Evolvent AI

The Scaling Laws of Skills in LLM Agent Systems

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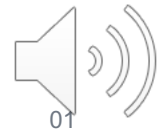
Evolvent AI Team



A library is a search space

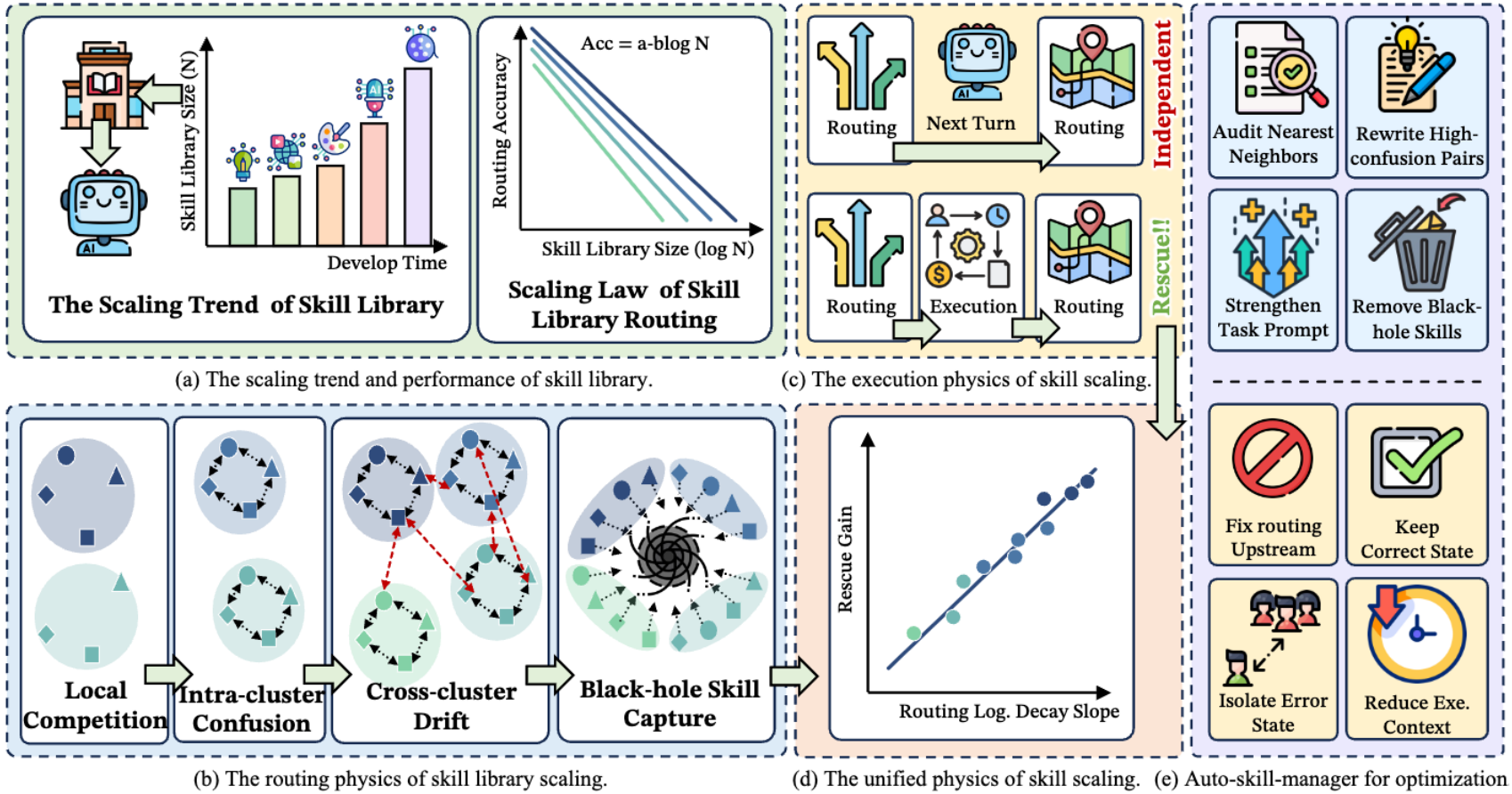
💡 **A larger skill library doesn't necessarily make an agent more capable.**

We found that large skill libraries don't fail at random. Instead, they follow a repeatable, analyzable progression: from local semantic congestion, to confusion within skill families, to cross-cluster drift, and finally to capture by "black-hole skills."



Three questions, one variable

The same library geometry governs routing, execution state, and their coupling



Q1: How fast does the router lose the right skill as the library grows?

Q2: When does one action help or hurt the next decision?

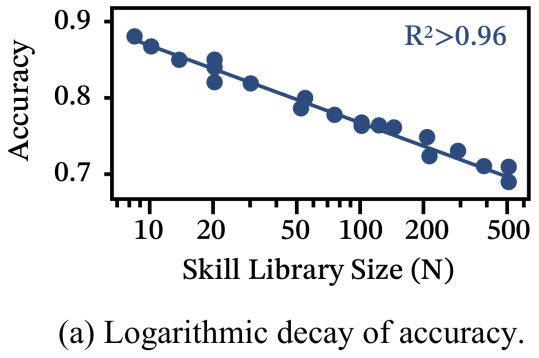
Q3: Can one measurable state variable explain both?

arXiv:2605.16508v1

What exactly is the mechanism of Skill routing?

✅ **As the skill library grows, accuracy declines logarithmically.**

❓ Once multiple skills must be planned in parallel and routed, things change: accuracy drops far below what independent probabilities would predict.



(a) Logarithmic decay of accuracy.

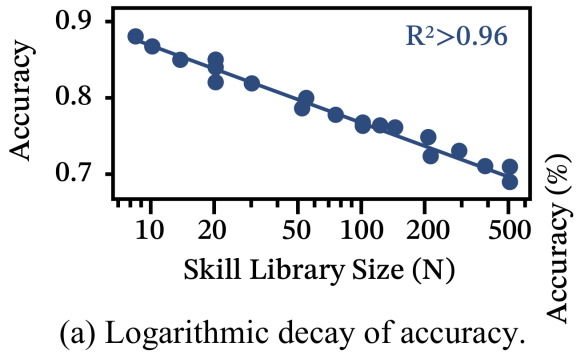
(b) Beyond independent logarithmic decay of 3 step parallel routing accuracy.

What exactly is the mechanism of Skill routing?

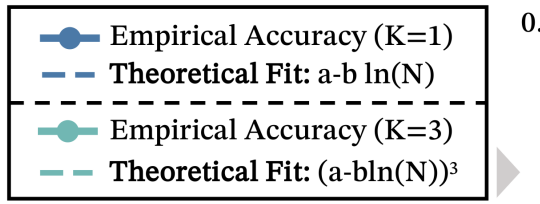
🎯 **Under the condition of parallel planning + routing of multiple skills:**

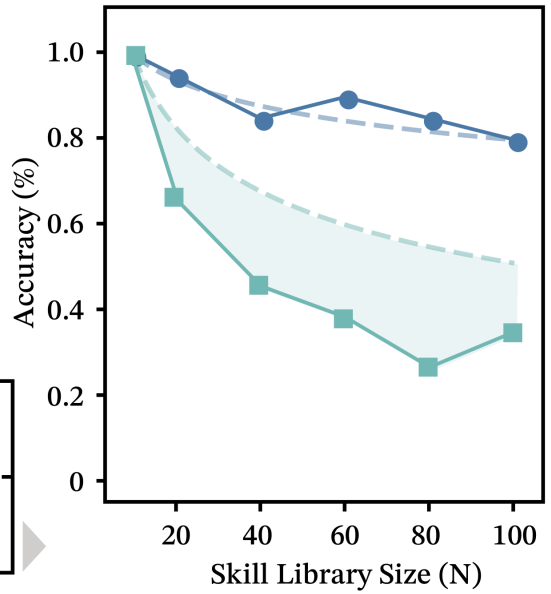
✅ Multi-step tasks further amplify this loss through an exponential factor:

$$Acc(N) = (a - b \ln N)^{\gamma K}$$

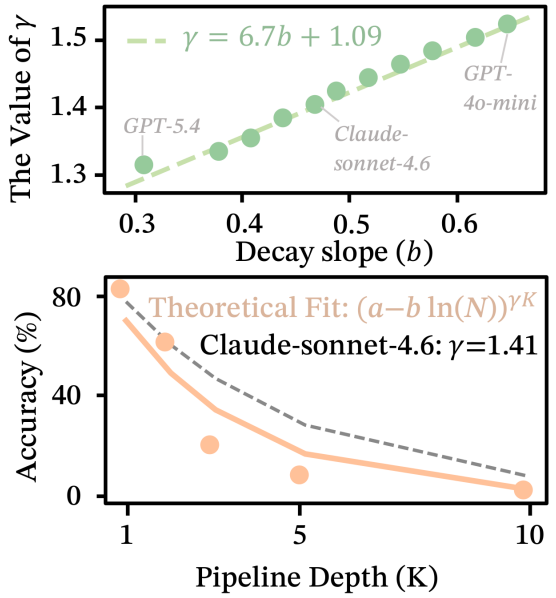


(a) Logarithmic decay of accuracy.

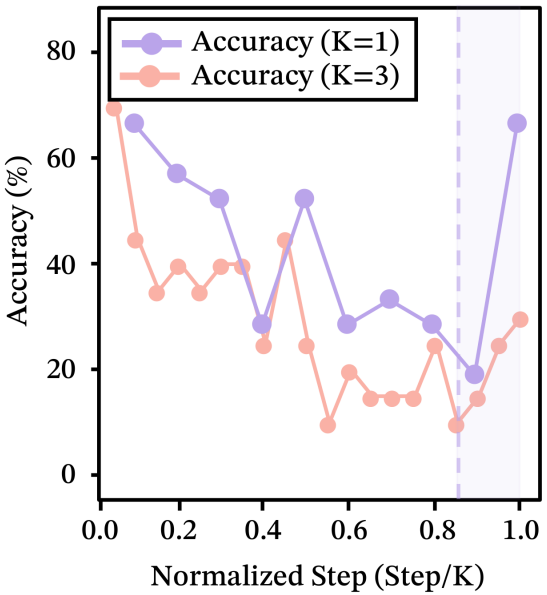




(b) Beyond independent logarithmic decay of 3 step parallel routing accuracy.



(c) Pipeline compounding law of accuracy strongly associated with decay slope (b) .



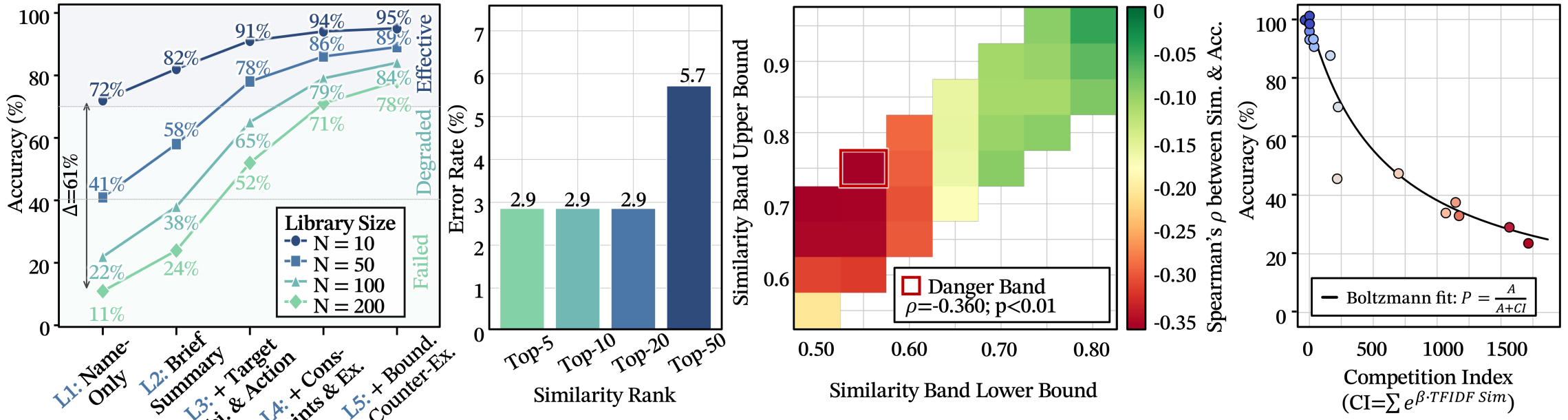
(d) The U-shape rebound of per-step accuracy in pipeline.

What exactly is the mechanism of Skill routing?

✅ **Semantic competition:** There is a dangerous, deceptively plausible skill region that models can easily be misled.

✅ **Pattern of semantic competition:** Within this region, competition level and accuracy follow a Boltzmann function.

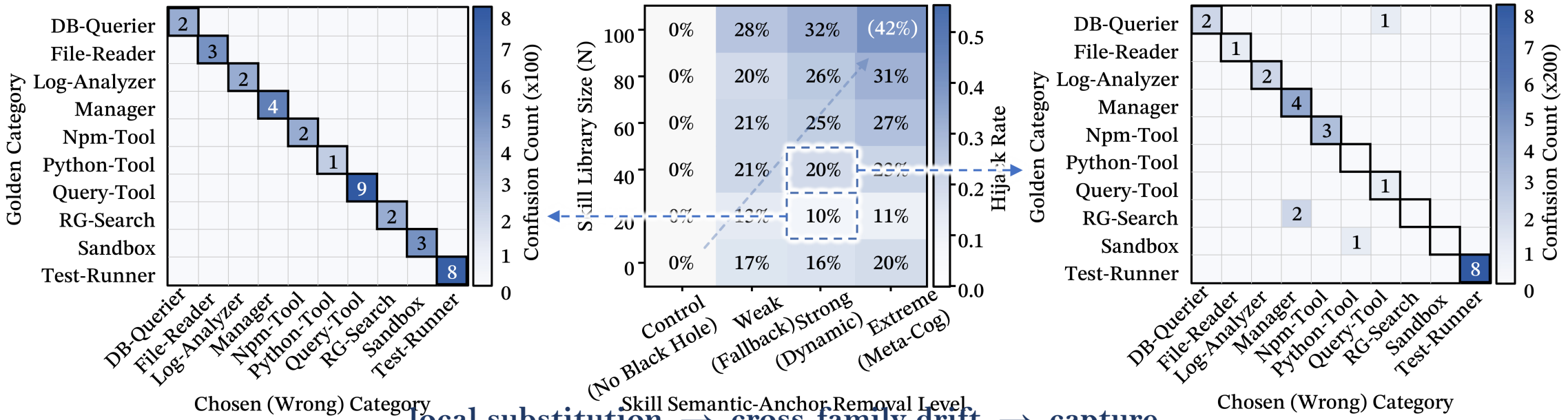
💡 **Essentially, the skill and the request match need to be sufficiently distinguishable.**



What exactly is the mechanism of Skill routing?

✅ We found that errors almost never cross functional clusters.

✅ They tend to occur in the parts that seem plausible but aren't quite right.



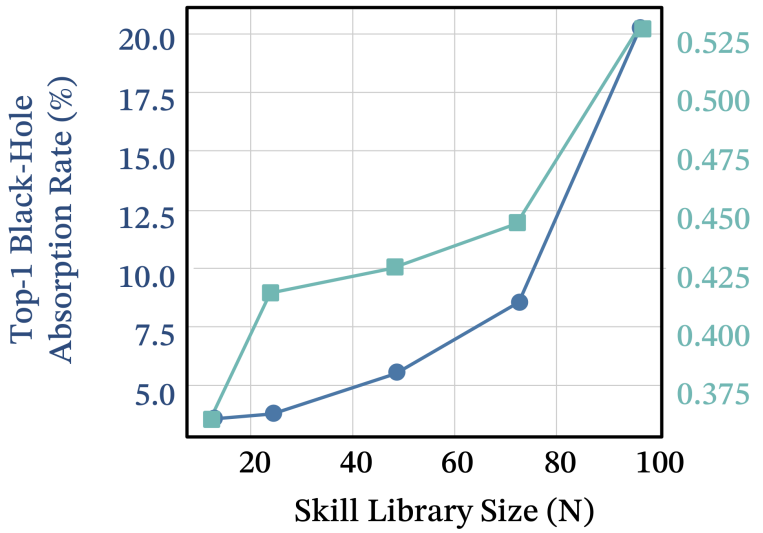
local substitution → cross-family drift → capture

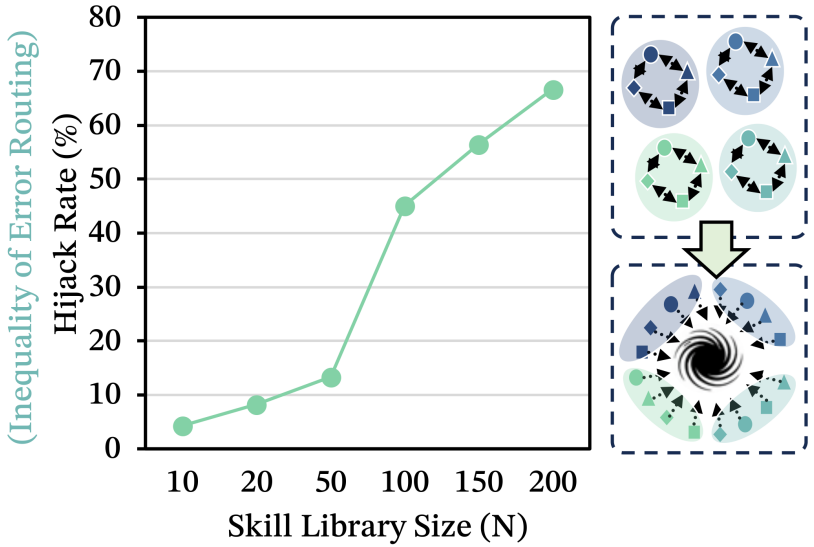
What exactly is the mechanism of Skill routing?

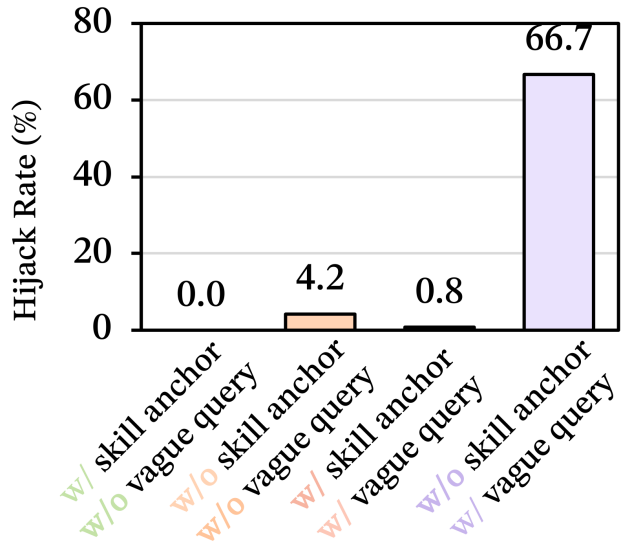
The Black-Hole Skill Effect

Is there a "black-hole skill" that attracts most of the routing traffic?

Yes. As the skill library grows, certain skills attract a disproportionate share of routes, and Gini coefficient rises sharply.





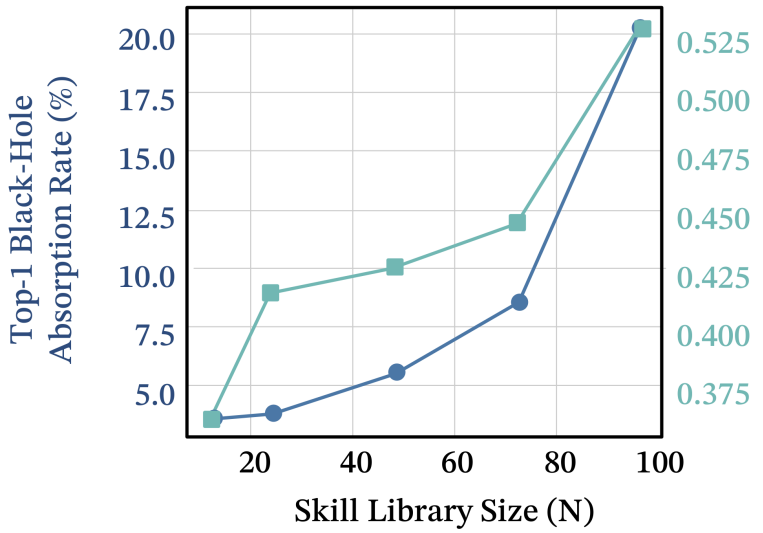


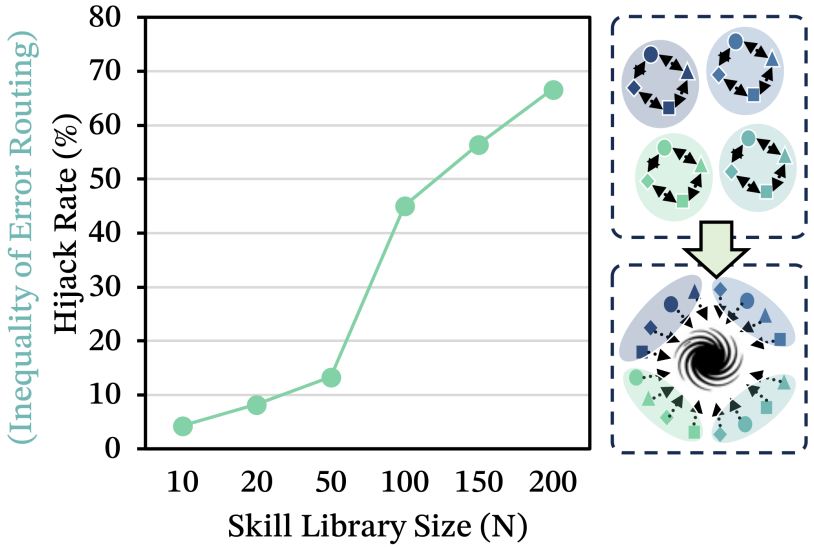
What exactly is the mechanism of Skill routing?

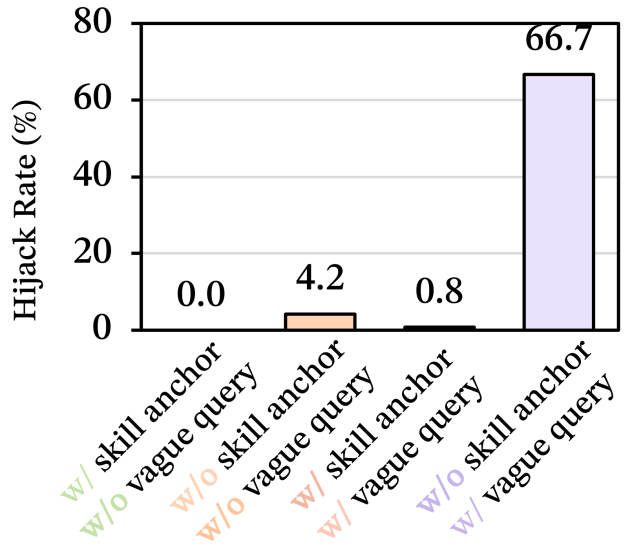
💡 The Black-Hole Skill Effect

❓ When does a “black-hole skill” emerge?

✅ When skill descriptions are vague and queries don’t clearly specify what skills they need. In those conditions, black-hole skills emerge and route requests to the wrong skill in ways users don’t want.



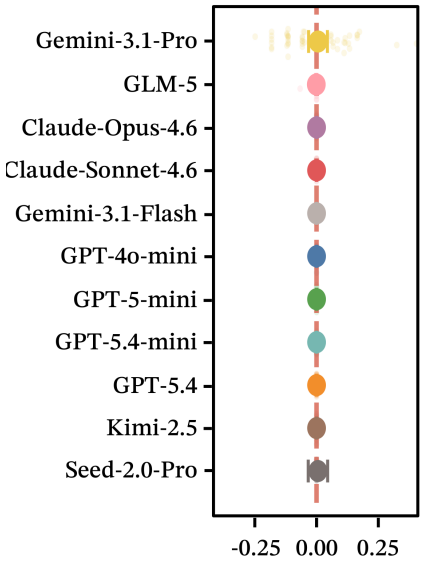




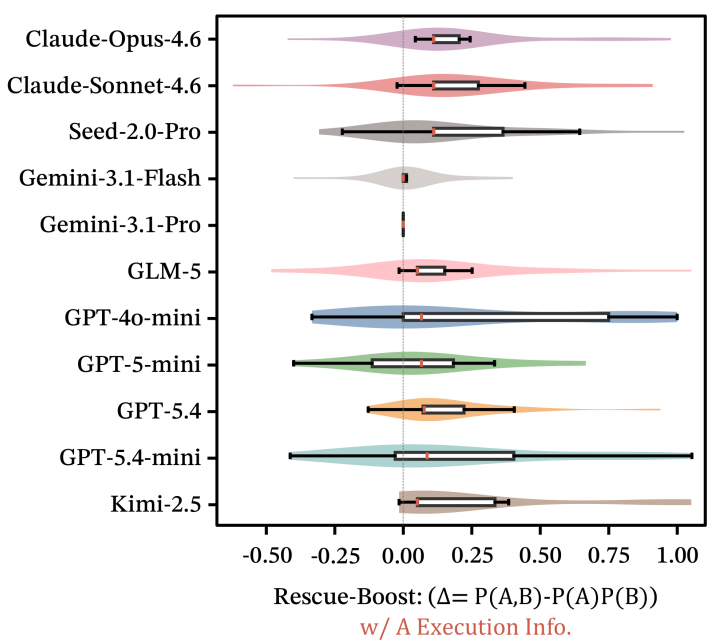
What exactly is the mechanism of Skill executing?

💡 **Sequential Routing Across Multiple Skills**

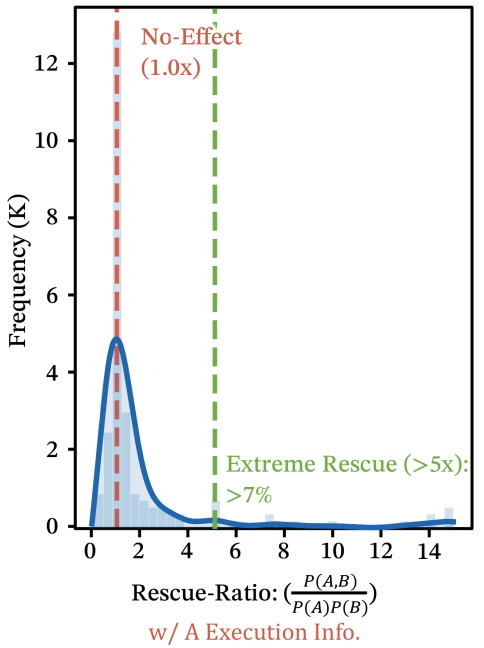
✅ When there's no execution-result information: only a record of which skills were called, the model routes to each skill ***independently***: calling Skill A has no effect on its routing to Skill B.



(a) The pipeline routing independence without execution information.



(b) The pipeline routing with rescue-boost with real execution information.

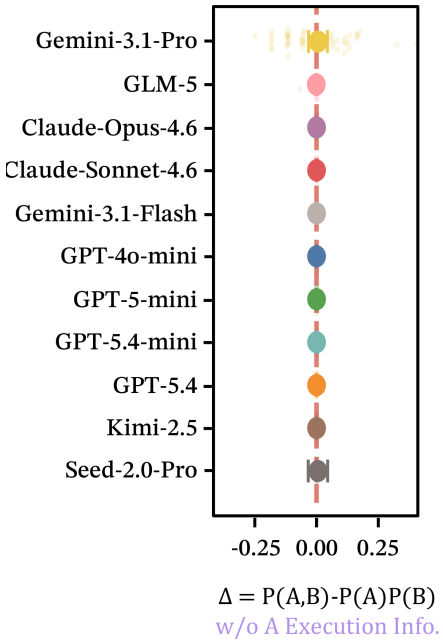


(c) The distribution of rescue-ratio with real execution information.

What exactly is the mechanism of Skill executing?

💡 Sequential Routing Across Multiple Skills

✅ When execution results are available alongside call information, routing shows a ***healing effect***: successful execution can rescue subsequent steps that would otherwise fail.



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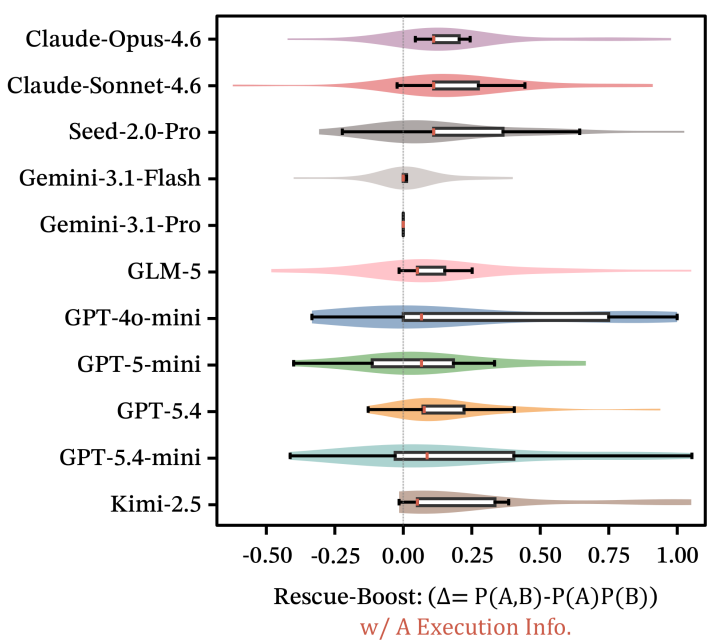

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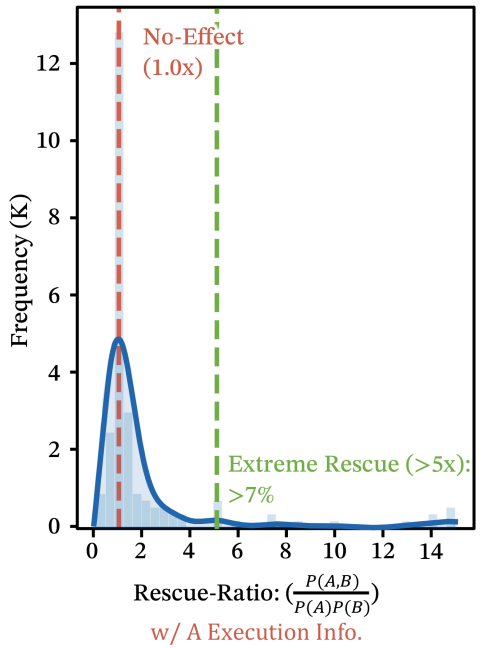


(c) The distribution of rescue-ratio with real execution information.

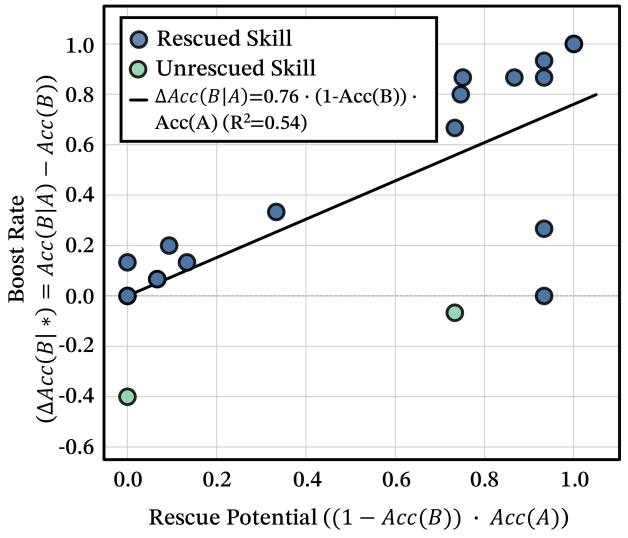
What exactly is the mechanism of Skill executing?

🎯 The Drag Effect of Execution Errors

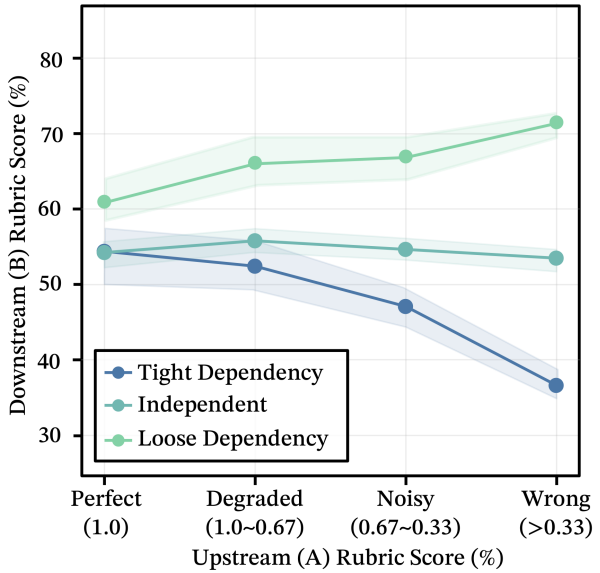
✅ Tightly dependent skills can have a major impact on the overall pipeline.

✅ Independent skills have little impact.

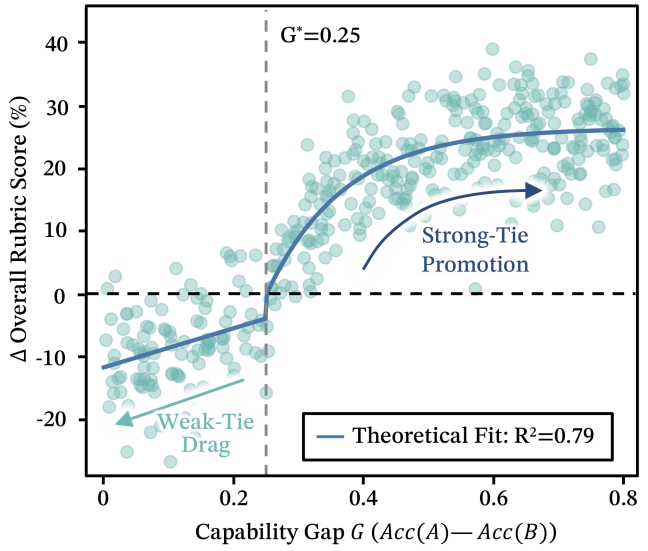
✅ Loosely coupled skills can actually help the overall pipeline recover.



(a) The validation of rescue law: $\Delta Acc(B|A)$=0.76 · (1-Acc(B)) · Acc(A) (R2=0.54)



(b) Rubric scores for two-step task completion under varying degrees of semantic coupling between skills.



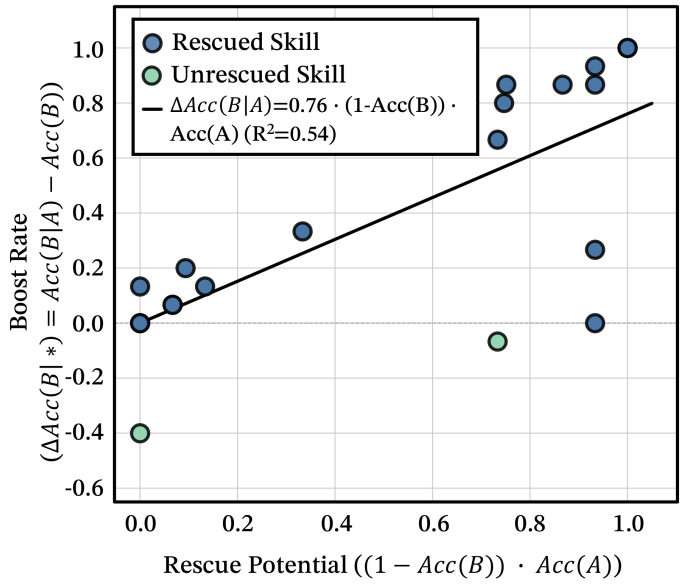
(c) Strong-Tie Promotion and Weak-Tie Drag under Crowding Risk.

What exactly is the mechanism of Skill executing?

💡 **Strong-to-Weak Lift, Weak-to-Strong Drag**

✅ If the skill for the first task is more capable than skill for the second task, it lifts the Acc. of subsequent tasks ***nonlinearly***.

✅ If the first task's skill is less capable than the second task's, it drags down subsequent tasks ***linearly***.



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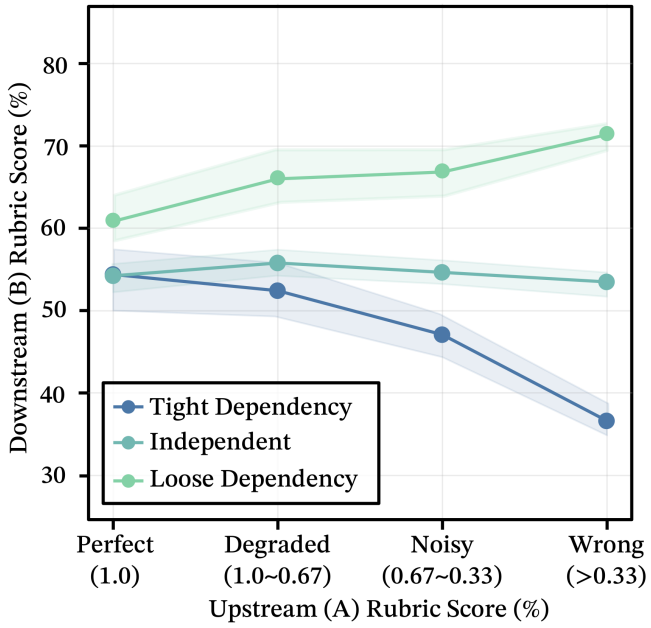

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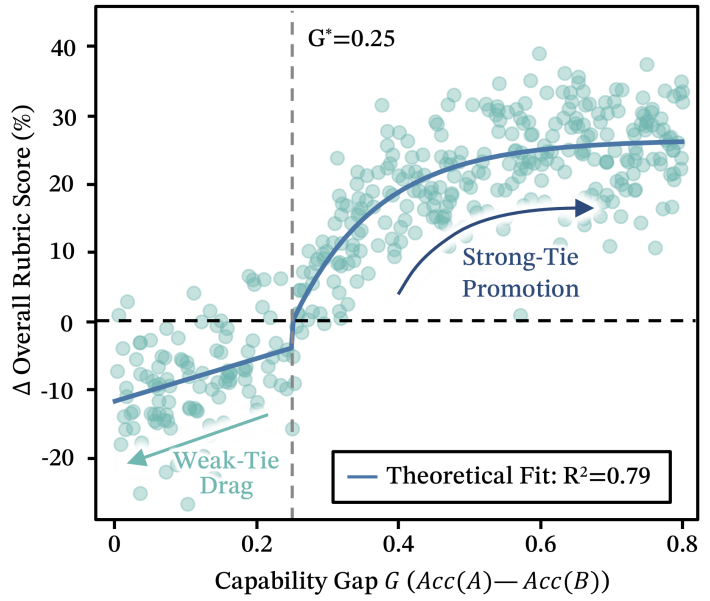

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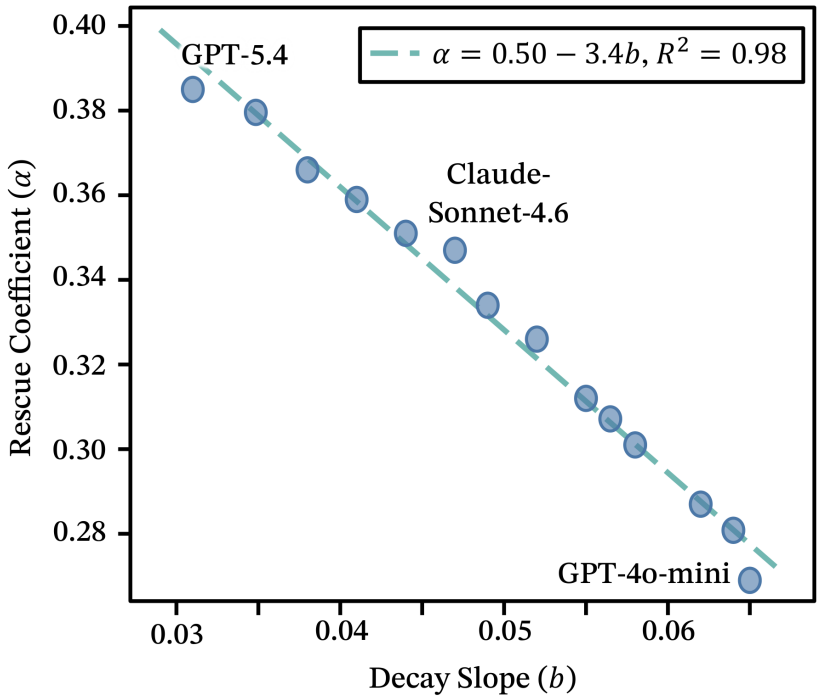
Unified Routing & Executing Law

The routing slope b is the shared state variable



$$Acc_{res}(B|N) = Acc(B|N) + 2\alpha\left(1 - Acc(B|N)\right)(\alpha - b \ln N)$$

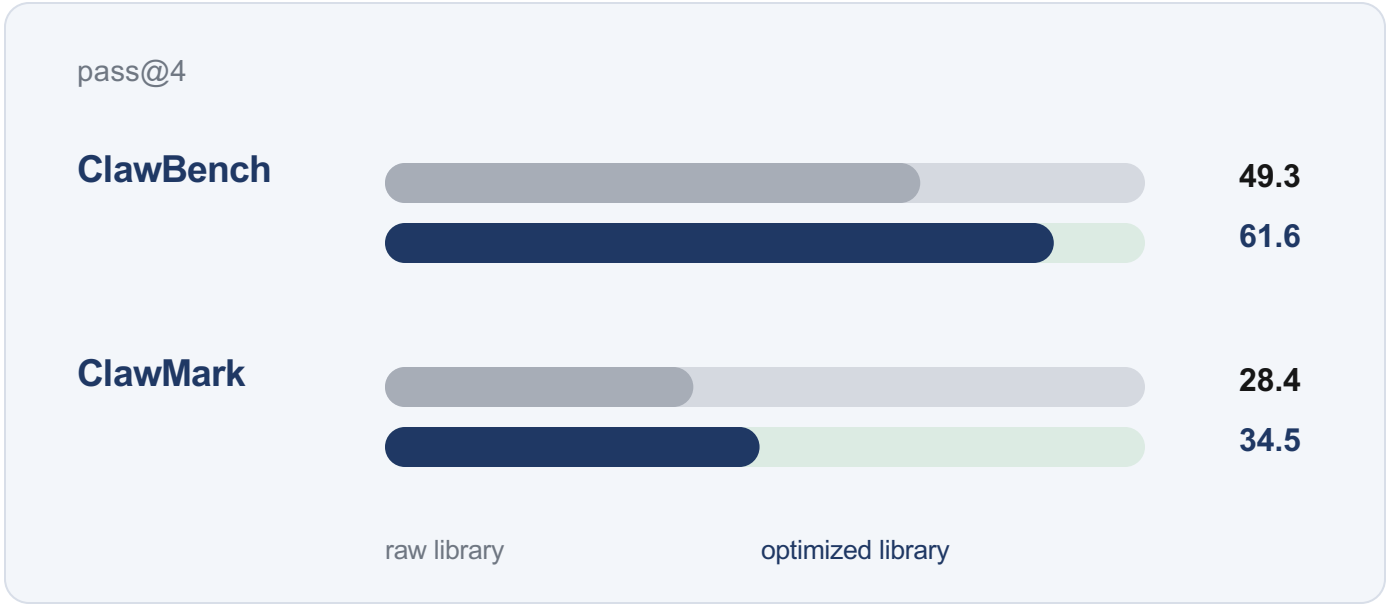
No new parameter is introduced. The same b that costs routing accuracy also determines how much correct state survives for downstream use.

Lowering b is the design objective

$R^2 = 0.98 \cdot \rho = 0.74$ on independent rescue measurements

The gain transfers across agents

The optimized library transfers across agents and domains



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domains improve

ClawBench

49.3 → 61.6

ClawMark

28.4 → 34.5

Design the library, not just the model

Large skill libraries should be structured systems, not pools of tools.

PAPER

CODE

BLOG