Gödel Agent: A Self-Referential Agent Framework for Recursively Self-Improvement

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Language Agent

- Agents require human design.
  - For different tasks, such as coding, shopping, traveling, etc., specialized designs are needed — It's too time-consuming and labor-intensive.

- Shouldn’t agents themselves be able to generalize to different tasks?
  - Meta agent?
    - Design an agent that can design task-specific agents for different tasks.
  - Self-referential Agent
    - The agent can modify itself.

Self-referentiality
is a very
important quality!

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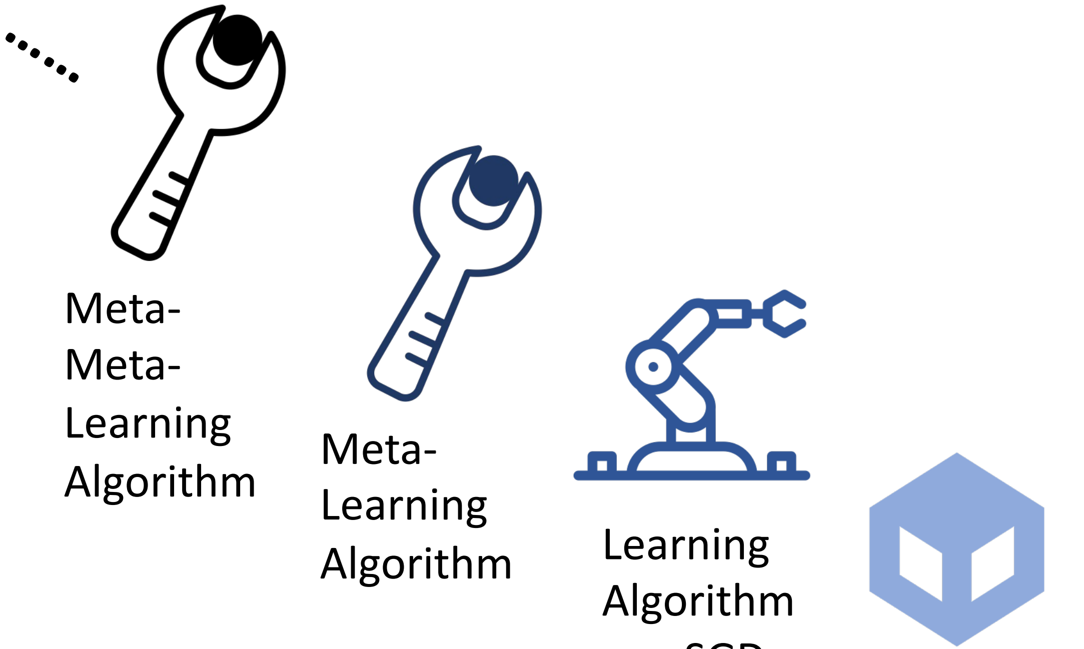
Self-referentiality

Human is self-referential!



……

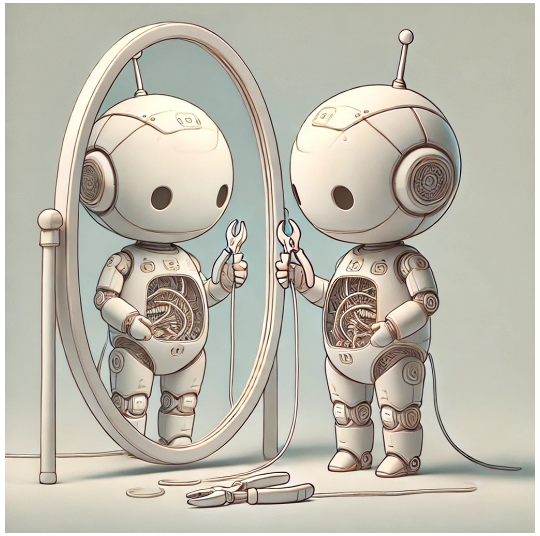
Meta-Meta-Learning Algorithm

Meta-Learning Algorithm

Learning Algorithm e.g. SGD, RL

Policy e.g. model weight

Traditional Paradigm
(optimization || policy)



Self-referential Paradigm
≈ infinite levels of *meta-meta-meta…* Learning
≈ self-scored self-updating RL

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One Analogy

	Human	**Self-Referential Agent**
Intelligent Module	brain	LLM
Perceptual and Action	body	code and tool
Self-Referential Feature	Humans can train their brain and body to improve, thus becoming better	Self-referential agents can modify their code, even the underlying LLM, to improve themselves
Self-Awareness	Can the brain recognize itself as a brain? Can it perceive its own mode?	Can LLM understand that it is one part of the modified codes?

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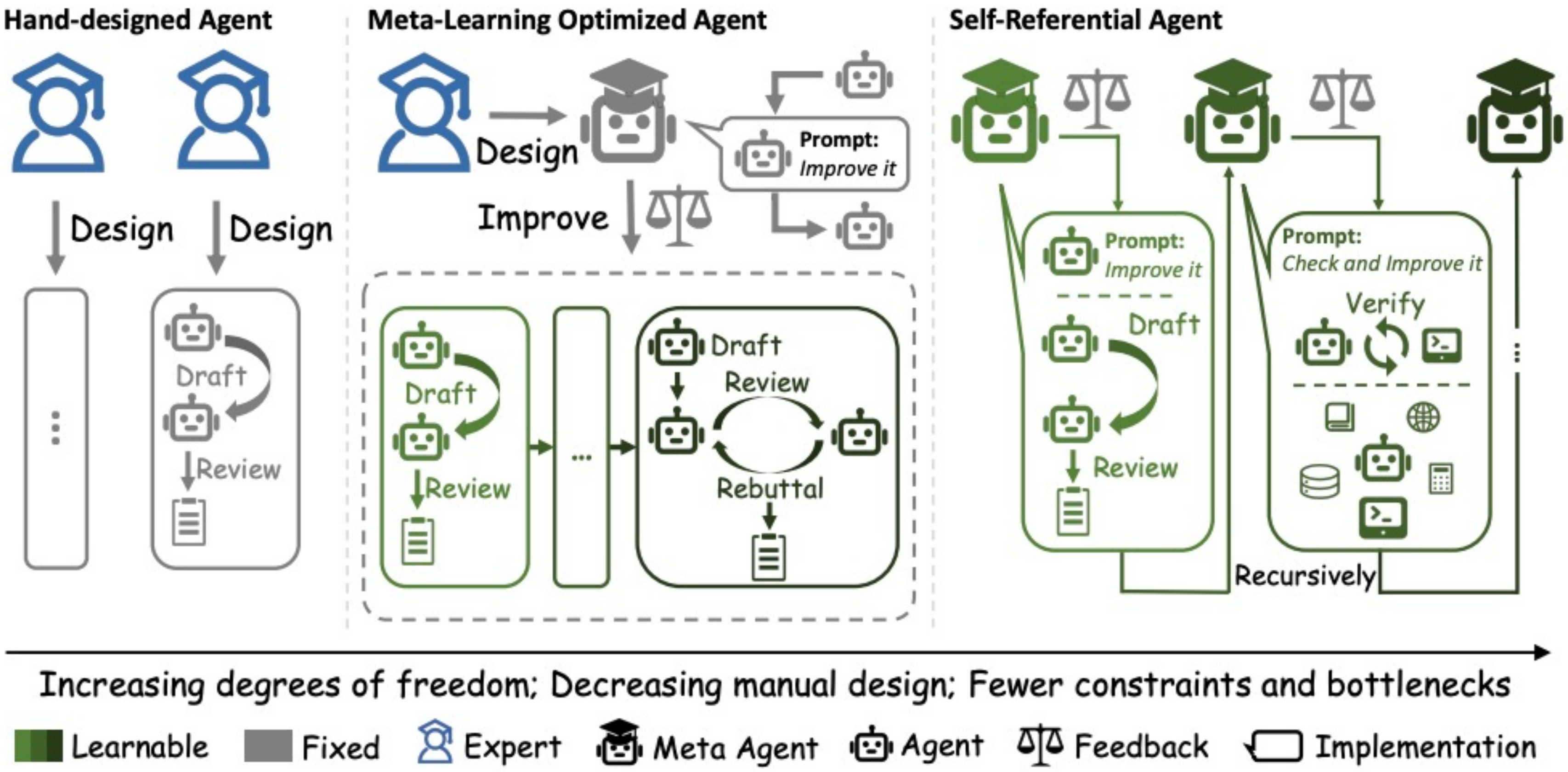
Self-Referential Agent (Gödel Agent)



The optimization module can be optimized by itself

Therefore the optimization capability is improving

So that in turn it can optimize itself better and better.

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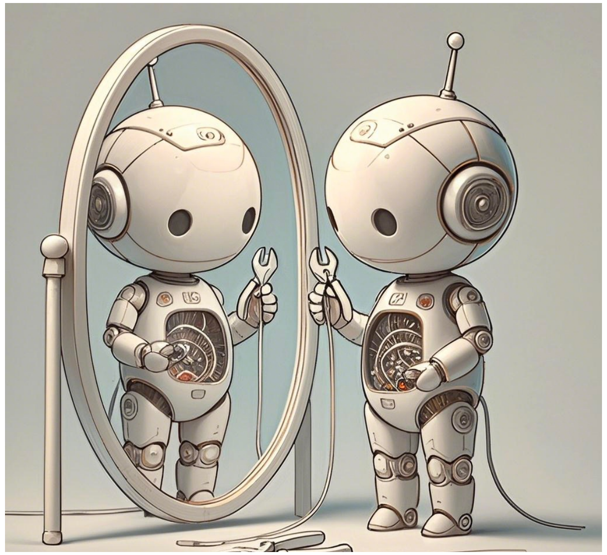
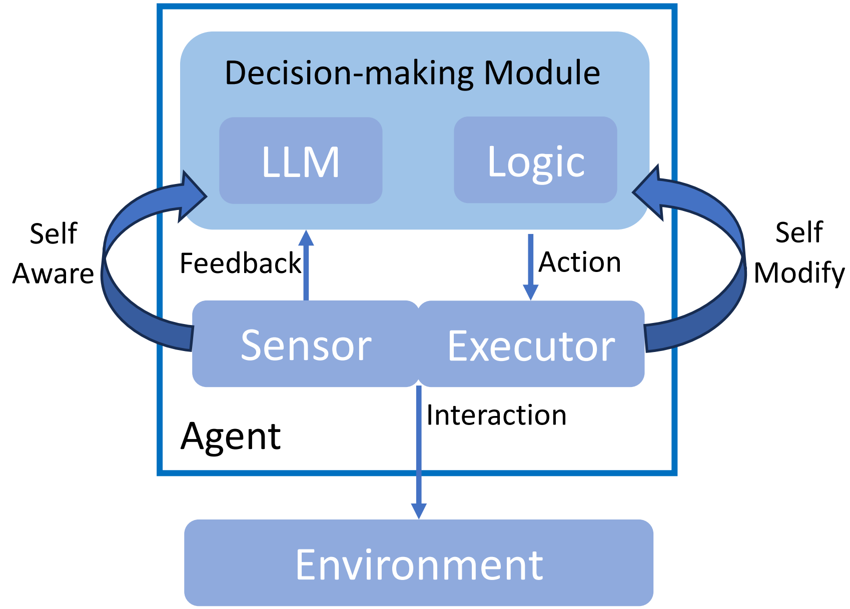
Different Perspectives of Gödel Agent

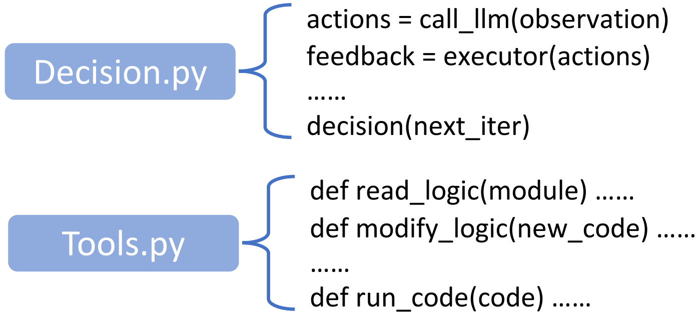
Overall Perspective



Module Perspective



Implementation Perspective



```
actions = call_llm(observation)
feedback = executor(actions)
……
decision(next_iter)
```

```
def read_logic(module) ……
def modify_logic(new_code) ……
……
def run_code(code) ……
```

1. Add the logic to read and modify the code.
2. But how to modify the context of the currently running function (the main process)?

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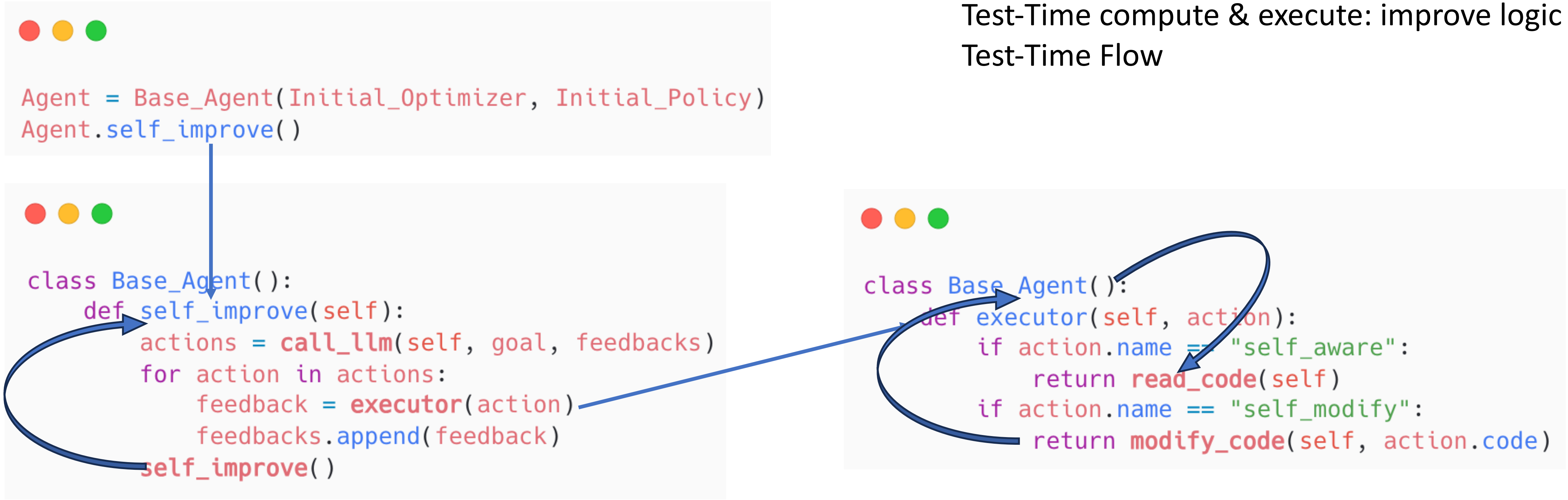
Implementation of Gödel Agent

Use recursive function instead of loop iteration.

Test-Time compute: improve text (context)
Test-Time compute & execute: improve logic
Test-Time Flow



```
Agent = Base_Agent(Initial_Optimizer, Initial_Policy)
Agent.self_improve()
```

```
class Base_Agent():
    def self_improve(self):
        actions = call_llm(self, goal, feedbacks)
        for action in actions:
            feedback = executor(action)
            feedbacks.append(feedback)
        self_improve()
```

```
class Base_Agent():
    def executor(self, action):
        if action.name == "self_aware":
            return read_code(self)
        if action.name == "self_modify":
            return modify_code(self, action.code)
```

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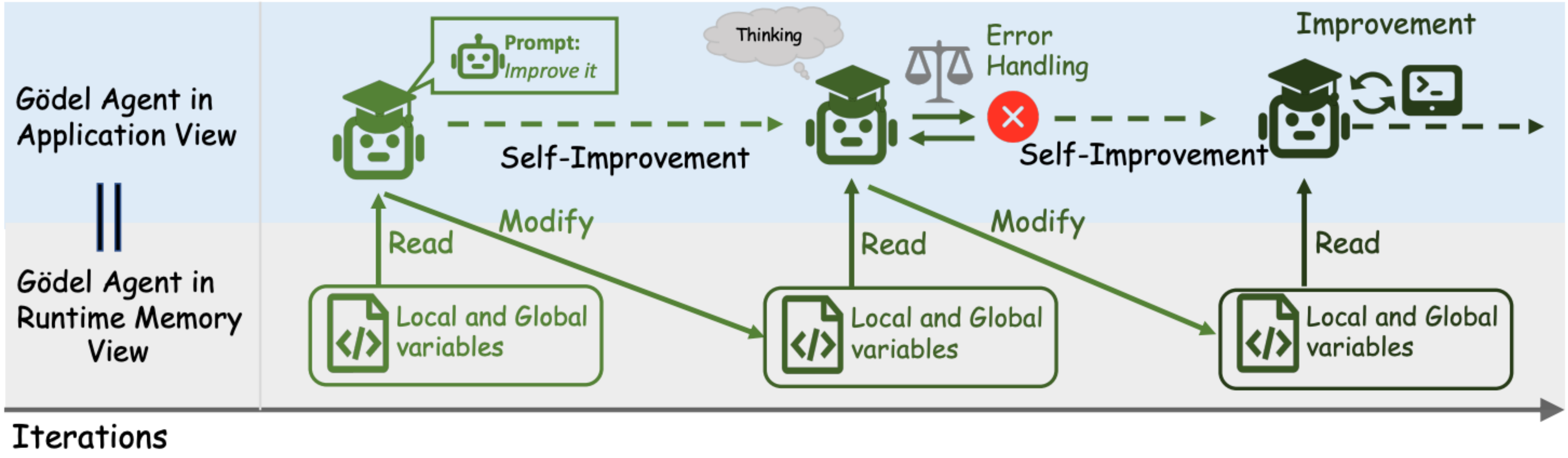
Implementation of Gödel Agent


Gödel Agent in Application View
||
Gödel Agent in Runtime Memory View
Prompt: Improve it
Thinking
Self-Improvement
Error Handling
Self-Improvement
Improvement
Read
Modify
Read
Modify
Read
Local and Global variables
Local and Global variables
Local and Global variables
Iterations

Monkey Patch: reading and writing the *runtime memory*
Error Handling: error trace feedback
Main part: one recursive function

} Actions

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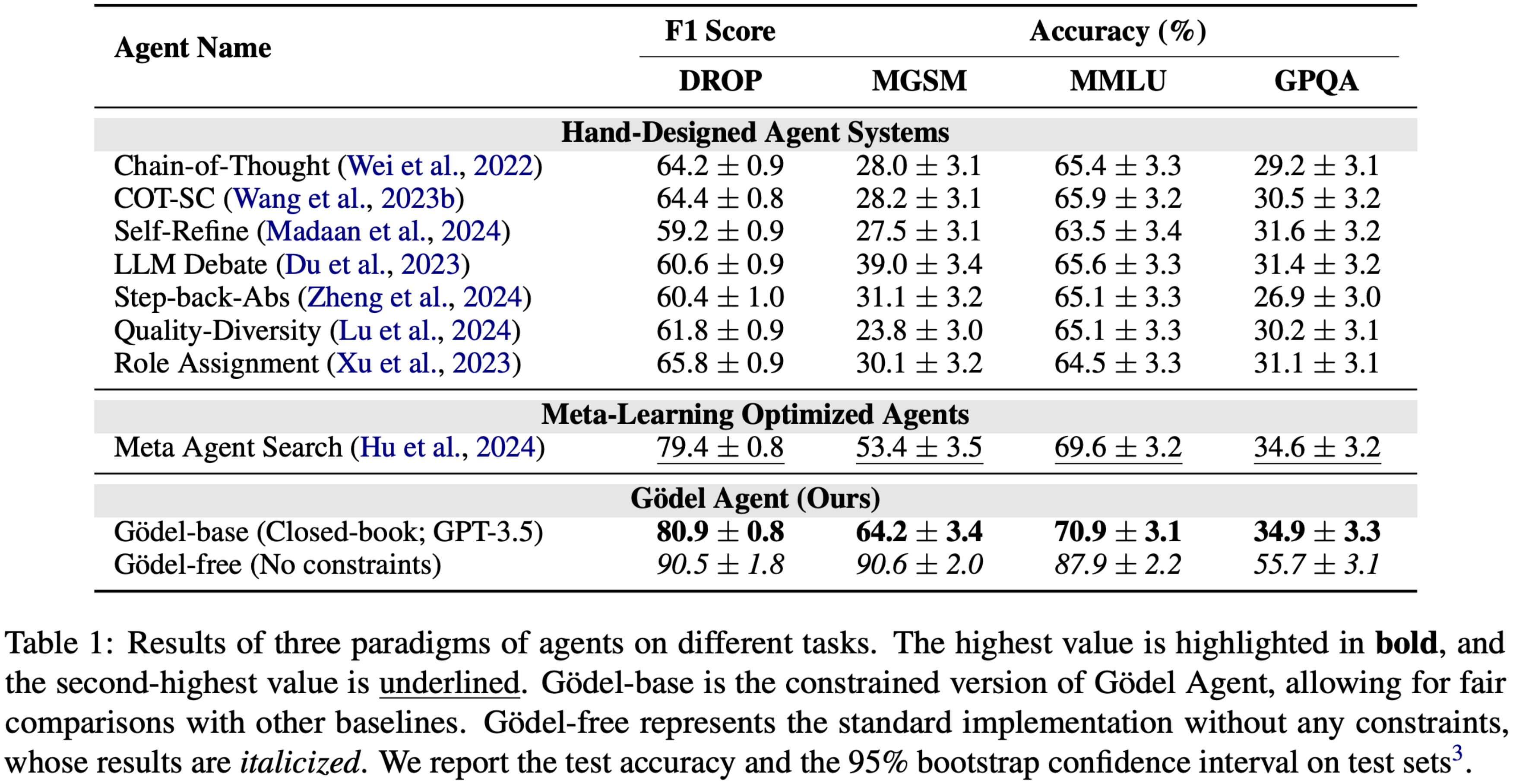
Results



Agent Name	F1 Score	Accuracy (%)		
	DROP	MGSM	MMLU	GPQA
Hand-Designed Agent Systems				
Chain-of-Thought (Wei et al., 2022)	64.2 ± 0.9	28.0 ± 3.1	65.4 ± 3.3	29.2 ± 3.1
COT-SC (Wang et al., 2023b)	64.4 ± 0.8	28.2 ± 3.1	65.9 ± 3.2	30.5 ± 3.2
Self-Refine (Madaan et al., 2024)	59.2 ± 0.9	27.5 ± 3.1	63.5 ± 3.4	31.6 ± 3.2
LLM Debate (Du et al., 2023)	60.6 ± 0.9	39.0 ± 3.4	65.6 ± 3.3	31.4 ± 3.2
Step-back-Abs (Zheng et al., 2024)	60.4 ± 1.0	31.1 ± 3.2	65.1 ± 3.3	26.9 ± 3.0
Quality-Diversity (Lu et al., 2024)	61.8 ± 0.9	23.8 ± 3.0	65.1 ± 3.3	30.2 ± 3.1
Role Assignment (Xu et al., 2023)	65.8 ± 0.9	30.1 ± 3.2	64.5 ± 3.3	31.1 ± 3.1
Meta-Learning Optimized Agents				
Meta Agent Search (Hu et al., 2024)	79.4 ± 0.8	53.4 ± 3.5	69.6 ± 3.2	34.6 ± 3.2
Gödel Agent (Ours)				
Gödel-base (Closed-book; GPT-3.5)	**80.9 ± 0.8**	**64.2 ± 3.4**	**70.9 ± 3.1**	**34.9 ± 3.3**
Gödel-free (No constraints)	*90.5 ± 1.8*	*90.6 ± 2.0*	*87.9 ± 2.2*	*55.7 ± 3.1*

Table 1: Results of three paradigms of agents on different tasks. The highest value is highlighted in **bold**, and the second-highest value is underlined. Gödel-base is the constrained version of Gödel Agent, allowing for fair comparisons with other baselines. Gödel-free represents the standard implementation without any constraints, whose results are *italicized*. We report the test accuracy and the 95% bootstrap confidence interval on test sets[3].

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Results

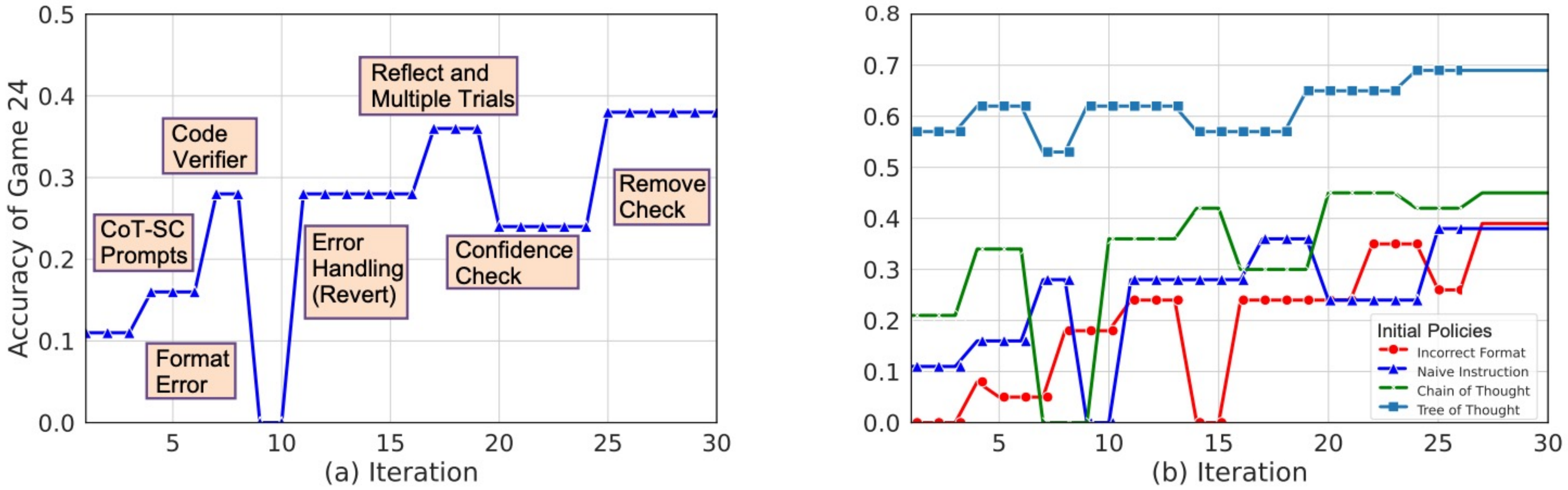

Figure 4: (a) One representative example of Game of 24. (b) Accuracy progression for different initial policies.

Self-correction; Exploration; Innovation

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	Hand-designed Agent	**Meta Agent**	**Self-Referential Agent**
Description	Designed by experts for specific tasks; logic remains unchanged	Experts design meta-learning algorithms, which optimize the agent for tasks	Designed to self-improve based on task feedback
Degree of Freedom	Minimal only selective memory accumulation allowed	Single-level task agents can be improved, but meta agent are fixed	Full agents and their **optimization module** can be improved

Advantages	controllable;
	practical
		partially controllable; further optimization is possible	high freedom;
			strong generalizability;
			high creativity

Disadvantages	labor-intensive; poor generalizability	limited by the effectiveness of meta agent	strong reasoning and long-context capabilities are required
Current State	various applications are under development	research ongoing	early stage
Representative Works	Tree of Thought, OpenDevin, WebAgent, OpenHands	MetaAgent, AgentSquare, Aflow, GPTSwarm	Gödel Agent

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Future Direction

- Improving Effectiveness:
    - Design stronger *optimization algorithms* to accelerate convergence, such as introducing MCTS and other algorithms.
    - Develop more detailed environmental feedback mechanisms.
- Self-Referencing Degree:
    - Allow the agent to modify its **goals**.
    - Allow the agent to modify its underlying **LLM**.
- Multi-Agent:
    - Multi-Gödel Agents with greater degrees of freedom, involving task splitting, parallel self-modification, communication etc.
- Other ways to improve model generalizability
    - (multi-modal, minimal data, dynamic environment, scientific tasks), self-referential intelligence

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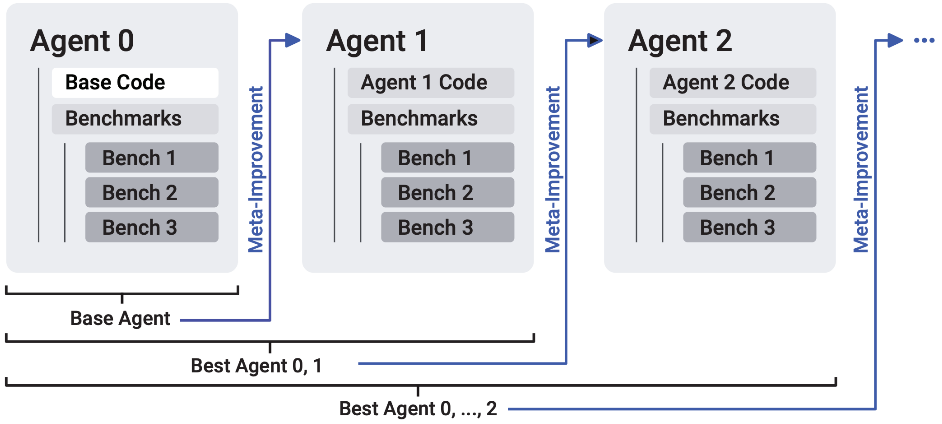
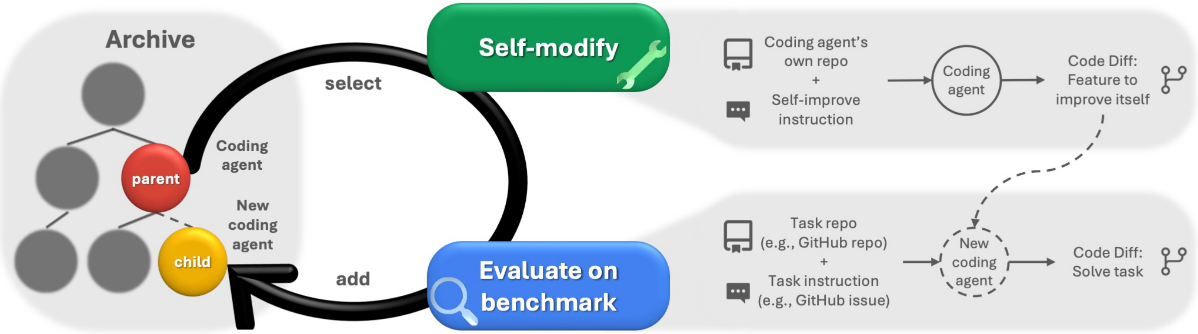
Following Works



A Self-Improving Coding Agent



Darwin Gödel Machine

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Thank you!

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