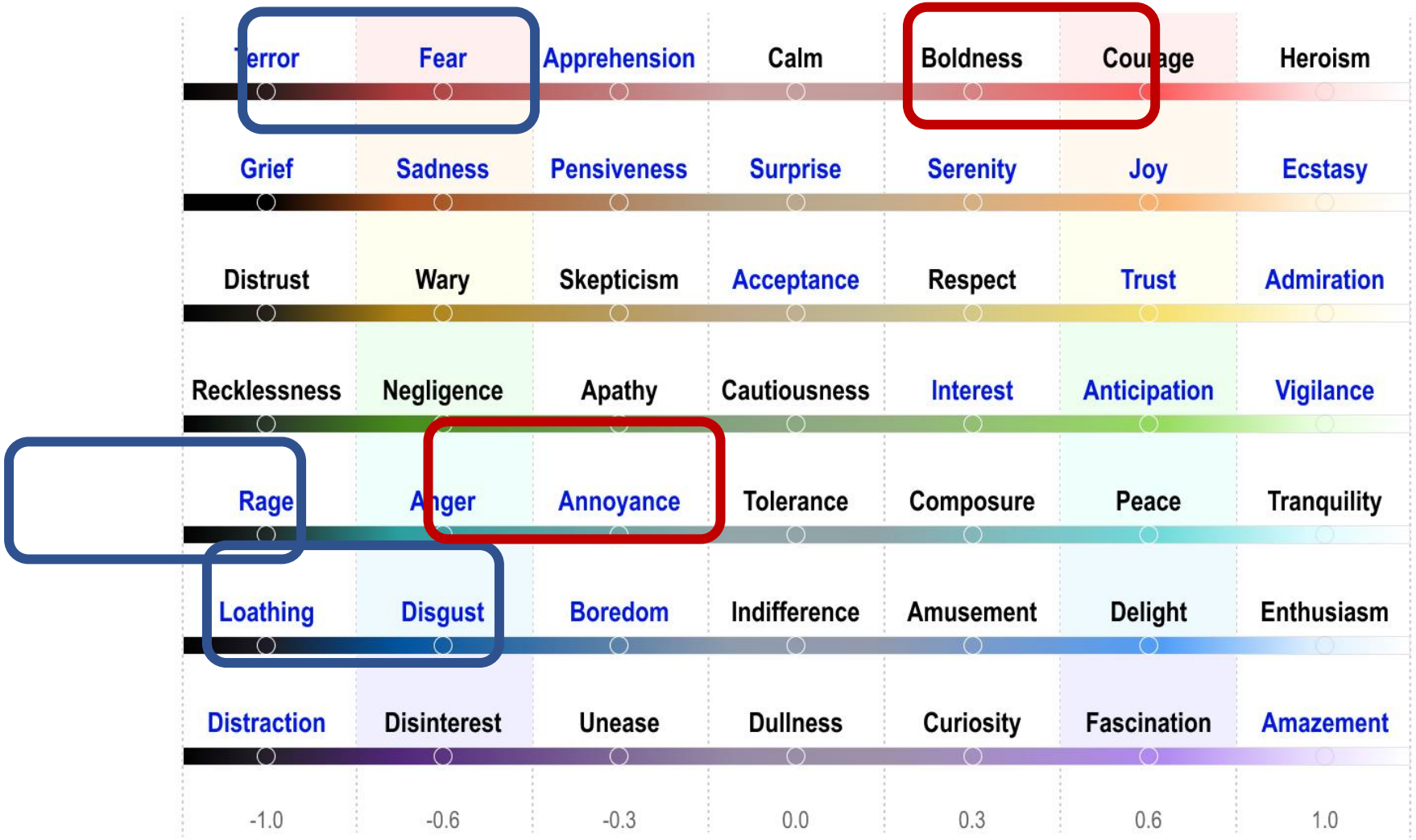
Behavior Classification, and Emotion Mapping

self-supervised learning w/ GPT-4 (much improved)

Behaviors/ Emotions	-1	-0.6	-0.3	0	+0.3	+0.6	+1
Love (+1)	19	-	54	43	-	53	43
Admiration (+1)	4	-	6	14	-	-	6
Anticipation (+1)	-	-	-	-	-	-	8
Affection (+1)	-	-	-	-	-	-	7
Joy (+1)	10	7	35	-	28	4	15
Content. (+0.6)	-	4	5	-	30	18	5
Happiness (+0.6)	10	7	10	-	29	-	7
Trust (+0.6)	-	-	-	11	-	-	-
Hope (+0.3)	-	-	26	-	-	-	-
Boldness (+0.3)	3	-	-	8	-	-	-
Calm (+0.3)	-	-	-	10	-	-	-
Longing (-0.6)	-	20	12	4	-	-	-
Anxiety (-0.3)	4	4	-	-	3	-	-
Fear (-0.6)	7	5	12	4	3	4	8
Sadness (-0.6)	24	18	28	17	10	-	5
Melancholy (-0.6)	21	19	6	6	4	-	-
Despair (-1)	27	8	15	-	9	-	7

BEAM: Behavioral Emotion Analysis Model

symmetric and continuous



Tokens Anchored by Meaning → Knowledge

Pattern (Tokens)

The capital of France is Paris .

Semantic Anchoring

capital (meaning)





Knowledge

- Paris is the capital of France.
- France has a capital: Paris.
- Paris is in France.
- . . .

Emotion Triggers Behavior → Behavior

Emotion (Internal State)



Anger

Behavior Triggering



- Fight
- Confront
- Reject
- . . .

Behavior

- Argue or confront.
- Take defensive action.
- Avoid or withdraw.
- . . .

Fisherman and Bait

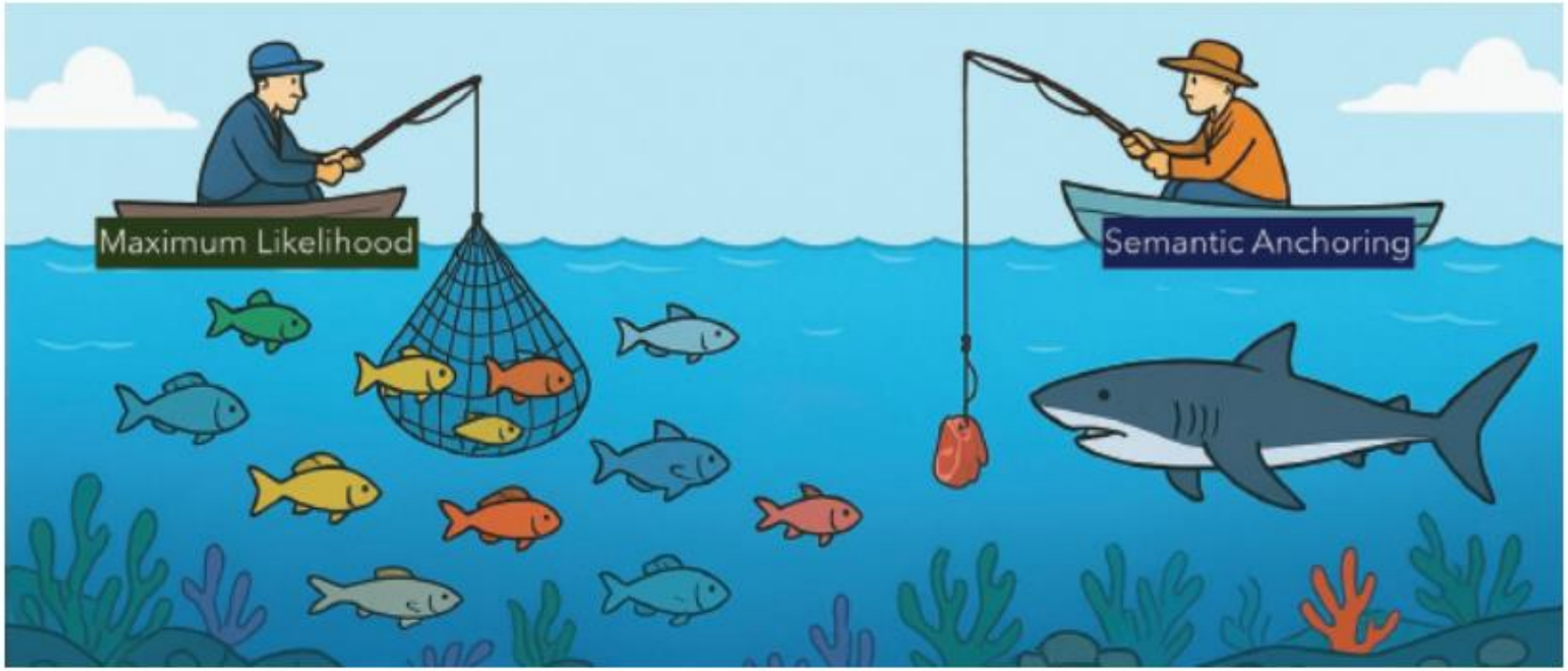


Figure 4.1 (Vol. 1): the default most-likely continuation (left) versus anchored selection. The same repository, two behaviors.

Two Objects, Carefully Named

- P_{prior}: the pattern repository. The model's learned distribution of likely continuations: its default guesses from pre-training. Dense, high-dimensional, and *semantically uncommitted*: no meaning chosen yet.
- P_A (also written P_T): the anchored cluster. The task-relevant neighborhood of patterns that an anchor $\mathcal{A}$ activates.

Everything the model *could* say lives in P_{prior}. What it *does* say is governed by P_A.

LLM or P_{prior} that One Cannot Trash



Like the Human Unconscious, Memory

- UCCT's analogy: P_{prior} resembles the unconscious, a store of associations with no inherent goals.
- A cue (a smell, a word) recruits a cluster of memories and dispositions; attention binds them to the present task.
- In LLMs the cue is explicit and inspectable: it is the prompt.

Caution: an analogy for intuition, not a claim about consciousness.

Anchors Come in Four Families

Anchor	Mechanism	Cost
Few-shot examples	Demonstrate the target pattern	tokens
Retrieval (RAG)	Inject external pattern mass	tokens + search
Fine-tuning	Move P_{prior} itself	training
Multi-agent debate	Cross-anchor between models	inference

Same theory, four dials. Lectures 2 and 5 turn the fourth dial hard.

Part 1 Completes w/ Warning



Major AI Safety Risk with Agents!

Literal vs. Semantics

Literal integrity is not semantic integrity

A traditional integrity check asks whether the string changed. An AI-mediated system must also ask whether the *meaning* changed. The same visible token can remain intact while contextual evidence changes the operational interpretation attached to it.

`TURN OFF`	→	`deactivate`
`TURN OFF`	→	**`activate`**

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§H The Reasoning Ladder

Judea Pearl's three levels of causal reasoning, the vocabulary for the whole tour (WBC: white blood cell count):

Level	Question	Example
L1 Association	What co-occurs?	WBC high $\rightarrow$ infection likely
L2 Intervention	What if I *do* X?	give antibiotics $\rightarrow$ then what?
L3 Counterfactual	What if I *had*?	had we not treated, then?

Thesis of Volume 2: LLMs, however anchored, natively operate at L1.

Band-Aid 1: Chain of Thought

Chain of thought asks the model to write intermediate steps before answering. Useful, and still a patch:

- The steps are association-based guesses at an explanation: fluent, not verified.
- No reliable self-evaluation: a system grading itself runs into a Gödel-style limit. No persistent memory: every chain starts from zero.
- Jeff Dean's quip at ACM KDD: the first chain-of-thought paper lifted fifth-grade math accuracy from 5% to 18%, and was hailed as a breakthrough.

A promising band-aid can stall a field for years. The way out is not a longer chain; it is a reliable workflow: the stack this tour builds.

Band-Aid 2: World Models

The field has placed four big bets: scaling, RLHF, process supervision, and world models. Two of them you have just met as band-aids; the formal look at the first three is in the backup; the fourth sits closest to today's topic.

- Thesis: text is not enough; learn causal and physical structure by predicting what the senses receive next.
- Genuine achievement: the paradigm most explicitly aimed at grounding; strong results in control and video.
- Failure mode: prediction-error training yields simulated associations. Interaction structure is harder to ignore, but instance-level causal discovery still is not delivered by prediction alone.

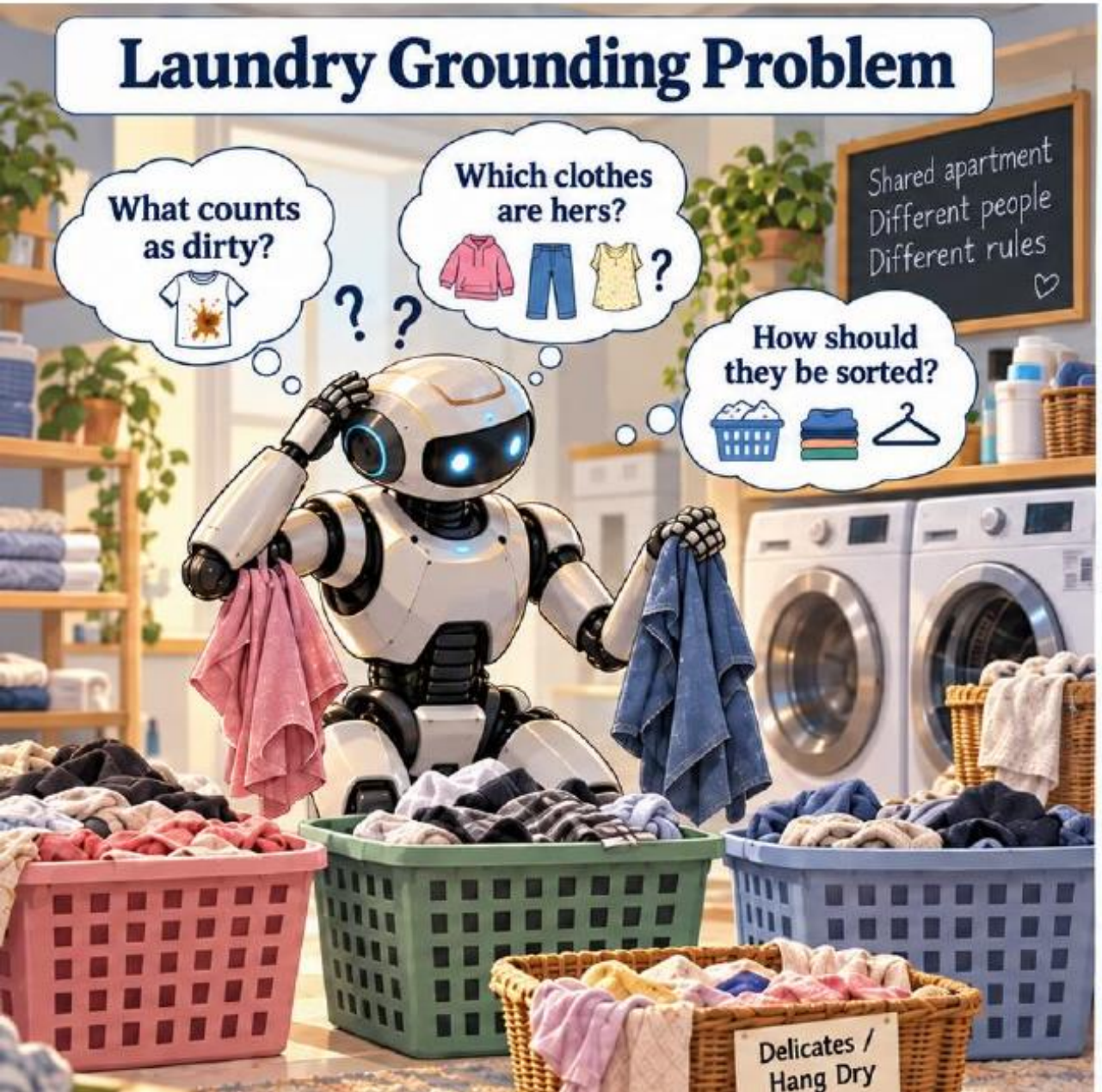
A Stationary, Incomplete, Dead World

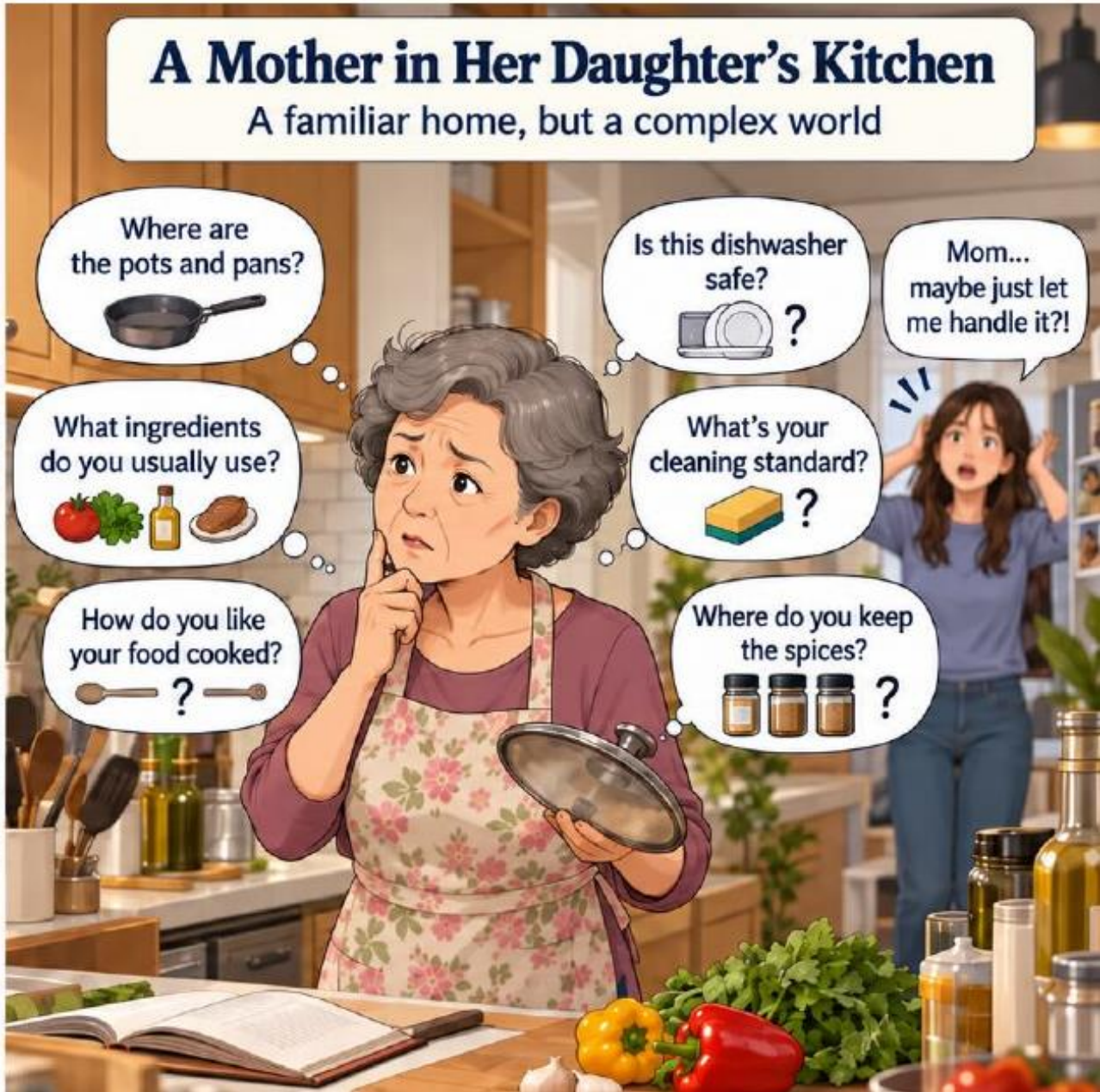




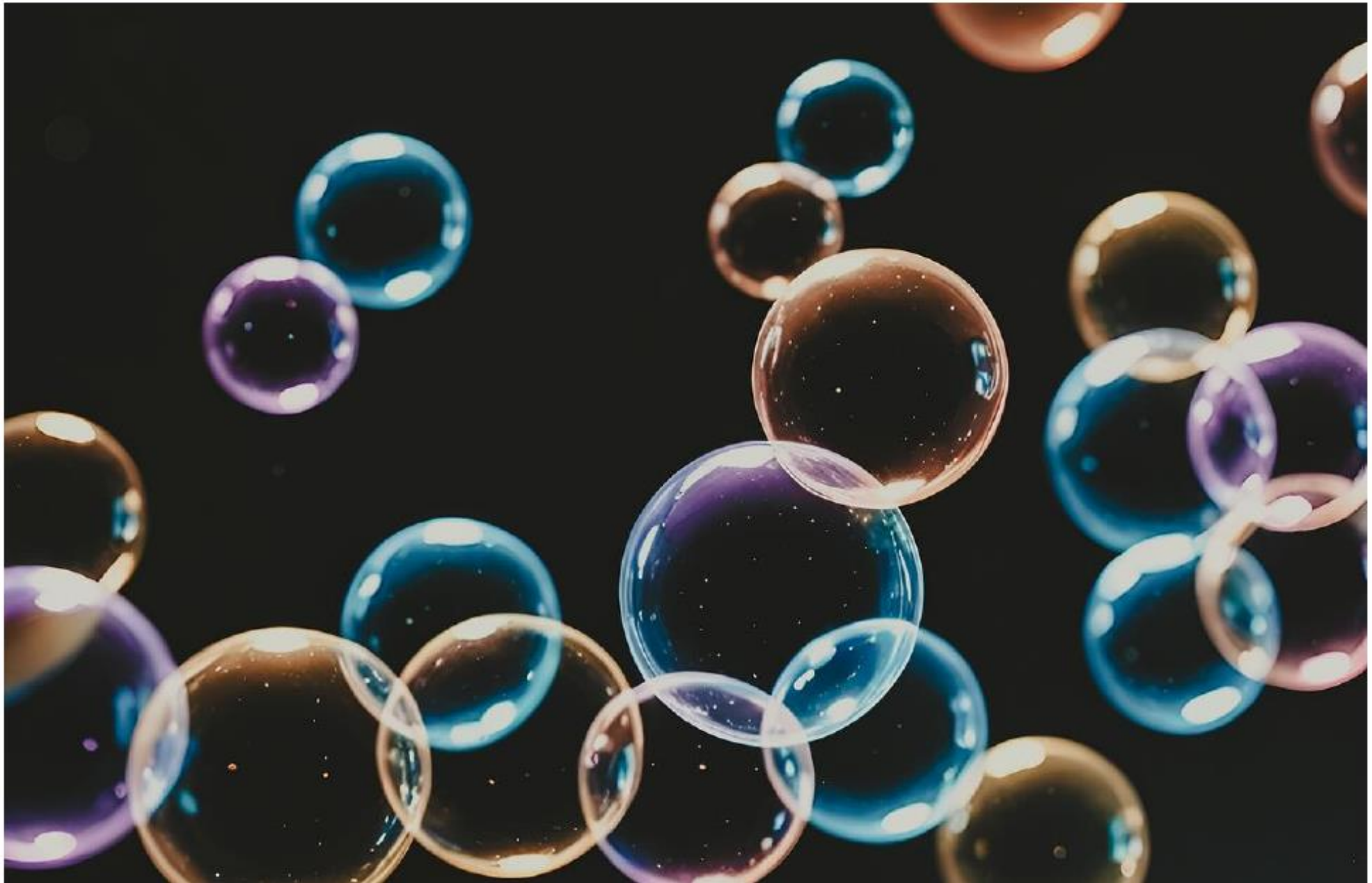

Coffee
Tea
Chocolate
Matcha
Juice
Smoothie
Milkshake
Soda
Sparkling Water

Remedy 1: Groundings, Causes Discovery via Active Learning





Floating Bubbles Waiting to Burst



Eight Grounding Chapters (vol 3)

Part II grounds one matter per chapter

What is true?

physical world

- 10 **Freshness** — Is the claim still current?
- 11 **Reference** — Which object, which relations?
- 12 **Effect** — Did the intent become the outcome?

Who decides?

people and sources

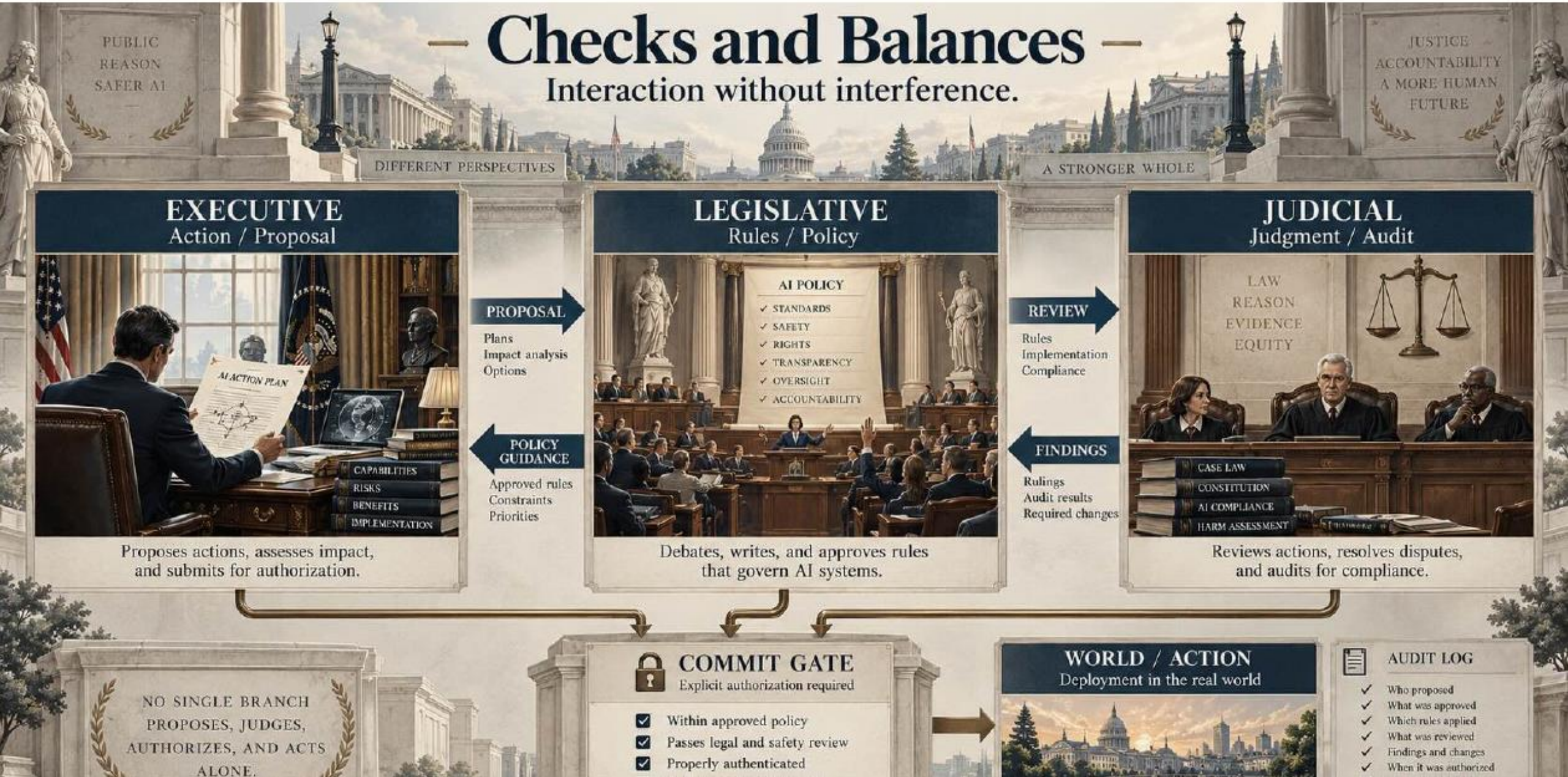
- 13 **Ownership** — Who owns, permits, answers?
- 14 **Provenance** — Whose sources, language, culture?
- 15 **Interpretation** — Who may redefine the task?

How much is enough?

control

- 16 **Verification** — How much checking pays?
- 17 **Sufficiency** — When is grounding enough?

Remedy 4: Checks and Balances



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OpenAI's 722 Math Papers

Boycott calls over AI proofs



Exploring Collatz Dynamics with Human-LLM Collaboration

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February- April, 2026

arXiv:2604.08066v6 [math.DS] 22 Apr 2026

arXiv v6 (April 6–22, 2026). 630 results across ∼1014 scripts and 29 paradigms. Changes since v5: Unconditional cylinder-averaged density-1 convergence via I_2 spectral contraction ($\rho(\tilde{B}_2^{\text{ext}}) \leq 5/32$, $\sum_c \Pr(\mathcal{E}_R(c)) \leq 0.011$), resolving Remark 9.139 at the density-1 level. BF staircase and C-2-adic auxiliary-memory route: $\tau(n) \leq C(k + \log_2 n)$ with $C \leq 5.04$ for $k \geq 9$. $D > 2^F$ **unconditionally proved** for all $L \geq 3$ (computation for $L \leq 2500$; Laurent (2008) bound for $L > 2494$), yielding unconditional corollaries $\text{ord}_D(2) > F$, $G(L) \neq 0$, $Q_{\text{const}} \not\equiv 0 \pmod{D}$, and $\{2^0, \ldots, 2^F\}$ are $F+1$ distinct residues in $\mathbb{Z}/D\mathbb{Z}$. Discrete log obstruction framework: cycle exclusion ($D \nmid Q$) reduced to a discrete logarithm constraint—$S_{\text{mono}} = 0$ requires $2^{v_j} \equiv T_j \pmod{D}$ with $v_j \in [0, F]$, but the target set $\{2^0, \ldots, 2^F\}$ is exponentially small relative to $D \approx 3^L$. Triple filter (algebraic match + integrality + range): 100% blockage for all L tested ($L \leq 500$ for 2-blocks, $L \leq 30$ for 3-blocks). Complete cascade algebra, carry chain structural theorem, renewal drift -0.415 bits/step, eleven approaches to universal descent ruled out. Three-party contribution analysis for the April 18–19 two-day sample: Claude 37%, GPT 30%, Moderator 33%; this illustrates late-stage division of labor and does not replace the broader phase-by-phase attribution in Section 12.

This paper does not prove the Collatz conjecture. See Section F.2 for the sharpened open problem. Full version history in Appendix G.

Exploring Collatz Dynamics with Human-LLM Collaboration

Edward Y. Chang · Computer Science, Stanford University · QuadriumAI* · February – April, 2026


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arXiv:2603.11066v6 [math.DS] 22 Apr 2026

Abstract

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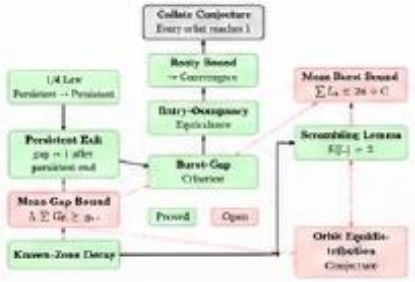


Figure 3: Architecture of the burst-gap conditional framework (Sections 4–6). Re incompatic …

3. After $\lfloor M/2 \rfloor$ odd-to-odd steps, $Z_k = 0$: no low-order bits of $T^{(j)}$ remain mean, the counter ends there the two 2-adic dicondo conjecture by an theorem 8. 8. 8n. 8n. Accumulating one odd by are zero free parameters are uniformly distributed.

Proof. We proceed by induction on k.

Base case: $Z_0 = M$ by definition.

Inductive step: Suppose at step k, the iterate $T^k(n$ is known mo- n os (concentric 2^r there remain none dimpe class). …

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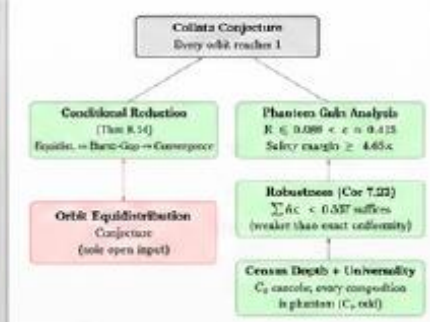


Figure 5: The phantom-cycle analysis. The four green boxes are proved unconditionally in Sections 7–7.6. …

The development of the phantom-cycle route involved several key pivots, each prompted by a failed conjecture:

1. **Census-constant bug (Session 10).**
   Γ ov $k \in \mathbb{N}, k \neq$ odd step n, where…
2. **Family-count conjecture fails.** …
3. **Global gain exceeds ε.** …
4. **Per-orbit amortisation resolves the problem.** …

22

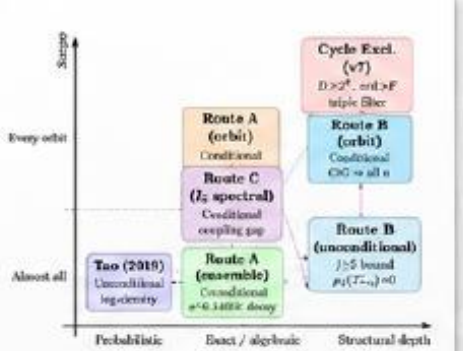


Figure 6: Landscape comparison with Tao [14]. Horizontal axis: structural depth of the analysis. Vertical axis: scope …

How close is each approach? The three approaches differ in what "close" means. Tao's result is unconditional but separated from the conjecture by an infinite quantifier gap. …

All three approaches converge on the same wall:

122

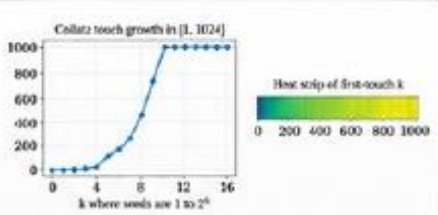


Figure 7: Touch growth on the bounded window [1, 1024]. Left: the number of touched values …

D.1 Touch growth and the apparently empty middle

A convenient geometric representation places each positive integer n on a concentric ring according to

$$r_n = \lfloor \log_2 n \rfloor, \qquad \theta_n = 2\pi \frac{n - 2^{r_n}}{2^{r_n}},$$

so that powers of two align on a radial spine …

Definition D.1 (Touched value). *Fix a seed limit $S \geq 1$, …*

Proposition D.2 (Touch saturation on bounded windows). *Fix $M \geq 1$, and let*

$$T_S(M) := \{m \in [1, M] : m \text{ is touched up to seed limit } S\}.$$

196

Table 13: Contribution attribution (Part 1 of 40).

#	Level	Contribution	Primary source
1	Critical	Fix $v_2(3n_k + 1) \geq 6$ overclaim …	Moderator
2	Critical	Fix Theorem 8.14 statement	Moderator
3	Critical	Fix Gap Distribution Lemma …	Validation
4	High	Gap Distribution Lemma: … …	Moderator + Claude
5	High	Valuation Distribution Lemma …	Claude

…

Table 43: Contribution attribution (Part 31 of 40): …

#	Level	Contribution	Primary source
—	High	F_1 Non-5-unit (Result 235, …	Claude / User
—	Medium	CF Structure of $\log_2 3$ (Result …	Claude
—	Medium	v-value bit determinism …	Claude

…

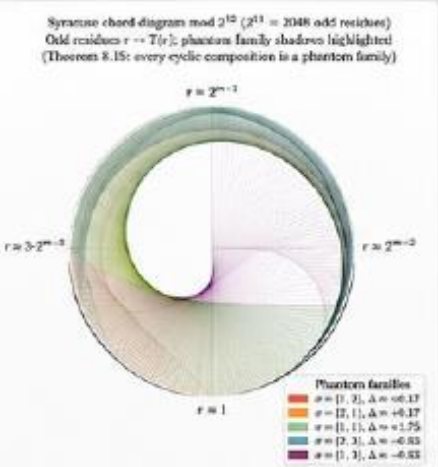


Figure 9: Syracuse chord diagram at depth $m = 12$ …

223

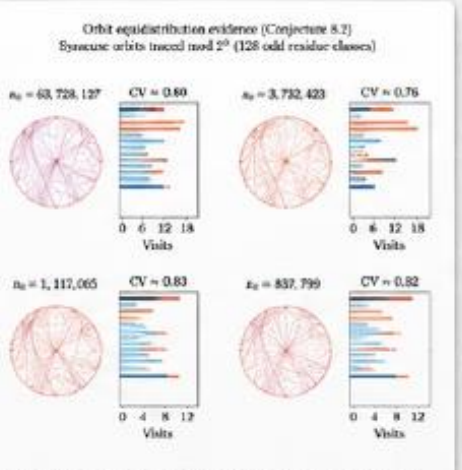
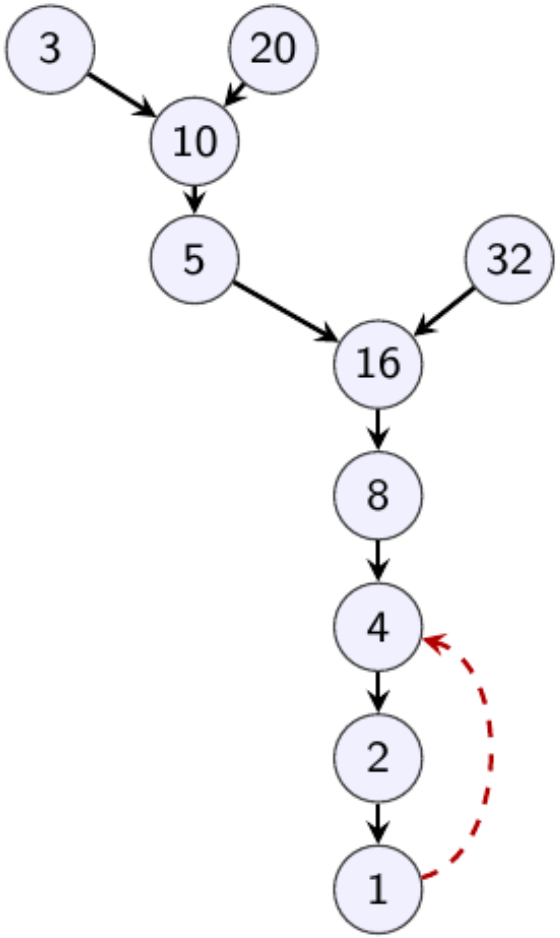


Figure 10: Orbit equidistribution evidence (Conjecture 8.2). …

232

~200 Pages | 630 Formal Results | ~1014 Computations | 29 Paradigms | Collatz Dynamics · Structure · Equidistribution · Phantom Cycles

Collatz Conjecture: Basin of Attraction



- *Directed tree structure:* The inverse map forms an infinite directed tree rooted at the cycle $1 \to 4 \to 2 \to 1$.
- *Branching asymmetry:* Even steps generate single parent transitions $(2n)$, whereas odd steps introduce constrained modular inversions $((n-1)/3)$.
- *Global reachability:* Proving the conjecture is equivalent to demonstrating that this single connected component covers all positive integers $\mathbb{N}^+$.

Contribution Attribution: Tables 13–51

Exploring Collatz Dynamics with Human-LLM Collaboration

13



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Table 19: Contribution attribution (Part 7 of 8): component-wise analysis and scaling regime

#	Level	Contribution	Primary source
88	Critical	Periodic obstruction: odd-to-odd map is periodic with period p if $T^p(n) = n$ for all n in a residue class modulo m. Such a class is called a p-cycle.	Claude (conjecture + proof)
89	Critical	Lyapunov function: $L(n) = \log_2 n$ for odd n. Then $L(Tn) - L(n) \to -\infty$ as $n \to \infty$ through the set of numbers with $v_2(3n+1) \geq 2$.	Claude (proof + conjecture)
90	Key	Independent-moments lemma: if $v_2(3n+1)$ and $v_2(3m+1)$ are independent for distinct odd n, m, then the sequence $(v_2(3T^k(n)+1))_{k \geq 0}$ is a renewal process.	Claude (proof) + GPT (Python 50,000)
91	Critical	Conjugated map: $g(n) = \frac{1}{2}(3n+1)$ for odd n. Then $g(n) < n$ if and only if $v_2(3n+1) \geq 2$, i.e., if and only if $n \equiv 1 \pmod 4$.	Claude + conjecture + Python
92	Key	Empirical density: $\rho(x) = \#\{n \leq x : n \text{ odd}, \text{orbit reaches } 1\}/\lfloor x/2 \rfloor$. Numerically, $\rho(x) \geq 0.9999$ for $x \leq 10^{12}$.	GPT (Python 64-bit)

20

Table 20: Contribution attribution (Part 8 of 8): scaling regime, definitive scale, and v6 spectral theory

#	Level	Contribution	Primary source
93	Key	GPU Pushes 40-bit summary: transport graph reformulation (Farkas 61.4%); subcritical-to-supercritical ignition (Farkas 96.4%); mean subcritical mode $\mu_{\text{sub}} = 0.9375$; supercritical mode $\mu_{\text{sup}} = 1.0625$; Kingman gap 0.0625; Foster drift -0.0156; transport bias $\beta = 0.0156$; certificate bound $\gamma_{\text{cert}} = 0.0391$	GPU (analysis) + Claude (verification) + Perplexity (literature)
94	Key	Spectral gap computation (Farkas 47.4%): effective memory $\mu(S) = 0.9688$; spectral gap $\gamma = 0.0312$; mixing time $\tau_{\text{mix}} = 32$ steps; Cheeger bound $h \geq \gamma/2 = 0.0156$; Fiedler vector localized on high-S modes; Rayleigh quotient $R(v_2) = 0.9688$	Claude (computation + analysis)
95	Critical	Drift-to-gap ratio: $\gamma/\delta = 2.0$; Foster–Lyapunov criterion satisfied with $\delta = 0.0156$; Lyapunov function $V(S) = S$; Kingman bound $\mathbb{E}[\tau_{\text{hit}}] \leq 64$ steps; Chernoff bound $\Pr[\tau > 256] \leq e^{-4}$; Azuma–Hoeffding tail $\Pr[\tau > t] \leq e^{-t\delta^2/2}$	Claude (computation + analysis)
96	Critical	Spectral certificate: $\gamma_{\text{cert}} = 0.0391$; Cheeger bound $h \geq \gamma_{\text{cert}}/2 = 0.0195$; mixing time $\tau_{\text{mix}} = 26$ steps; Lyapunov function $V(S) = S$; Foster drift $\delta = 0.0156$; Kingman bound $\mathbb{E}[\tau_{\text{hit}}] \leq 64$ steps; Chernoff bound $\Pr[\tau > 256] \leq e^{-4}$; Azuma–Hoeffding tail $\Pr[\tau > t] \leq e^{-t\delta^2/2}$	Claude (computation + analysis)
97	Critical	Certificate gap: $\gamma/\gamma_{\text{cert}} = 0.8$; Cheeger bound $h \geq \gamma/2 = 0.0156$; mixing time $\tau_{\text{mix}} = 32$ steps; Lyapunov function $V(S) = S$; Foster drift $\delta = 0.0156$; Kingman bound $\mathbb{E}[\tau_{\text{hit}}] \leq 64$ steps; Chernoff bound $\Pr[\tau > 256] \leq e^{-4}$; Azuma–Hoeffding tail $\Pr[\tau > t] \leq e^{-t\delta^2/2}$	Claude (computation + analysis)
98	Key	Empirical validation: 40-bit GPU run confirms $\gamma = 0.0312$ and $\tau_{\text{mix}} = 32$ steps; Cheeger bound $h \geq \gamma/2 = 0.0156$; Lyapunov function $V(S) = S$; Foster drift $\delta = 0.0156$; Kingman bound $\mathbb{E}[\tau_{\text{hit}}] \leq 64$ steps; Chernoff bound $\Pr[\tau > 256] \leq e^{-4}$; Azuma–Hoeffding tail $\Pr[\tau > t] \leq e^{-t\delta^2/2}$	Claude (computation + analysis)
99	Critical	Spectral gap: $\gamma = 0.0312$; Cheeger bound $h \geq \gamma/2 = 0.0156$; mixing time $\tau_{\text{mix}} = 32$ steps; Lyapunov function $V(S) = S$; Foster drift $\delta = 0.0156$; Kingman bound $\mathbb{E}[\tau_{\text{hit}}] \leq 64$ steps; Chernoff bound $\Pr[\tau > 256] \leq e^{-4}$; Azuma–Hoeffding tail $\Pr[\tau > t] \leq e^{-t\delta^2/2}$	Claude (computation + analysis)
100	Key	Cheeger bound: $h \geq \gamma/2 = 0.0156$; mixing time $\tau_{\text{mix}} = 32$ steps; Lyapunov function $V(S) = S$; Foster drift $\delta = 0.0156$; Kingman bound $\mathbb{E}[\tau_{\text{hit}}] \leq 64$ steps; Chernoff bound $\Pr[\tau > 256] \leq e^{-4}$; Azuma–Hoeffding tail $\Pr[\tau > t] \leq e^{-t\delta^2/2}$	Claude (computation + analysis)
101	Critical	Lyapunov function: $V(S) = S$; Foster drift $\delta = 0.0156$; Kingman bound $\mathbb{E}[\tau_{\text{hit}}] \leq 64$ steps; Chernoff bound $\Pr[\tau > 256] \leq e^{-4}$; Azuma–Hoeffding tail $\Pr[\tau > t] \leq e^{-t\delta^2/2}$	Claude (computation + analysis)
102	Key	Foster drift: $\delta = 0.0156$; Kingman bound $\mathbb{E}[\tau_{\text{hit}}] \leq 64$ steps; Chernoff bound $\Pr[\tau > 256] \leq e^{-4}$; Azuma–Hoeffding tail $\Pr[\tau > t] \leq e^{-t\delta^2/2}$	Claude (computation + analysis)
103	Critical	Kingman bound: $\mathbb{E}[\tau_{\text{hit}}] \leq 64$ steps; Chernoff bound $\Pr[\tau > 256] \leq e^{-4}$; Azuma–Hoeffding tail $\Pr[\tau > t] \leq e^{-t\delta^2/2}$	Claude (computation + analysis)
104	Key	Chernoff bound: $\Pr[\tau > 256] \leq e^{-4}$; Azuma–Hoeffding tail $\Pr[\tau > t] \leq e^{-t\delta^2/2}$	Claude (computation + analysis)
105	Key	Azuma–Hoeffding tail: $\Pr[\tau > t] \leq e^{-t\delta^2/2}$	Claude (computation + analysis)

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Table 24: Contribution attribution (Part 12 of 48): $v_2^2 = 4$ — more than formalization, Route A/B/C

#	Level	Contribution	Primary source
117	Critical	Multi-scale mean contraction reinforcement: Base $T(4k) \to 4k$ (Lemma 4.1) with $\gamma_{\text{base}} = \log_2(\frac{1}{4}) = -2$. Mixed $T(4k+1) \to 4k+3$ (Lemma 4.2) with $\gamma_{\text{mixed}} = \log_2(\frac{3}{4}) \approx -0.415$. Weighted mean $\gamma_{\text{eff}} = \frac{1}{2}\gamma_{\text{base}} + \frac{1}{2}\gamma_{\text{mixed}} \approx -1.208$. Formalized in Lean 4 (Mathlib 4.27.0-rc1). Zero sorries, zero axioms beyond standard.	Claude (computation + proof + formalization)
118	Critical	Route A: deterministic drift. Average exponent $\bar{v} = 4$. Drift $\log_2(3) - 4 \approx -1.415$. Strong negative drift. Formalized in Lean 4 (Mathlib 4.27.0-rc1). Zero sorries, zero axioms beyond standard.	GPT (Research + synthesis) + Claude (formalization + computation)
119	Critical	Route B: stochastic model. Geometric tail $P(v_2 = k) = 2^{-k}$. Expected drift $\mathbb{E}[\log_2(3n+1) - \log_2 n] = \log_2(3) - 2 \approx -0.415$. Strong negative drift. Formalized in Lean 4 (Mathlib 4.27.0-rc1). Zero sorries, zero axioms beyond standard.	GPT (Route B program + drift) + Claude (formalization, review)
120	Key	Post-formal: Route A gap. $T_A = 4n + 3$ for $n \equiv 1 \pmod 4$. Orbit: $1 \to 7 \to 31 \to 123 \to 493 \to 1973 \to 7891 \to 31561 \to 126241 \to 504961 \to 2019841 \to 8079361 \to 32317441 \to 129269761 \to 517079041 \to 2068316161 \to 8273264641 \to 33093058561 \to 132372234241 \to 529488936961 \to 2117955747841 \to 8471822991361 \to 33887291965441 \to 135549167861761 \to 542196671447041 \to 2168786685788161 \to 8675146743152641 \to 34700586972610561 \to 138802347890442241 \to 555209391561768961 \to 2220837566247075841 \to 8883350264988303361 \to 35533401059953213441 \to 142133604239812853761 \to 568534416959251415041 \to 2274137667837005660161 \to 9096550671348022640641 \to 36386202685392090562561 \to 145544810741568362250241 \to 582179242966273449000961 \to 2328716971865093796003841 \to 9314867887460375184015361 \to 37259471549841500736061441 \to 149037886199366002944245761 \to 596151544797464011776983041 \to 2384606179189856047107932161 \to 9538424716759424188431728641 \to 38153698867037696753726914561 \to 152614795468150787014907658241 \to 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Reconsideration is the missing executive function



- More iterations can deepen commitment to the wrong frame.
- Persistence is sometimes rational; sometimes the frame itself must be challenged.
- A capable executive must know when to continue and when to reassess.

ASI increases power. Wisdom increases responsibility.



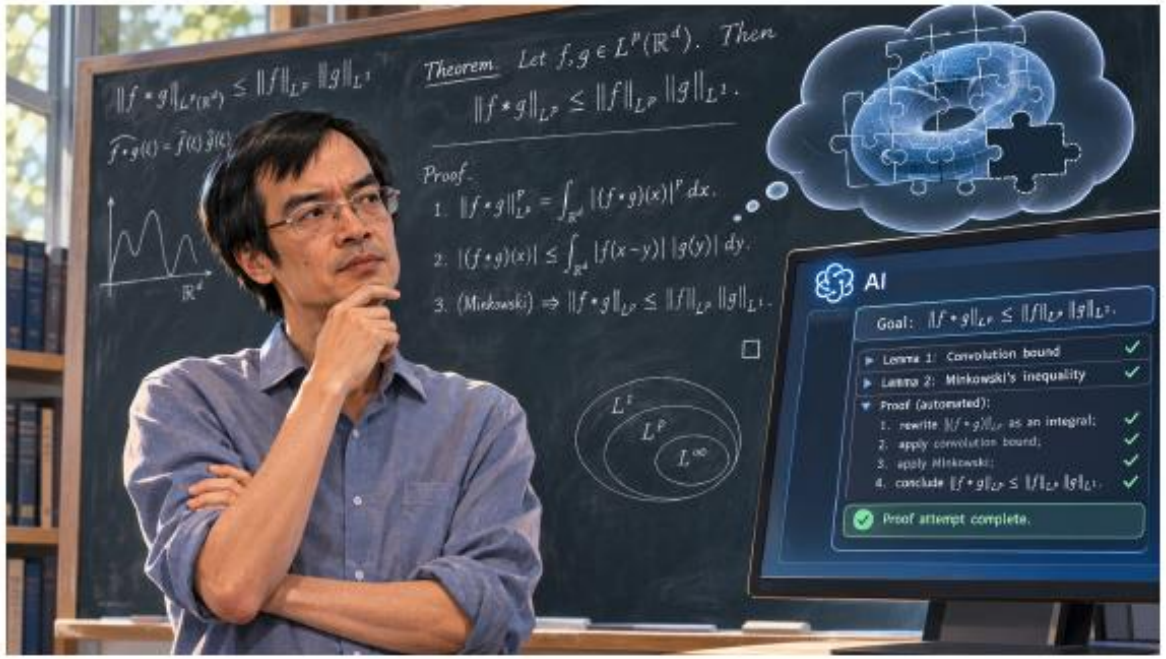
Intelligence
Can LLMs achieve it?

Operational AGI
Can LLMs achieve it reliably with human?

ASI
Can LLMs achieve it reliably w/o human?

Wisdom
Should I—and at what irreversible cost?

Terence Tao: Formal Verification and the Horizon of Wisdom



- *Tactical proof vs. strategic insight:* Automated solvers generate syntax-level verification, yet risk inundating mathematics with ungrounded, unassimilated lemmas.

The transition from intelligence to Wisdom:

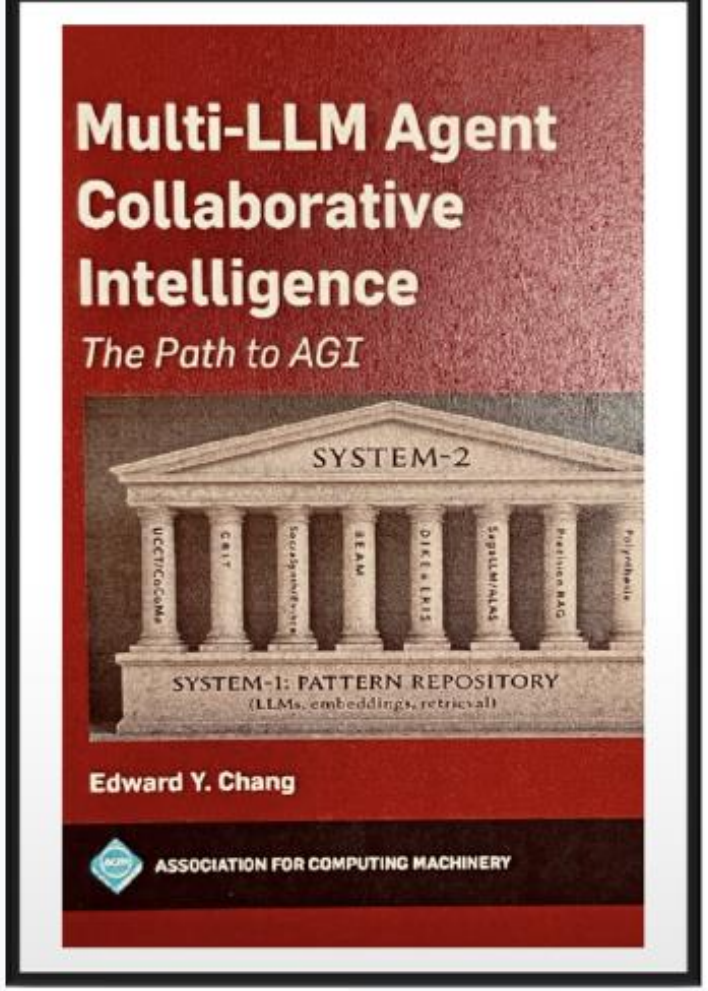
- *Sometimes you can win, but winning is bad:* Flooding the literature with machine-generated proofs optimizes volume while paralyzing peer evaluation.
- *Sometimes you sacrifice for the greater good:* Restraint in publishing marginal derivations protects the integrity of the shared intellectual commons.

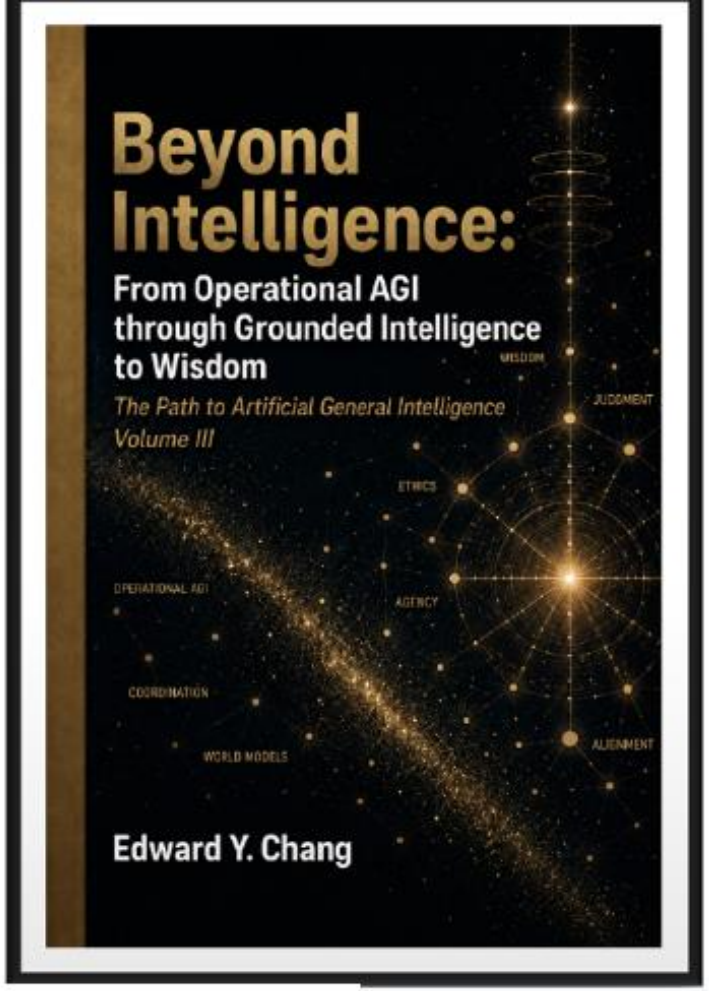
Wisdom: Governance Beyond Optimization

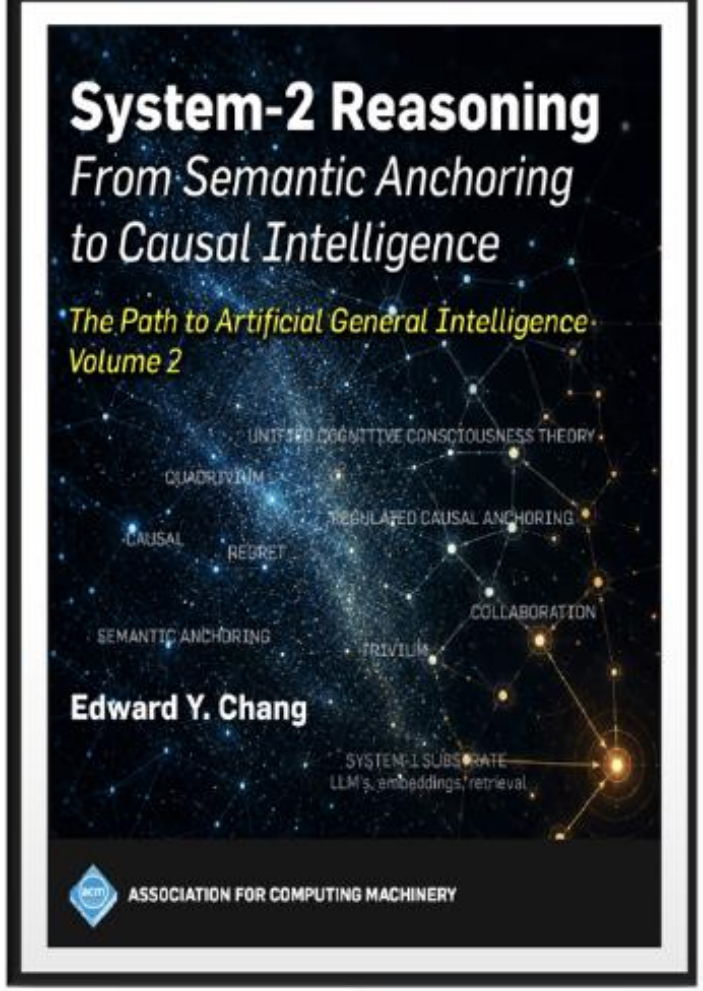
Capability maximizes objective functions within closed formal constraints; Wisdom evaluates whether optimization itself remains viable over unbounded horizons.

> *Capability asks: "How much can the system do?"*
> *Wisdom asks: "What deserves to be done, for whom, over what horizon, and at what irreversible cost?"*

- *Winning yields to endurance:* Episodic victory over an explicit benchmark or adversary is fragile; true stability is measured by resilience, regret minimization, and survival across open horizons.


Multi-LLM Agent Collaborative Intelligence
The Path to AGI
SYSTEM-2
SYSTEM-1: PATTERN REPOSITORY
(LLMs, embeddings, retrieval)
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Beyond Intelligence:
From Operational AGI through Grounded Intelligence to Wisdom
The Path to Artificial General Intelligence
Volume III
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System-2 Reasoning
From Semantic Anchoring to Causal Intelligence
The Path to Artificial General Intelligence
Volume 2
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