Zeta Alpha

CUSTOMIZING DEEP RESEARCH: ELO EVALS AND OPTIMIZATION OF ADVANCED AI AGENTS

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AI IN KNOWLEDGE INTENSIVE INDUSTRIES

CHEMISTRY, HIGH TECH MANUFACTURING, LIFE SCIENCES, PHARMA ETC.

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DEEP RESEARCH
WHAT IF YOU NEED ALL THE ANSWERS?

innovative methods to improve the structural properties of PHA and PLA

Summary | Table | Research NEW

Innovative methods to improve the structural properties of PHA and PLA include:

1. **Blending and Copolymerization**: Combining PLA with PHA or other polymers can enhance mechanical and thermal properties. For instance, blending PLA with P3HB using melt processing improves structural characteristics 5 .
2. **Nanocomposites**: Incorporating nanofillers like cellulose or other nanoparticles into PLA/PHA composites enhances interfacial adhesion, thermal stability, and mechanical properties 2 3 .
3. **Nucleating Agents**: Developing green and efficient nucleating agents can improve the crystallinity and heat resistance of PLA 4 .
4. **Plasticizers**: Using biobased plasticizers can improve the flexibility and mechanical properties of PLA/PHA blends 1 .

These approaches are tailored to address specific limitations of these biopolymers.

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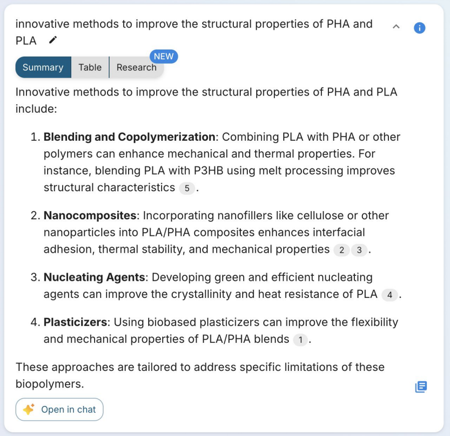
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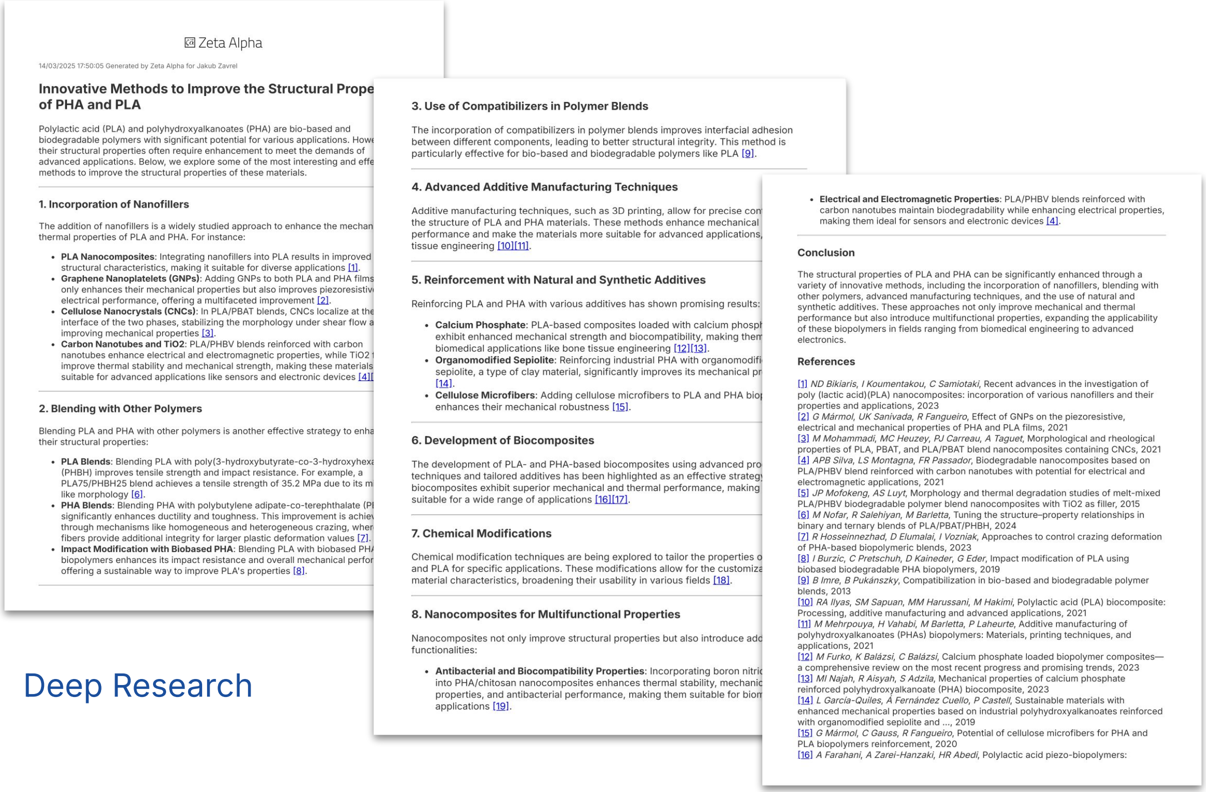
Quick Summary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Innovative Methods to Improve the Structural Prope of PHA and PLA

Polylactic acid (PLA) and polyhydroxyalkanoates (PHA) are bio-based and biodegradable polymers with significant potential for various applications. Howe their structural properties often require enhancement to meet the demands of advanced applications. Below, we explore some of the most interesting and effe methods to improve the structural properties of these materials.

1. Incorporation of Nanofillers

The addition of nanofillers is a widely studied approach to enhance the mechan thermal properties of PLA and PHA. For instance:

- **PLA Nanocomposites**: Integrating nanofillers into PLA results in improved structural characteristics, making it suitable for diverse applications [1].
- **Graphene Nanoplatelets (GNPs)**: Adding GNPs to both PLA and PHA films only enhances their mechanical properties but also improves piezoresistive electrical performance, offering a multifaceted improvement [2].
- **Cellulose Nanocrystals (CNCs)**: In PLA/PBAT blends, CNCs localize at the interface of the two phases, stabilizing the morphology under shear flow a improving mechanical properties [3].
- **Carbon Nanotubes and TiO2**: PLA/PHBV blends reinforced with carbon nanotubes enhance electrical and electromagnetic properties, while TiO2 improve thermal stability and mechanical strength, making these materials suitable for advanced applications like sensors and electronic devices [4][

2. Blending with Other Polymers

Blending PLA and PHA with other polymers is another effective strategy to enha their structural properties:

- **PLA Blends**: Blending PLA with poly(3-hydroxybutyrate-co-3-hydroxyhexa (PHBH) improves tensile strength and impact resistance. For example, a PLA75/PHBH25 blend achieves a tensile strength of 35.2 MPa due to its m like morphology [6].
- **PHA Blends**: Blending PHA with polybutylene adipate-co-terephthalate (P significantly enhances ductility and toughness. This improvement is achie through mechanisms like homogeneous and heterogeneous crazing, wher fibers provide additional integrity for larger plastic deformation values [7].
- **Impact Modification with Biobased PHA**: Blending PLA with biobased PH biopolymers enhances its impact resistance and overall mechanical perfor offering a sustainable way to improve PLA's properties [8].

3. Use of Compatibilizers in Polymer Blends

The incorporation of compatibilizers in polymer blends improves interfacial adhesion between different components, leading to better structural integrity. This method is particularly effective for bio-based and biodegradable polymers like PLA [9].

4. Advanced Additive Manufacturing Techniques

Additive manufacturing techniques, such as 3D printing, allow for precise con the structure of PLA and PHA materials. These methods enhance mechanical performance and make the materials more suitable for advanced applications, tissue engineering [10][11].

5. Reinforcement with Natural and Synthetic Additives

Reinforcing PLA and PHA with various additives has shown promising results:

- **Calcium Phosphate**: PLA-based composites loaded with calcium phosph exhibit enhanced mechanical strength and biocompatibility, making them biomedical applications like bone tissue engineering [12][13].
- **Organomodified Sepiolite**: Reinforcing industrial PHA with organomodifi sepiolite, a type of clay material, significantly improves its mechanical pr [14].
- **Cellulose Microfibers**: Adding cellulose microfibers to PLA and PHA biop enhances their mechanical robustness [15].

6. Development of Biocomposites

The development of PLA- and PHA-based biocomposites using advanced pro techniques and tailored additives has been highlighted as an effective strateg biocomposites exhibit superior mechanical and thermal performance, making suitable for a wide range of applications [16][17].

7. Chemical Modifications

Chemical modification techniques are being explored to tailor the properties o and PLA for specific applications. These modifications allow for the customiza material characteristics, broadening their usability in various fields [18].

8. Nanocomposites for Multifunctional Properties

Nanocomposites not only improve structural properties but also introduce add functionalities:

- **Antibacterial and Biocompatibility Properties**: Incorporating boron nitric into PHA/chitosan nanocomposites enhances thermal stability, mechanic properties, and antibacterial performance, making them suitable for biom applications [19].

- **Electrical and Electromagnetic Properties**: PLA/PHBV blends reinforced with carbon nanotubes maintain biodegradability while enhancing electrical properties, making them ideal for sensors and electronic devices [4].

Conclusion

The structural properties of PLA and PHA can be significantly enhanced through a variety of innovative methods, including the incorporation of nanofillers, blending with other polymers, advanced manufacturing techniques, and the use of natural and synthetic additives. These approaches not only improve mechanical and thermal performance but also introduce multifunctional properties, expanding the applicability of these biopolymers in fields ranging from biomedical engineering to advanced electronics.

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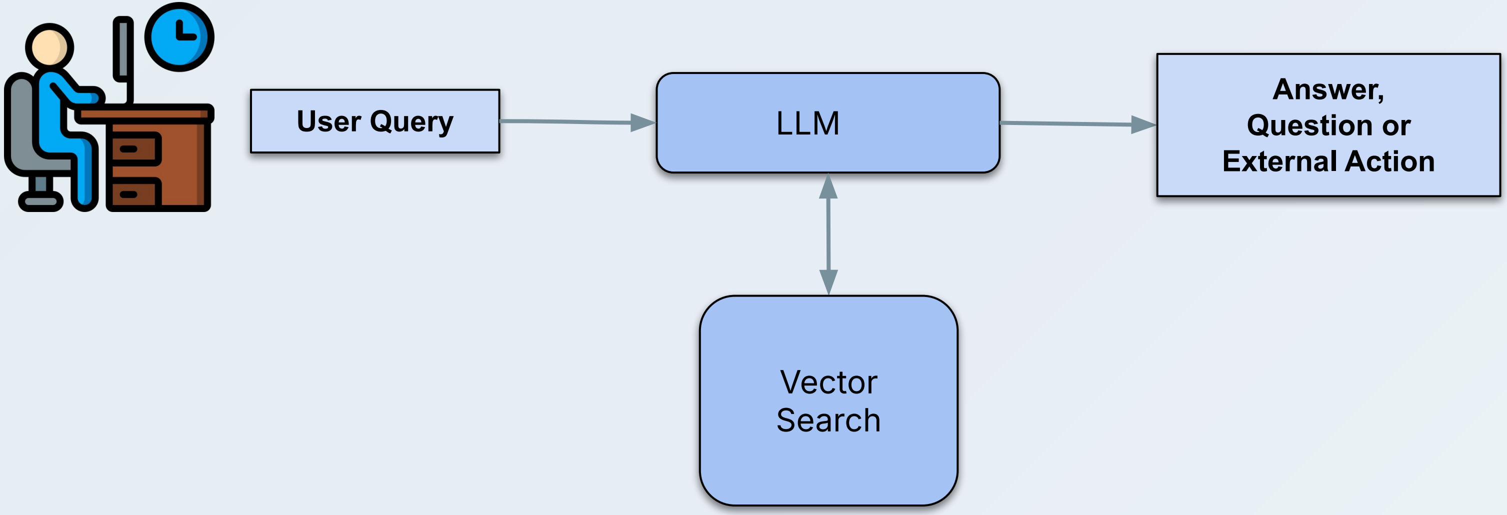
Deep Research

FROM RAG TO AI AGENTS



FROM RAG TO AI AGENTS

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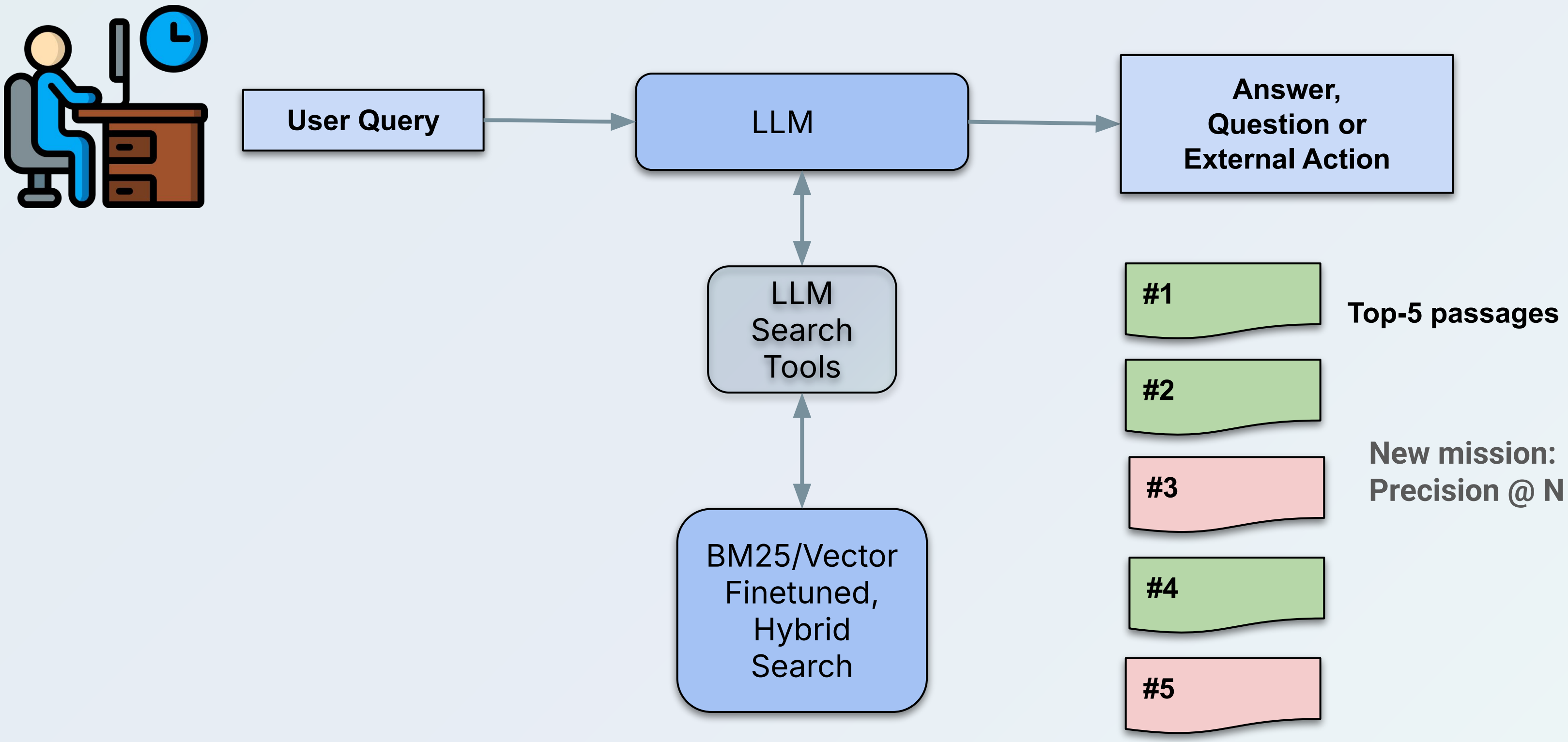

COMPLEX AGENTIC SEARCH PIPELINES

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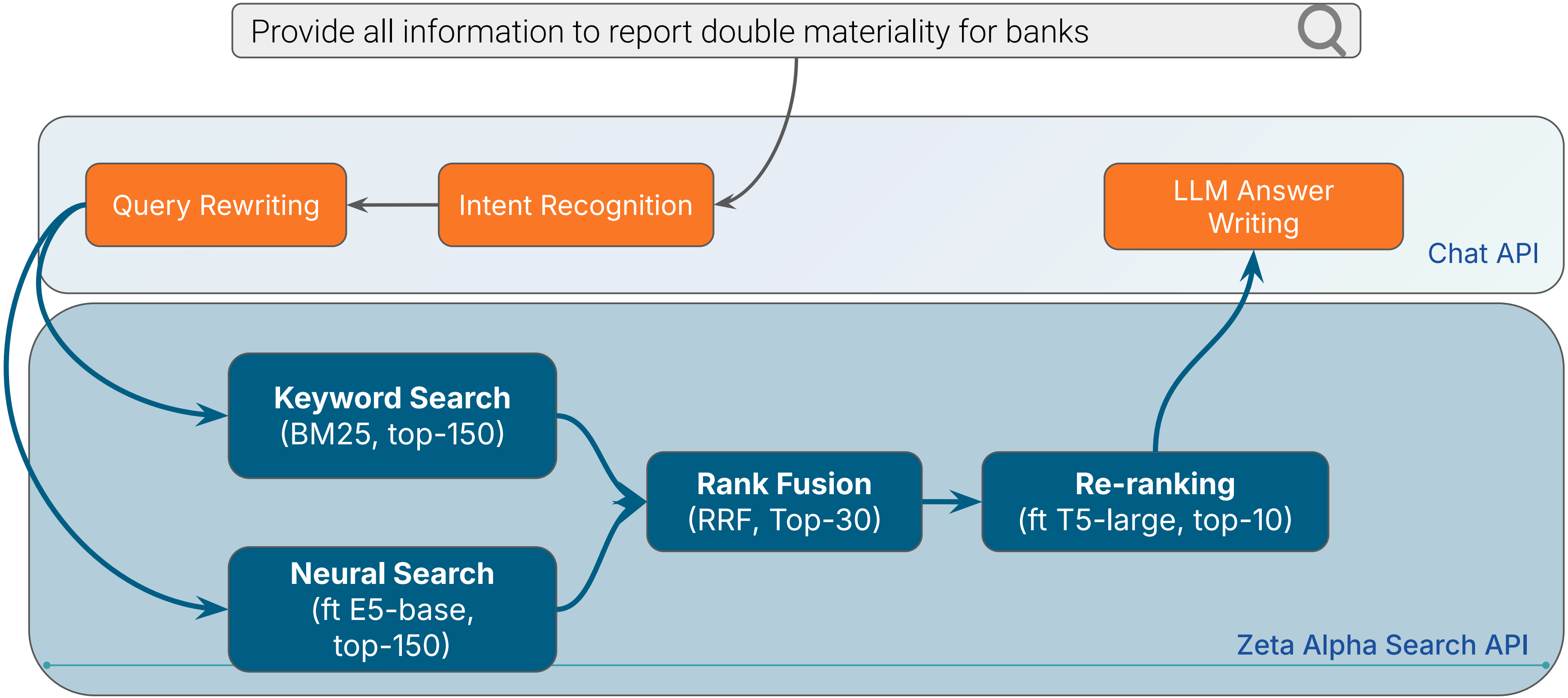

FROM RAG TO AI AGENTS

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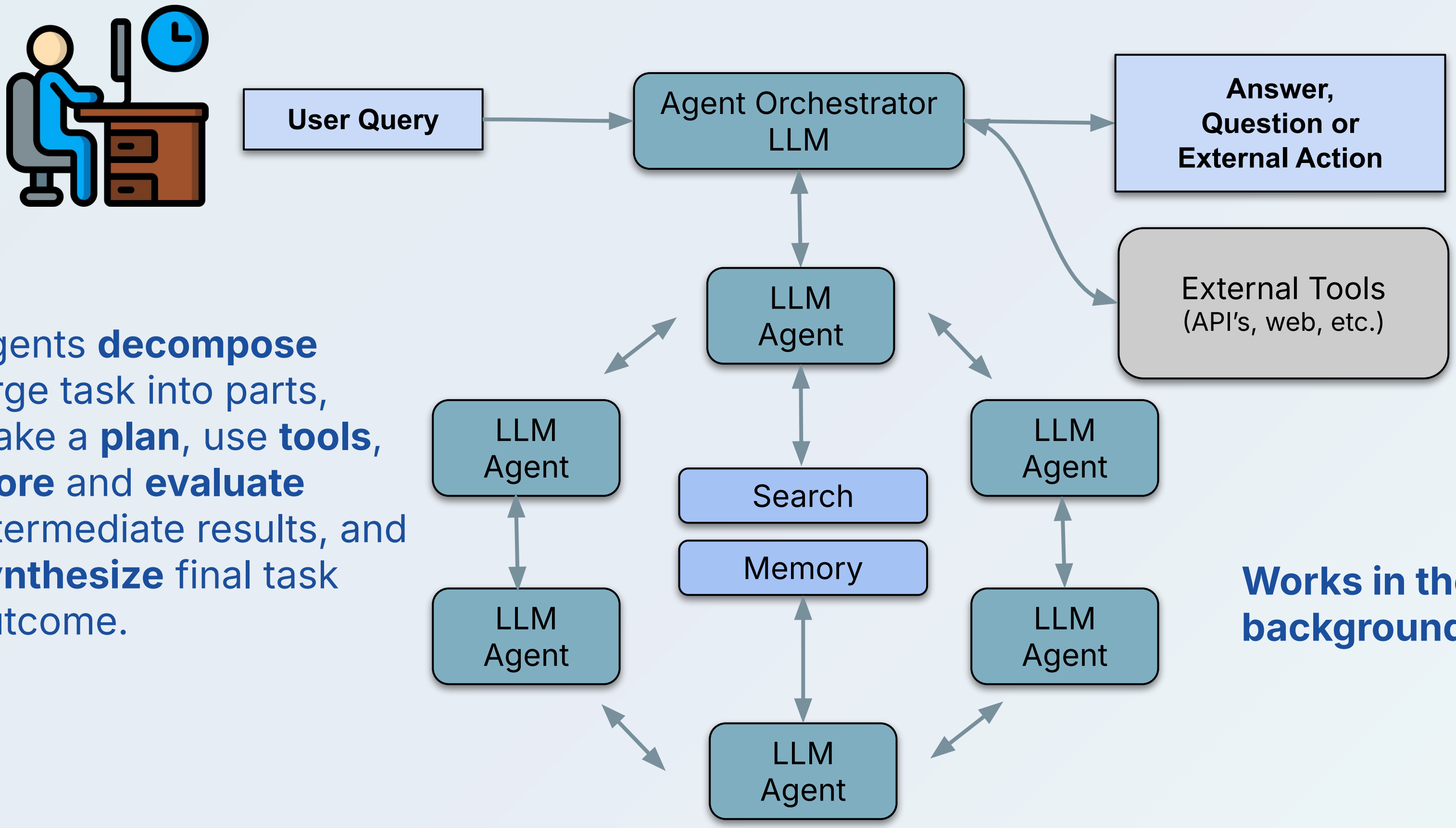

gets the full task done

Agents **decompose** large task into parts, make a **plan**, use **tools**, **store** and **evaluate** intermediate results, and **synthesize** final task outcome.

Works in the background…

AI AGENT EVALUATION

EVALUATION IN THE ENTERPRISE

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Can we use synthetic queries to evaluate our system?

- Large test collection for **reliably** is usually not available.
- Performance on public benchmarks doesn't always translate into performance in **private data**.
- Why not use LLM-generated queries for **evaluating** your pipeline?
  – *after bootstrapping on a handful of expert queries* –

`What is the definition of sustainability in European legislation incl. guidance from ESAs?`

`What is the rate of hydrogenation of alpha-D-glucose in MeCONMe2?`

`Provide all information to report double materiality for banks`

`Which programming languages can be used for PLC programming?`

`which valve is compatible with VABM-B10-25-G12-2-P53?`

LLM AS A JUDGE: POINTWISE

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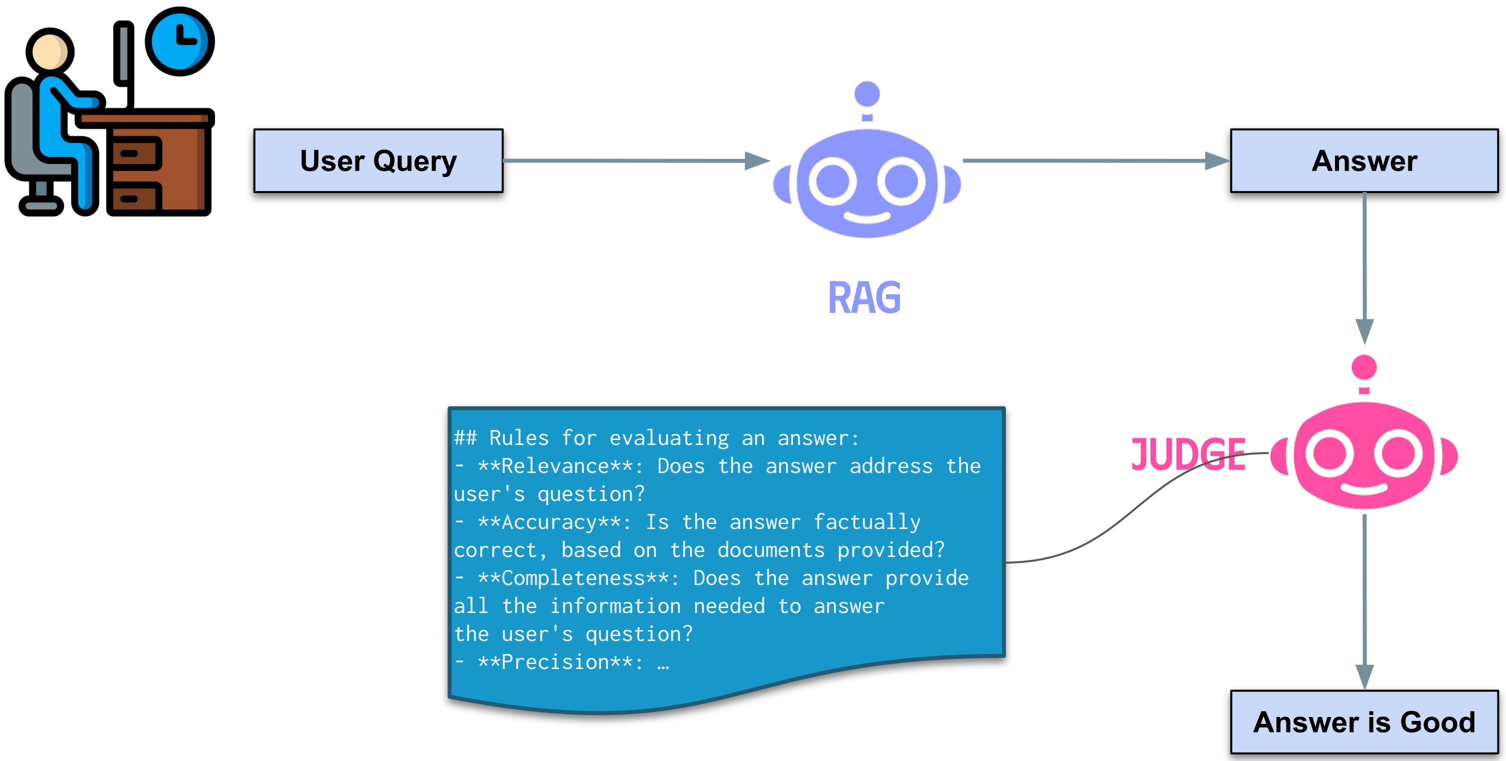

LLM AS A JUDGE VS EXPERTS

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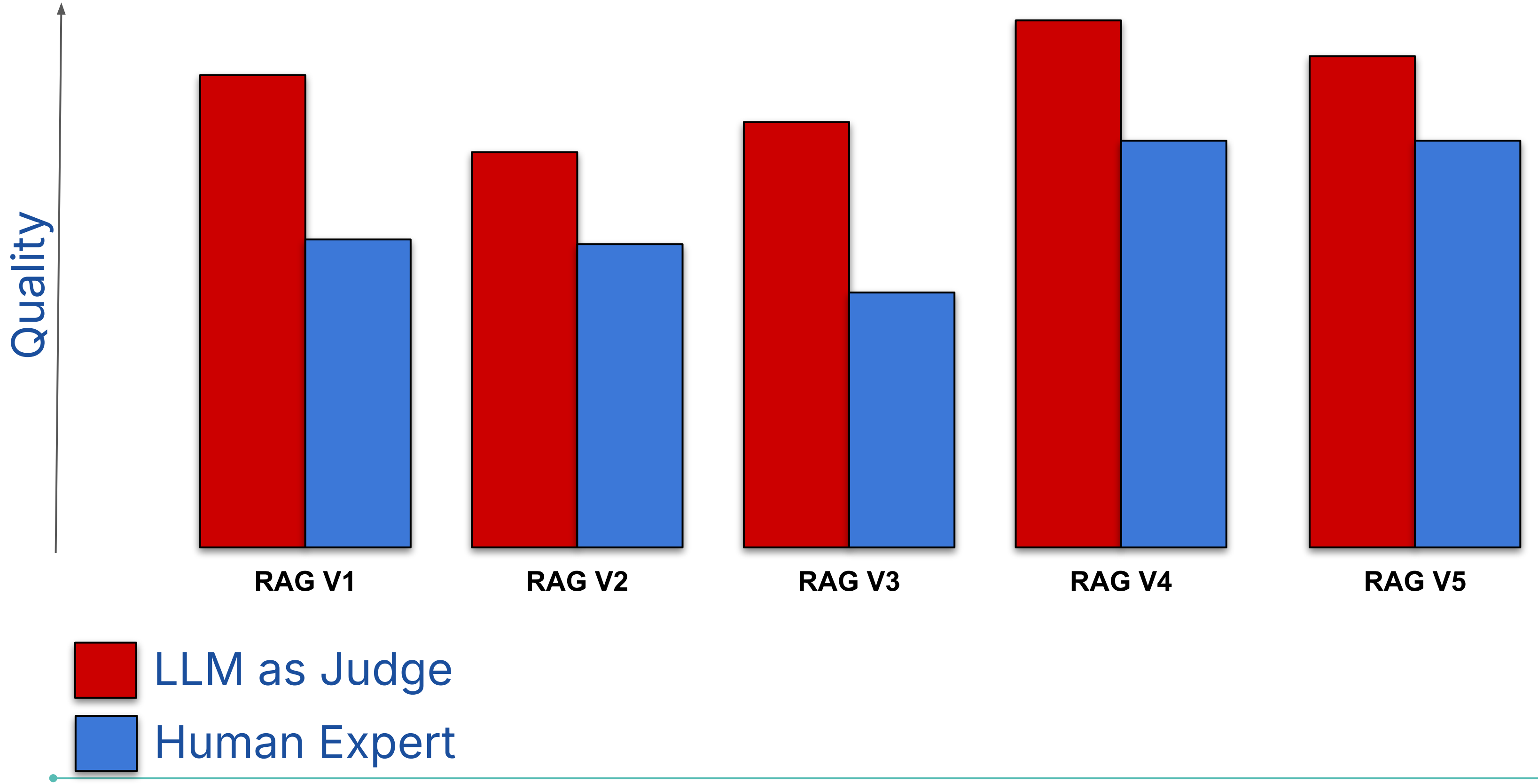

LLM AS A JUDGE VS EXPERTS

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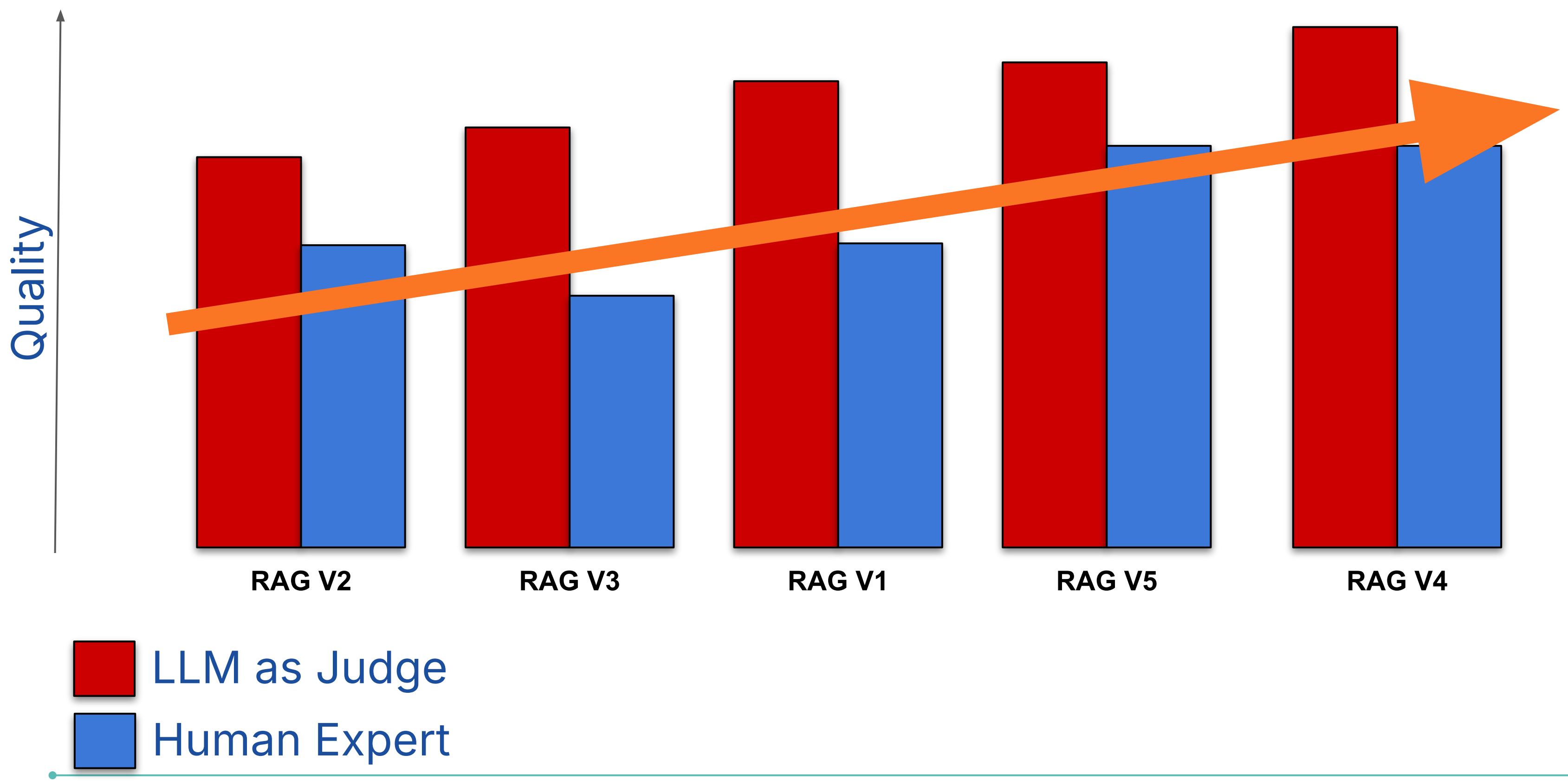

LLM AS JUDGE VS HUMAN ANNOTATION

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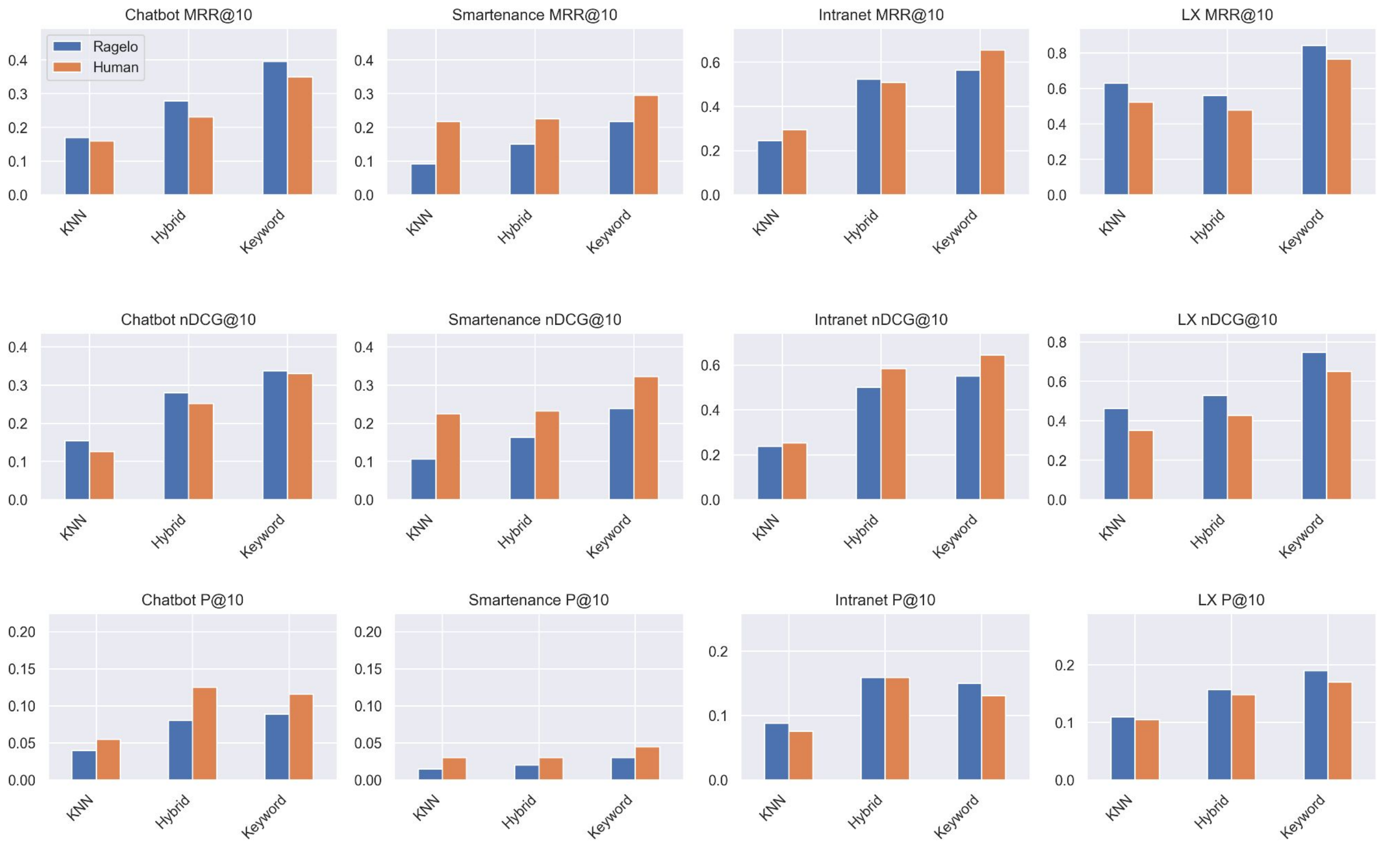

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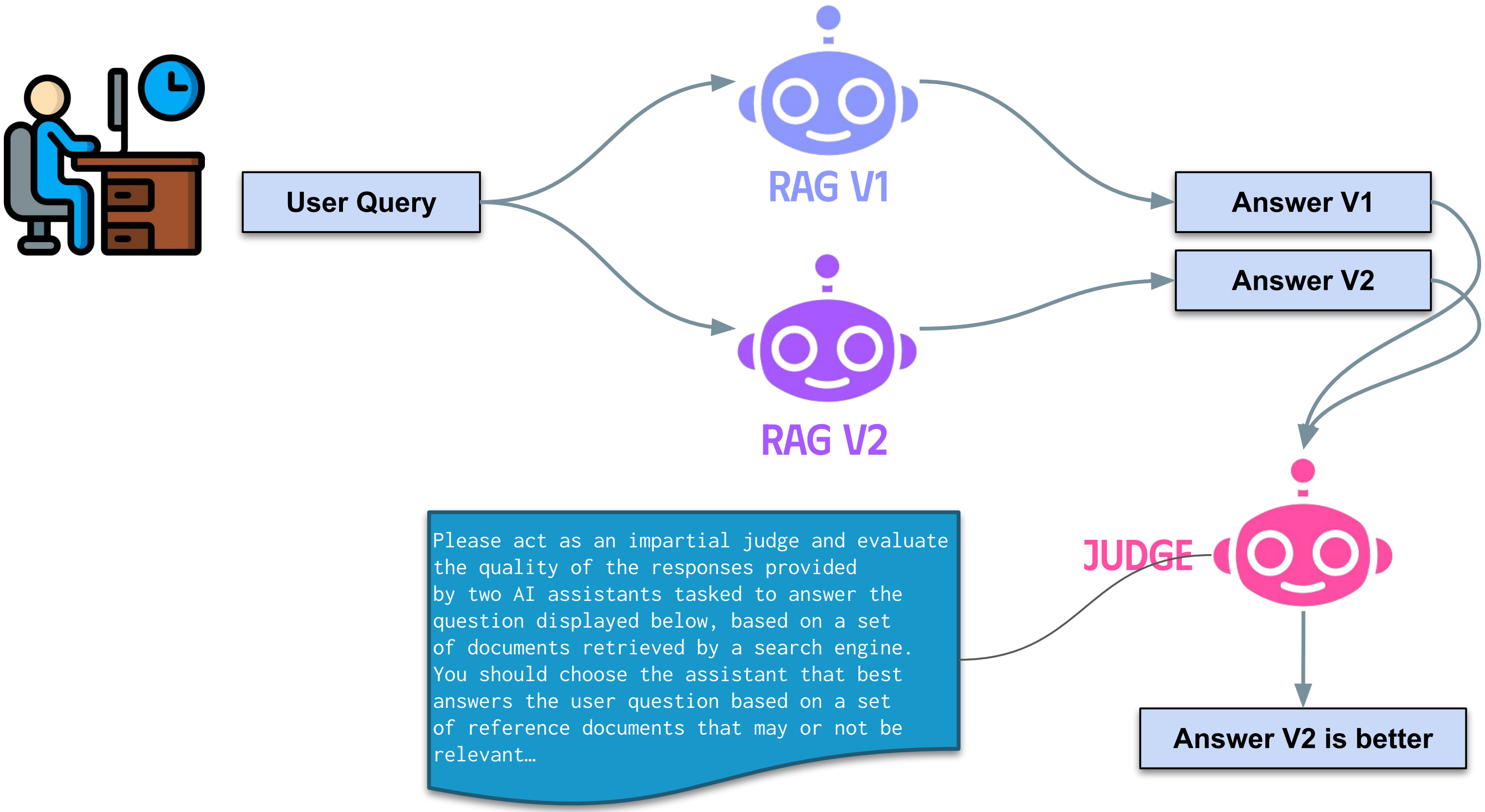
WHAT IF WE ASK THE LLM TO COMPARE TWO ANSWERS?

LLM AS A JUDGE: PAIRWISE



HOW DO WE RANK PAIRWISE?

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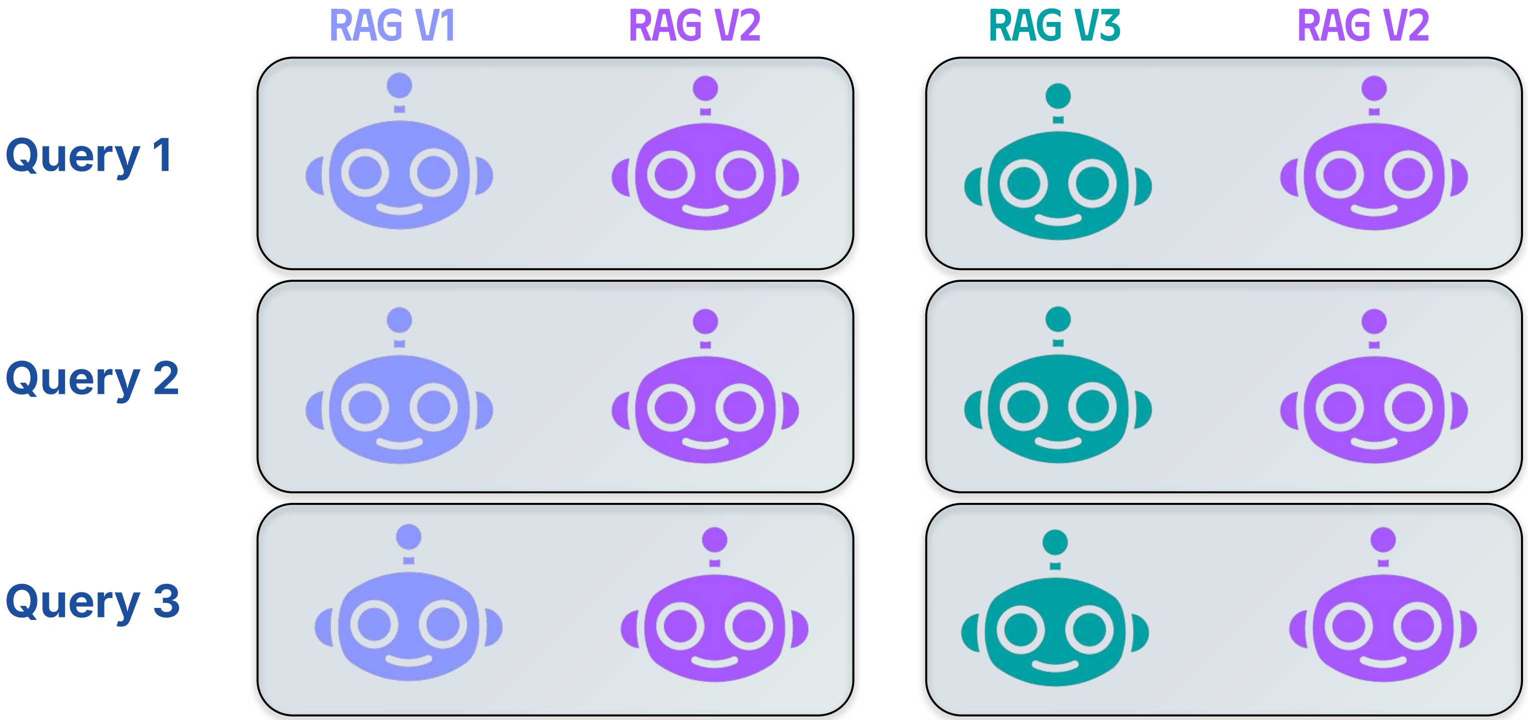

THE ELO RANKING SYSTEM

Idea: Keep an ELO tournament between all the generated agents?

- Each **agent** (or RAG system) is a … tournament with an initial rank.
- Each **query** is **game** played betwe… agents.
- A **game** between **Agent A** and **Agent B** is played by prompting an LLM to select which answer to the same **query** is better.
- If **A** wins and its ranking is **higher** than **B**:
  - ↗ Score of **A** increases a bit.
  - ↘ Score of **B** decreases a bit.
- If **A** wins and its ranking is **lower** than **B**:
  - ↖ Score of **A** increases more.
  - ↘ Score of **B** decreases more.

RAGELO TOOLKIT

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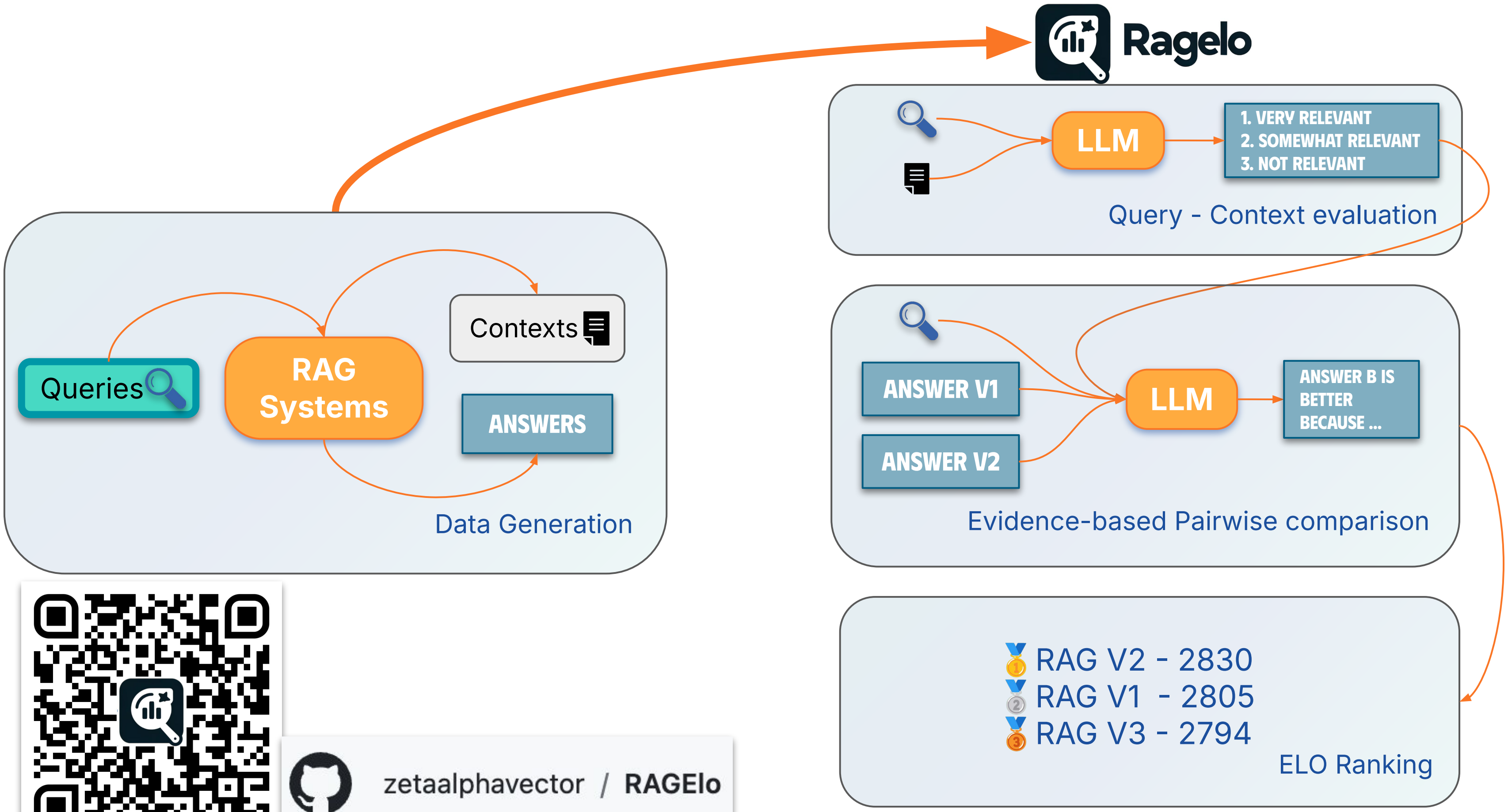

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ELO EVALUATION – KEY ADVANTAGES

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Can we use synthetic queries and judgments to evaluate our system?

- Extrapolation from a few expert generated examples.
- No ‘gold standard’ metric needed.
- We can add ***new*** ‘players’ later without re-running the whole tournament.

AI AGENT OPTIMIZATION

AI AGENTS: HOW DO YOU OPTIMIZE THIS?

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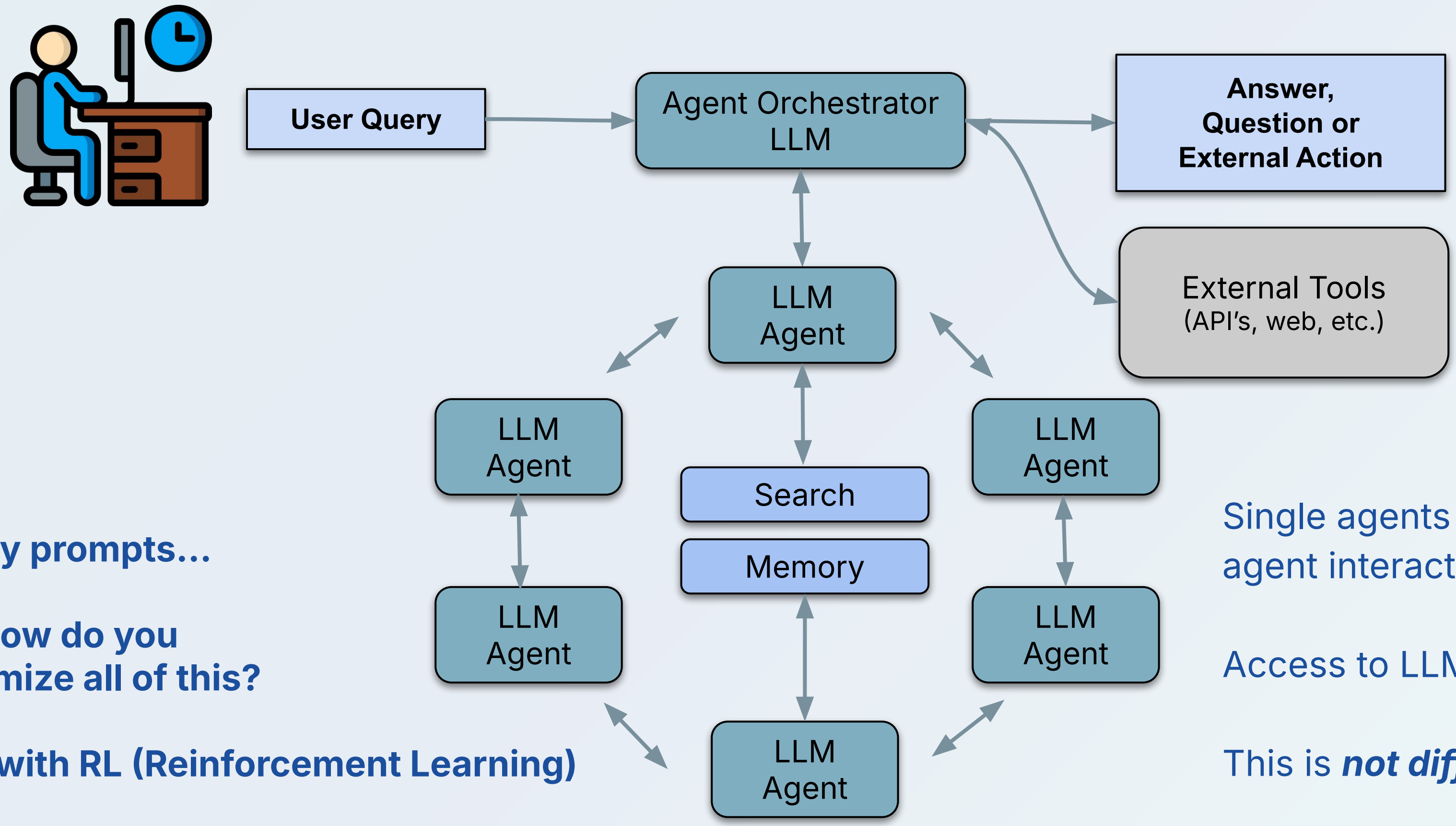

Many prompts...

So how do you optimize all of this?

Not with RL (Reinforcement Learning)

Single agents + agent interactions.

Access to LLM weights?

This is ***not differentiable!***

A DEEP RESEARCH ARCHITECTURE

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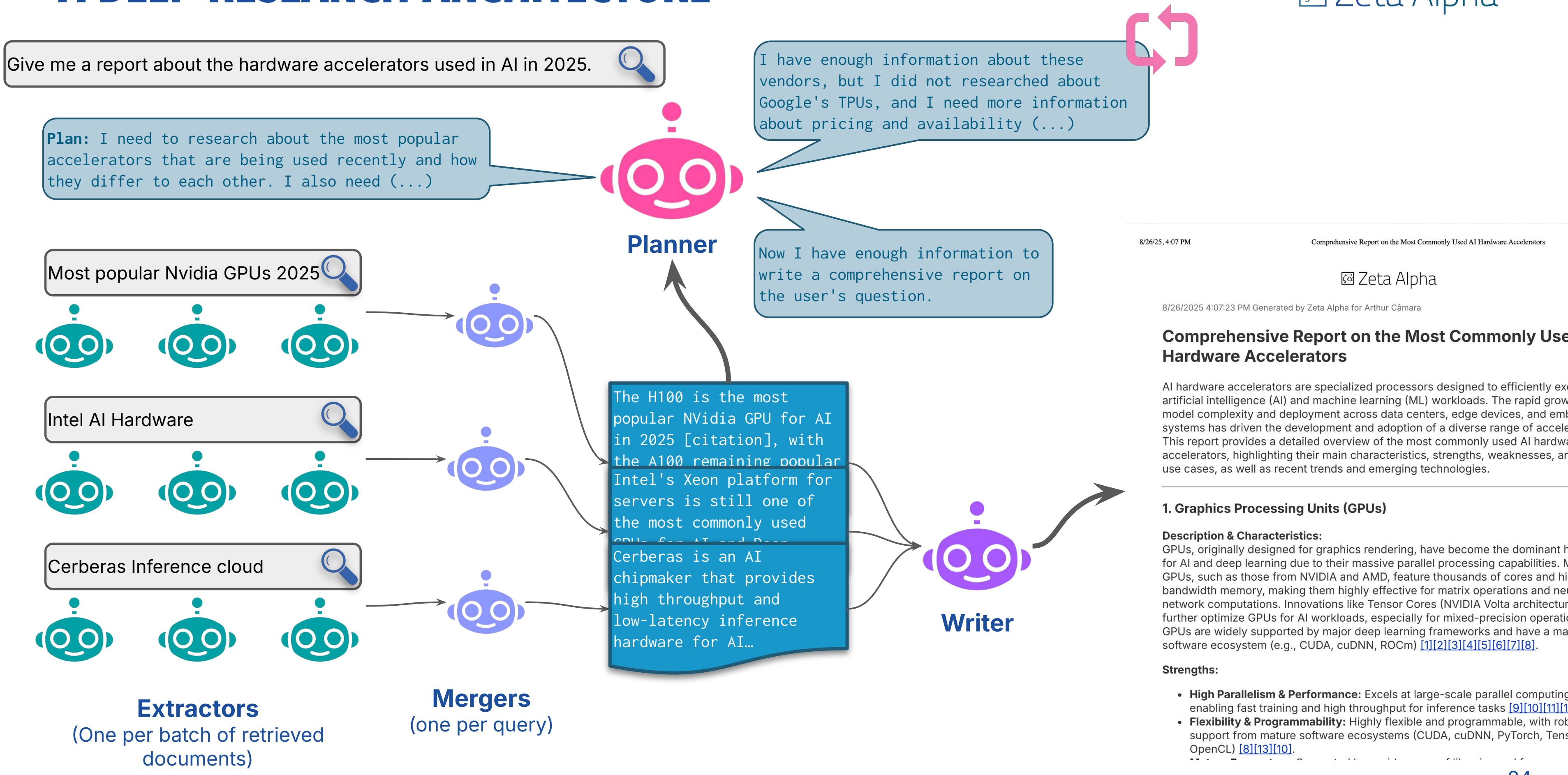

AGENTIC AI OPTIMIZATION

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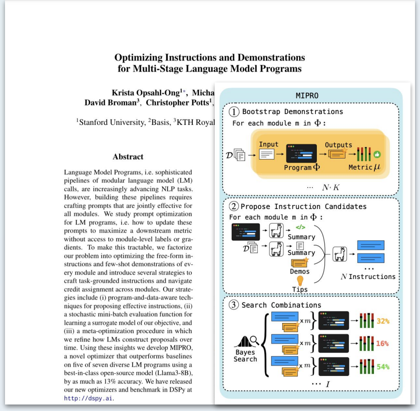
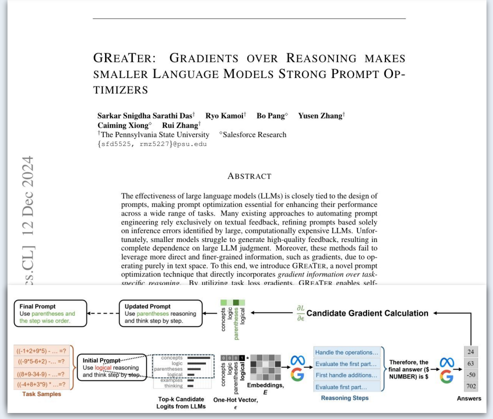
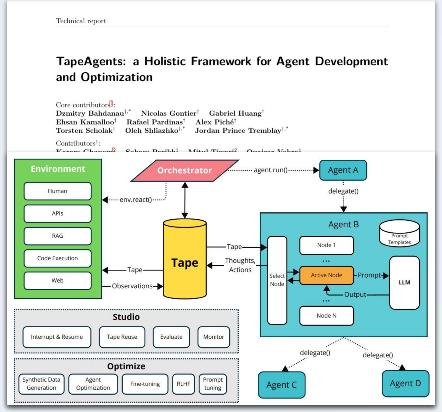
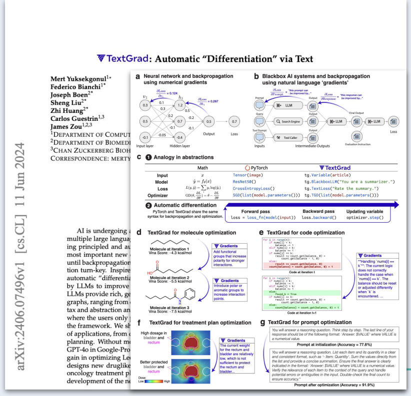
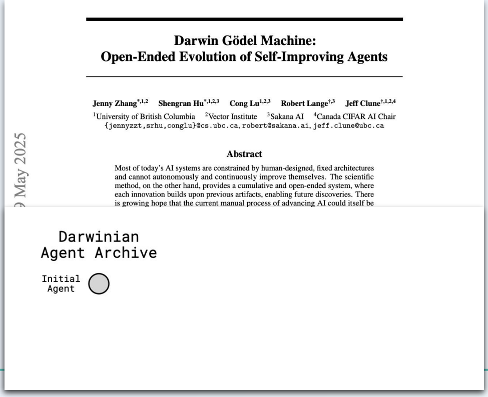
Recent surge in research...

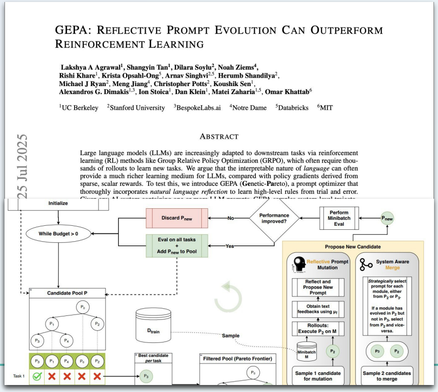












Key element:

Use the raw intelligence of the LLM itself as an operator to come up with improved versions of the system.

Stanford University

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TEXTGRAD: AUTOMATIC "DIFFERENTIATION" VIA TEXT (JULY 2024)

By Mert Yuksekgonul et al. (+6 authors)

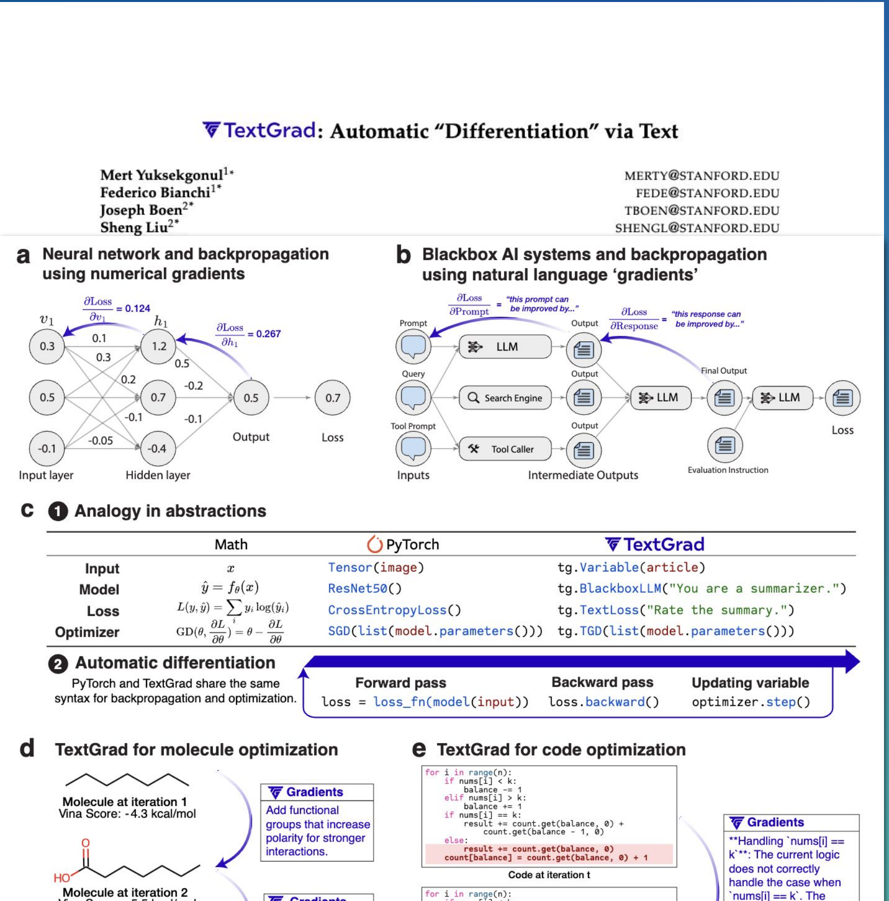
TextGrad: LLMs to perform automatic "**differentiation**" through text-based feedback.

Feedback/ gradient generator

- Given an answer and evaluation, generates a **feedback to the answer.**
- For each sub-agent, generates **feedback to its prompt**.
- Feedbacks are "**back-propagated**" across sub-agents

Optimizer

- For each sub-agent, **Feedback to its prompt**. Generates a **new prompt**.



OPTIMIZING AGENT SYSTEMS: TEXTGRAD EXPLORATION

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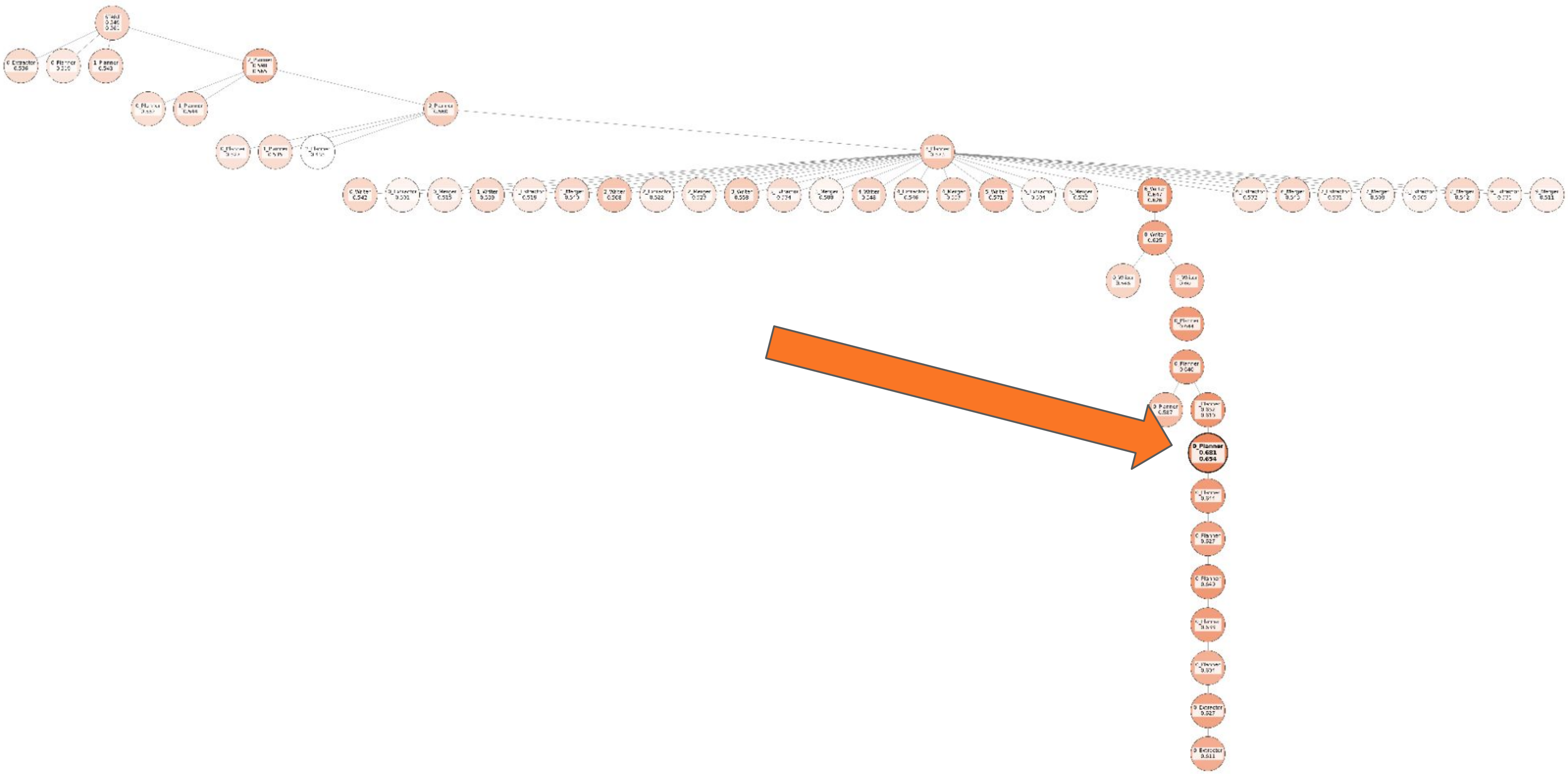

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GEPA: REFLECTIVE PROMPT EVOLUTION CAN OUTPERFORM REINFORCEMENT LEARNING (JULY 2025)

By Lakshya A Agrawal et al. (+16 authors)

GEPA: LLMs for prompt reflection and pareto-optimality to quickly select the best agents and merge sub-agents.

Feedback/ gradient generator

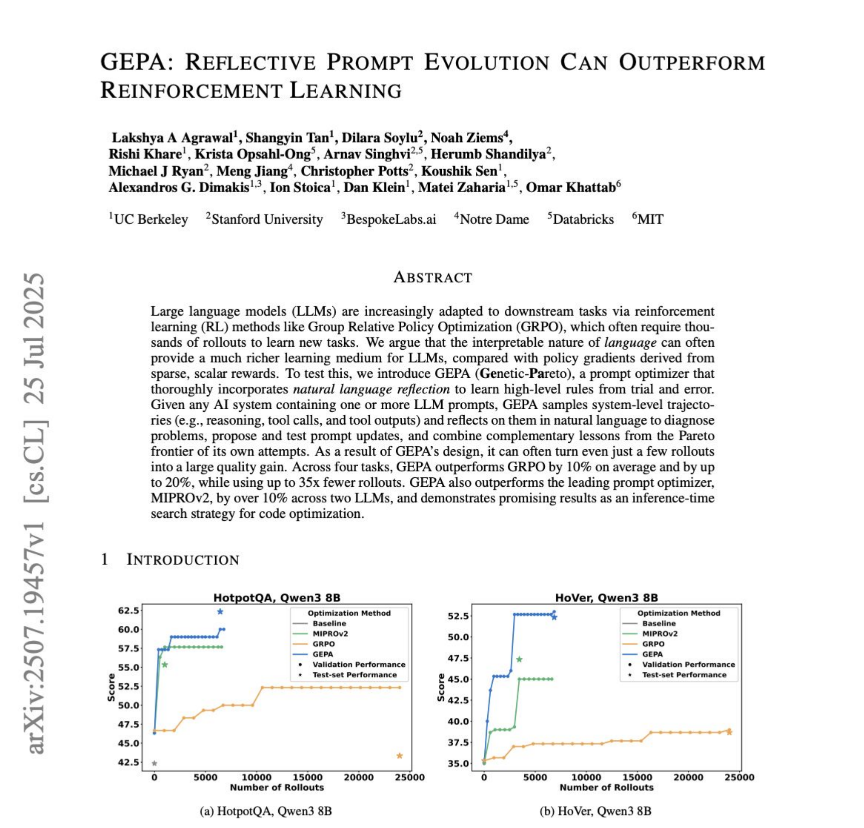
- Given one agent, get the answers **mini-batch of training queries**, obtain textual **feedback on its output.**

Optimizer

- With the **feedback on the mini-batch**, refine the prompt of one sub-agent at a time.
- Optionally, select another agent and combine its (other) sub-agents with this new sub-agent.

Agent selection

- If the new agent is better, add to **pool of candidate agents**.
- At each step, select from the agents that are **pareto-optimal** on a set of training samples



arXiv:2507.19457v1 [cs.CL] 25 Jul 2025

GEPA: REFLECTIVE PROMPT EVOLUTION CAN OUTPERFORM REINFORCEMENT LEARNING

Lakshya A Agrawal[1], Shangyin Tan[1], Dilara Soylu[2], Noah Ziems[4], Rishi Khare[1], Krista Opsahl-Ong[5], Arnav Singhvi[2,5], Herumb Shandilya[2], Michael J Ryan[2], Meng Jiang[4], Christopher Potts[2], Koushik Sen[1], Alexandros G. Dimakis[1,3], Ion Stoica[1], Dan Klein[1], Matei Zaharia[1,5], Omar Khattab[6]

[1]UC Berkeley [2]Stanford University [3]BespokeLabs.ai [4]Notre Dame [5]Databricks [6]MIT

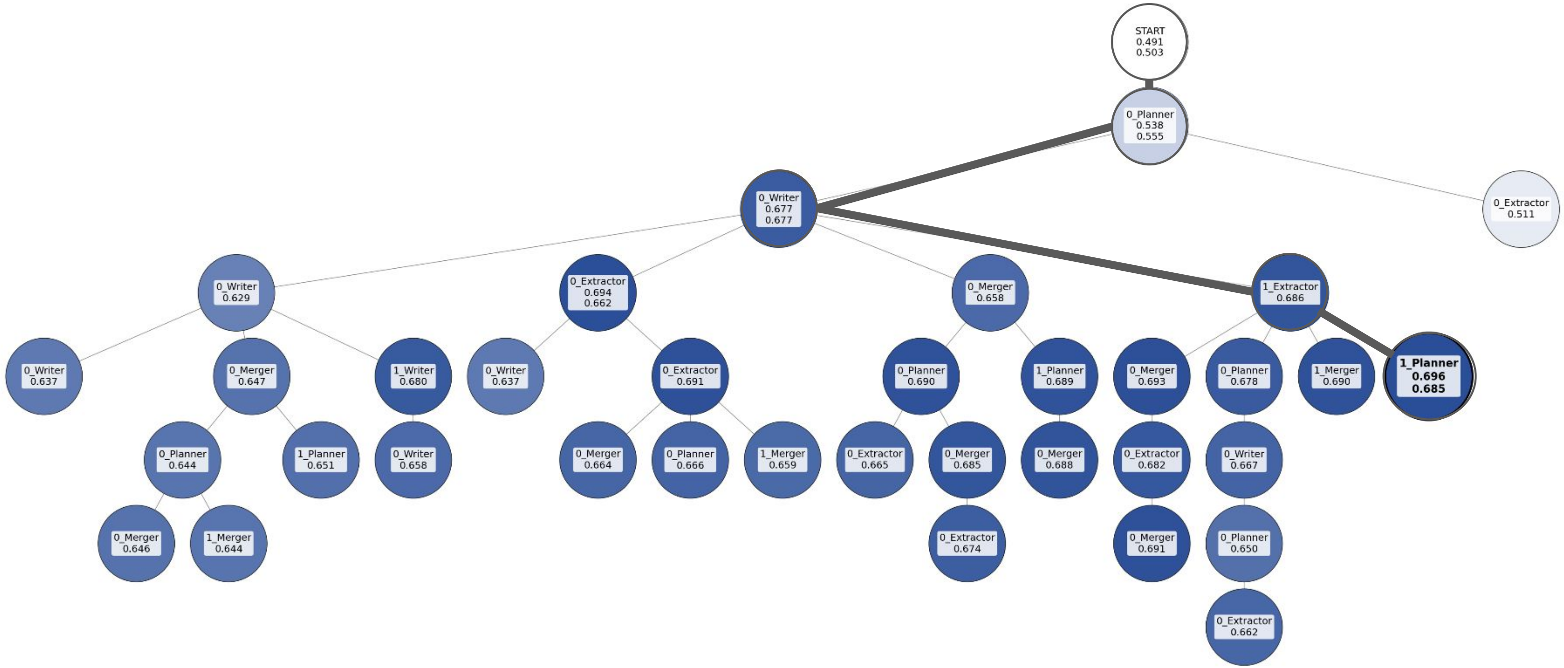
ABSTRACT

Large language models (LLMs) are increasingly adapted to downstream tasks via reinforcement learning (RL) methods like Group Relative Policy Optimization (GRPO), which often require thousands of rollouts to learn new tasks. We argue that the interpretable nature of *language* can often provide a much richer learning medium for LLMs, compared with policy gradients derived from sparse, scalar rewards. To test this, we introduce GEPA (**Ge**netic-**Pa**reto), a prompt optimizer that thoroughly incorporates *natural language reflection* to learn high-level rules from trial and error. Given any AI system containing one or more LLM prompts, GEPA samples system-level trajectories (e.g., reasoning, tool calls, and tool outputs) and reflects on them in natural language to diagnose problems, propose and test prompt updates, and combine complementary lessons from the Pareto frontier of its own attempts. As a result of GEPA's design, it can often turn even just a few rollouts into a large quality gain. Across four tasks, GEPA outperforms GRPO by 10% on average and by up to 20%, while using up to 35x fewer rollouts. GEPA also outperforms the leading prompt optimizer, MIPROv2, by over 10% across two LLMs, and demonstrates promising results as an inference-time search strategy for code optimization.

1 INTRODUCTION

(a) HotpotQA, Qwen3 8B (b) HoVer, Qwen3 8B

OPTIMIZING AGENT SYSTEMS: GEPA EXPLORATION



OPTIMIZING AGENT SYSTEMS: RESULTS

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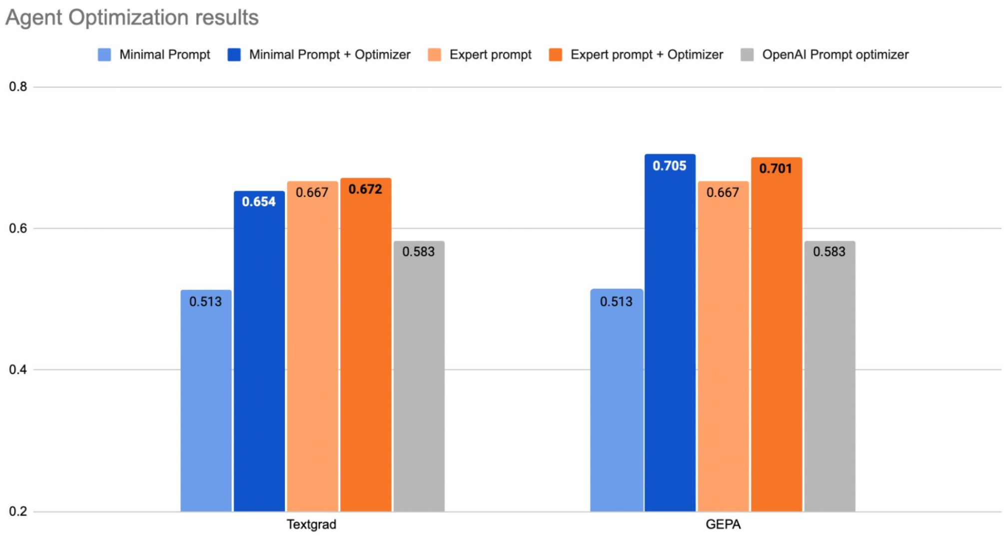

- **ScholarQA-CS** Benchmark. For retrieval, we use the **DeepResearchGym** API.
- Agents init from two starting points:
  - minimal prompt for each sub-agent
  - human-optimized
- LLM used GPT-4.1-mini.
- We also used OpenAI's prompt optimizer for GPT-4.1

- **Self-Optimized Agents match or outperform human-optimized.**
- **GEPA better results than Textgrad.**
- Gains are more pronounced when **starting from simple**, non-optimized prompts.

NEXT STEPS: A CO-EVOLUTION FRAMEWORK

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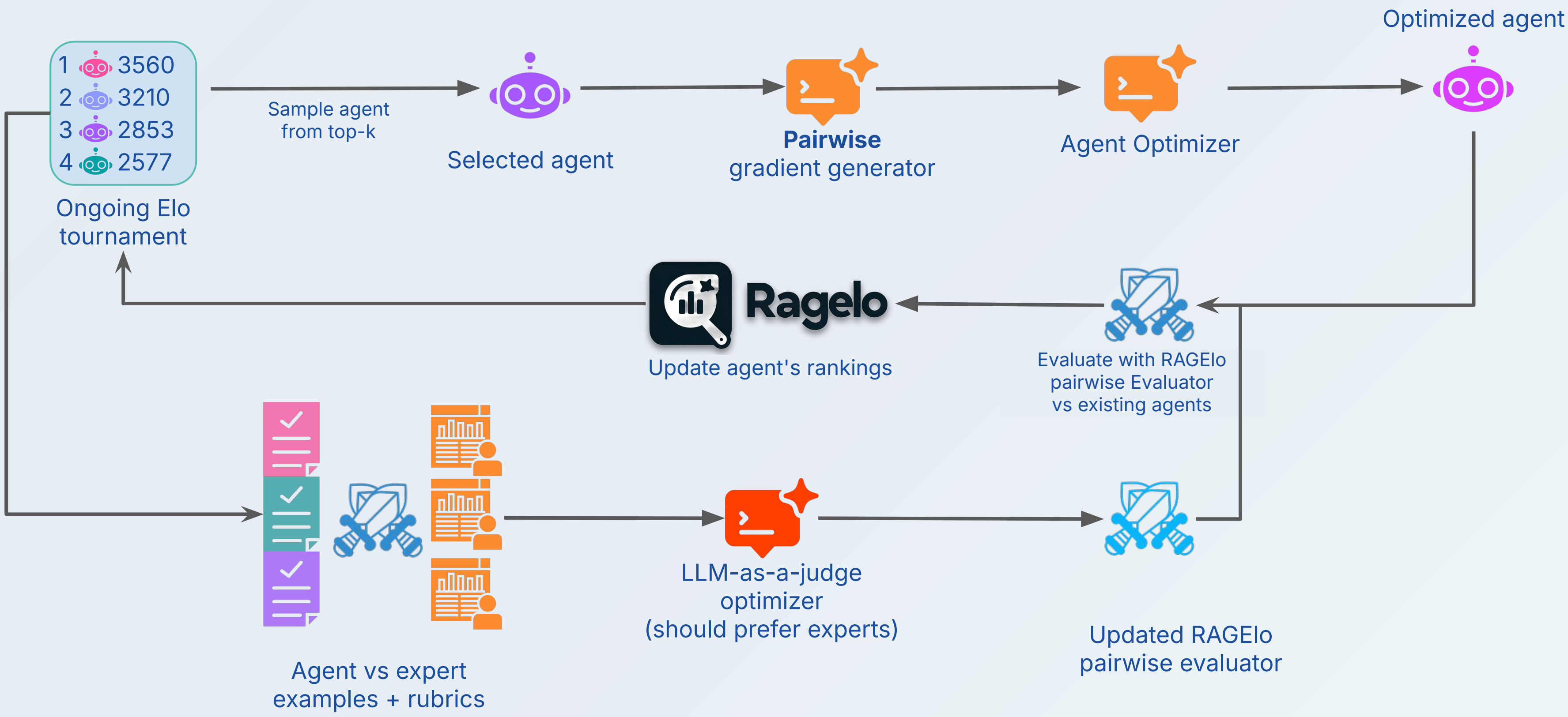

SUMMARY & NEXT STEPS

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COMPLEX AGENTS

RAG was just the beginning.

Now we orchestrate more complex agentic pipelines.

How to evaluate long-format responses?

LLM-as-a-judge and Elo style tournaments.

DEEP RESEARCH & CO.

Delivering value to experts.

What are best prompts and architectures?

How to Improve quality and customize?

What if you only have some examples?

OPTIMIZATION

Evaluate and Iterate.

GEPA works for efficiently optimizing your agents.

Next step: co-evolve agents and judges based on examples..

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QUESTIONS?

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