

LLMs and Tools

Part-3: Agentic Workflow

Large Language Models: Introduction and Recent Advances

ELL881 · AIL821



Dinesh Raghu
Senior Researcher, IBM Research

LLMs and Tools

Part 1: Incorporating Tools during Fine-tuning (Tool Augmentation)

Part 2: Teaching LLMs to Use APIs and Functions (Function Calling)

Part 3: Automating Complex, Multi-step Tasks (Agentic Workflows)



Motivation

1. How do we work on programming assignments?
2. How do we write research papers?



Motivation

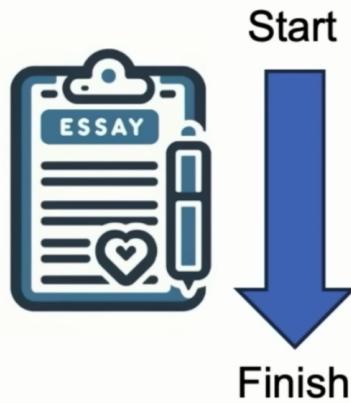
1. How do we work on programming assignments? **Agentic Flow**
2. How do we write research papers? **Agentic Flow**



Agentic Workflow

Non-agentic workflow (zero-shot):

Please type out an essay on topic X from start to finish in one go, without using backspace.



Agentic workflow:

Write an essay outline on topic X

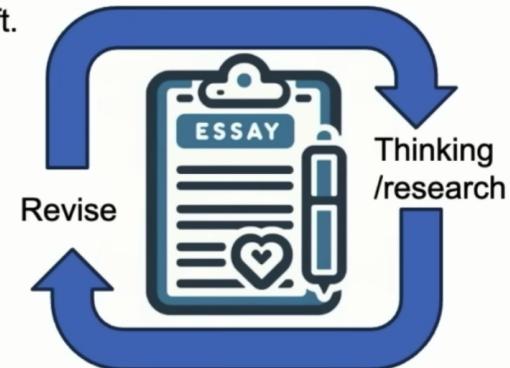
Do you need any web research?

Write a first draft.

Consider what parts need revision or more research.

Revise your draft.

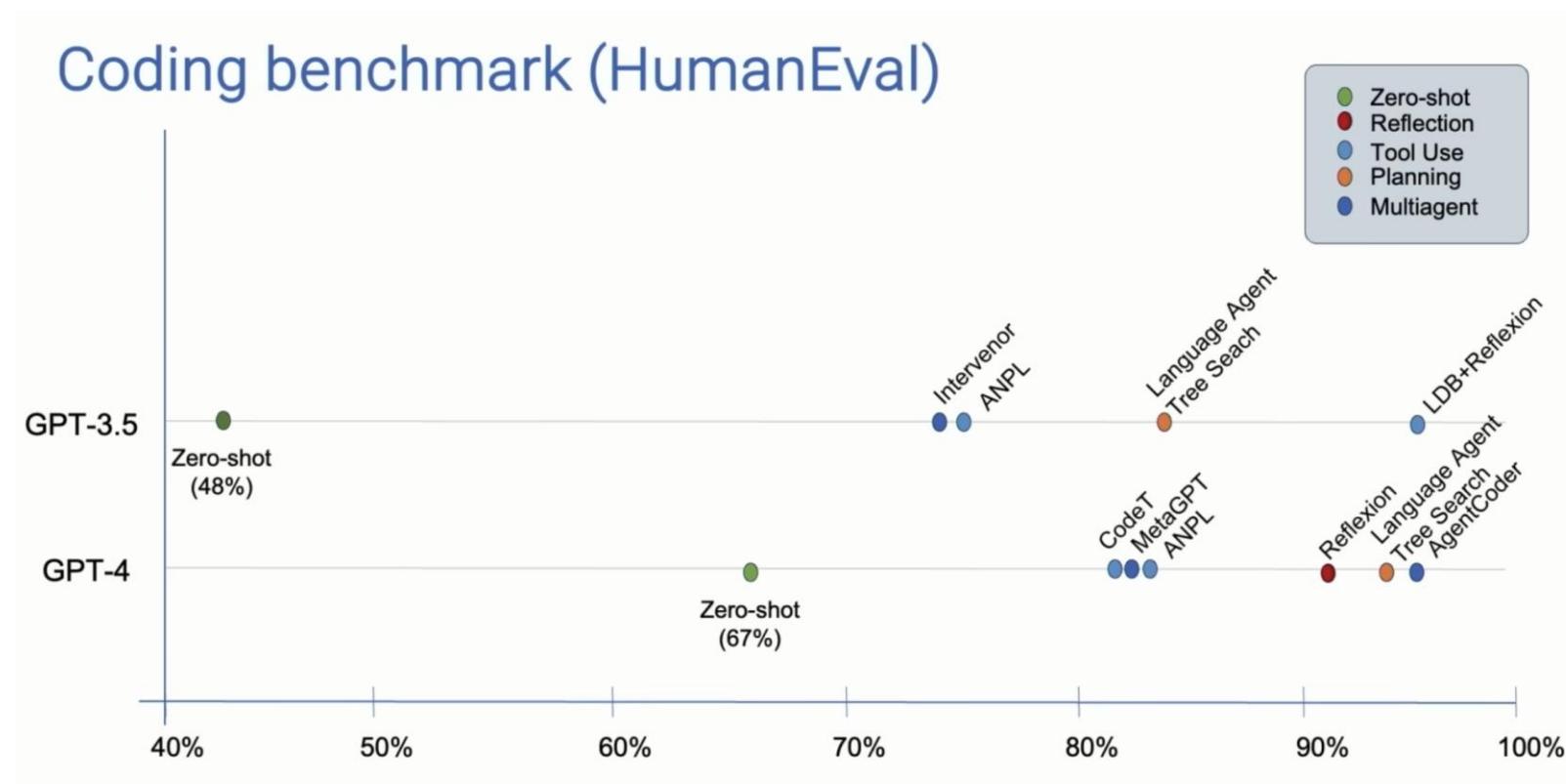
....



Screenshot from <https://www.youtube.com/watch?v=sal78ACtGTc>



Agentic vs Non-Agentic Workflows



[Thanks to Joaquin Dominguez and John Santerre for help with analysis.]

Andrew Ng

Screenshot from <https://www.youtube.com/watch?v=sal78ACtGTc>



LLMs: Introduction and Recent Advances



Dinesh Raghu

Agentic Workflow Example: SWE-Bench

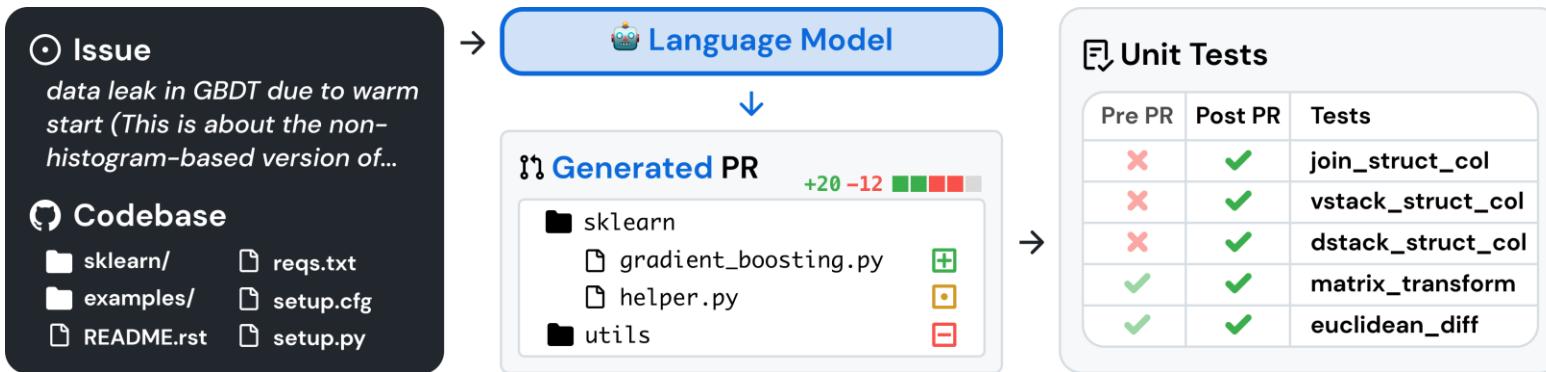


Image credits: <http://www.swebench.com>



LLMs: Introduction and Recent Advances



Dinesh Raghu

Outline

- ReACT
- Self-Refine
- Reflexion
- ReWoo & HuggingGPT



ReACT

Example from HotPotQA
[[Yang et. Al., 2018](#)]

Paragraph A: 2016–17 Chicago Bulls season

The 2016–17 Chicago Bulls season was the 51st season of the franchise in the National Basketball Association (NBA). Former 2011 MVP and 2009 Rookie of the Year Derrick Rose was traded from his hometown team to the New York Knicks. This was the first season without Rose since the 2012–13 season. Dwyane Wade, who played for the Miami Heat from 2003 to 2016, decided to leave the Heat and sign with his hometown team, the Chicago Bulls. The Bulls traded Tony Snell to the Milwaukee Bucks for Michael Carter-Williams on October 17, 2016.

Paragraph B: Michael Carter-Williams

Michael Carter-Williams (born October 10, 1991) is an American professional basketball player for the Charlotte Hornets of the National Basketball Association (NBA). He was drafted 11th overall in the 2013 NBA draft by the Philadelphia 76ers, after playing college basketball for the Syracuse Orange. He was named NBA Rookie of the Year in 2014, and has also played for the Milwaukee Bucks and Chicago Bulls.

Q: To what team was the 2014 NBA Rookie of the Year traded in October 2016?

A: Chicago Bulls

* ReAct: Synergizing Reasoning and Acting in Language Models, Yao et. al., Mar 2023



ReACT

(1) Hotspot QA

Question: Aside from the Apple Remote, what other device can control the program Apple Remote was originally designed to interact with?

(1a) Standard

Answer: iPod



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ReACT

(1) Hotspot QA

Question: Aside from the Apple Remote, what other device can control the program Apple Remote was originally designed to interact with?

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Answer: iPod



(1b) CoT (Reason Only)

Thought: Let's think step by step. Apple Remote was originally designed to interact with Apple TV. Apple TV can be controlled by iPhone, iPad, and iPod Touch. So the answer is iPhone, iPad, and iPod Touch.

Answer: iPhone, iPad, iPod Touch



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What if the model has access to a **TOOL** for searching over a corpus of documents?

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ReACT

(1) Hotspot QA

Question: Aside from the Apple Remote, what other device can control the program Apple Remote was originally designed to interact with?

(1a) Standard

Answer: iPod

(1c) Act-Only

Act 1: `Search[Apple Remote]`

Obs 1: The Apple Remote is a remote control ...

Act 2: `Search[Front Row]`

Obs 2: Could not find [Front Row]. Similar: ...

Act 3: `Search[Front Row (software)]`

Obs 3: Front Row is a discontinued media center software ...

Act 4: `Finish[yes]`

(1b) CoT (Reason Only)

Thought: Let's think step by step. Apple Remote was originally designed to interact with Apple TV.

Apple TV can be controlled by iPhone, iPad, and iPod Touch. So the answer is iPhone, iPad, and iPod Touch.

Answer: iPhone, iPad, iPod Touch

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(1c) Act-Only

Act 1: Search[Apple Remote]
Obs 1: The Apple Remote is a remote control ...

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Act 3: Search[Front Row (software)]

Obs 3: Front Row is a discontinued media center software ...

Act 4: Finish[yes]



(1d) ReAct (Reason + Act)

Thought 1: I need to search Apple Remote and find the program it was originally designed to interact with.

Act 1: Search[Apple Remote]

Obs 1: The Apple Remote is a remote control introduced in October 2005 by Apple ... originally designed to control the Front Row media center program ...

Thought 2: Apple Remote was originally designed to control the Front Row media center program. I need to search Front Row next and find what other device can control it.

Act 2: Search[Front Row]

Obs 2: Could not find [Front Row]. Similar: ['Front Row Seat to Earth', 'Front Row Motorsports', 'Front Row (software)', ...]

Thought 3: Front Row is not found. I need to search Front Row (software) .

Act 3: Search[Front Row (software)]

Obs 3: Front Row is a discontinued media center software ...

Thought 4: Front Row (software) is controlled by an Apple Remote or the keyboard function keys. So the answer is keyboard function keys.

Act 4: Finish[keyboard function keys]



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ReACT

Consider an agent interacting with the environment.

Only ACT:

- See an observation
- Sample an action based on observation (and the trajectory so far) following a policy

ReACT:

- expands the action space with natural language
- as language is extremely large, strong priors are needed

(1d) ReAct (Reason + Act)

Thought 1: I need to search Apple Remote and find the program it was originally designed to interact with.

Act 1: `Search[Apple Remote]`

Obs 1: The Apple Remote is a remote control introduced in October 2005 by Apple ... originally designed to control the Front Row media center program ...

Thought 2: Apple Remote was originally designed to control the Front Row media center program. I need to search `Front Row` next and find what other device can control it.

Act 2: `Search[Front Row]`

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Thought 3: Front Row is not found. I need to search `Front Row (software)`.

Act 3: `Search[Front Row (software)]`

Obs 3: Front Row is a discontinued media center software ...

Thought 4: `Front Row (software)` is controlled by an Apple Remote or the keyboard function keys. So the answer is keyboard function keys.

Act 4: `Finish[keyboard function keys]`



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ReACT

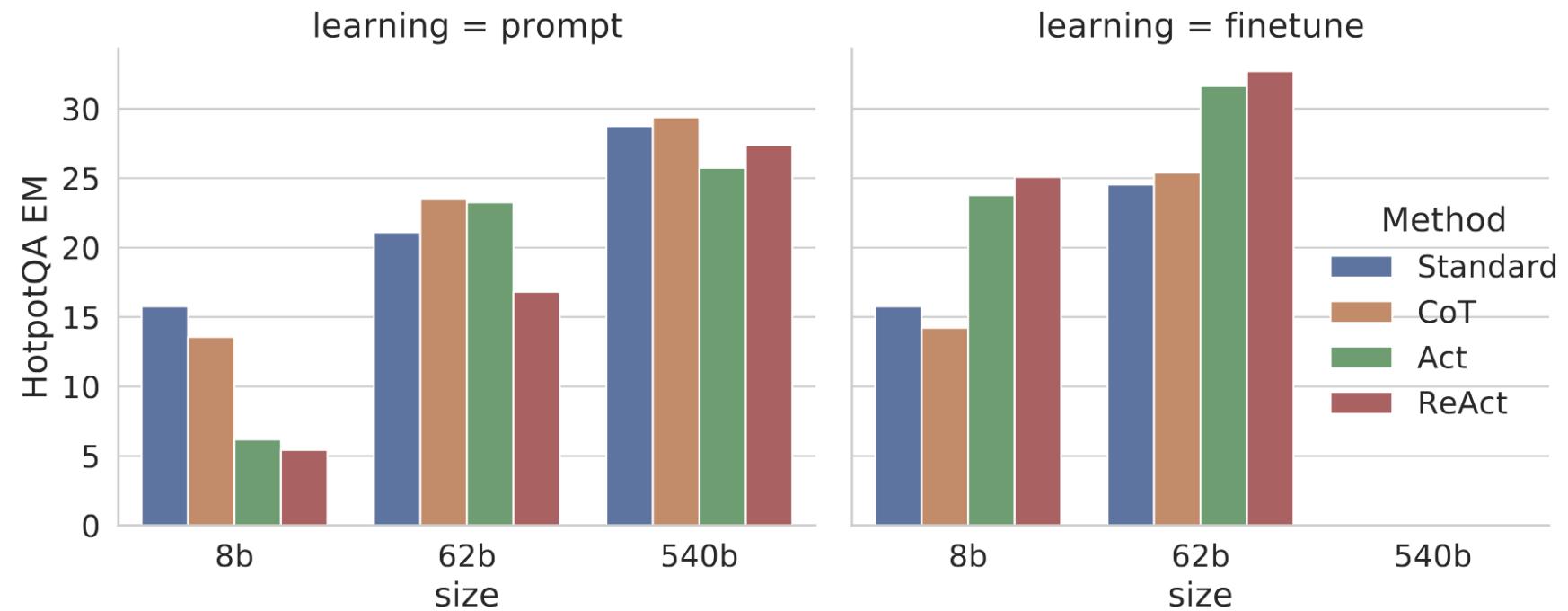
Prompt Method ^a	HotpotQA (EM)	Fever (Acc)
Standard	28.7	57.1
CoT (Wei et al., 2022)	29.4	56.3
CoT-SC (Wang et al., 2022a)	33.4	60.4
Act	25.7	58.9
ReAct	27.4	60.9
CoT-SC → ReAct	34.2	64.6
ReAct → CoT-SC	35.1	62.0
Supervised SoTA^b	67.5	89.5

PaLM-540B prompting results on HotpotQA and Fever

* ReAct: Synergizing Reasoning and Acting in Language Models, Yao et. al., Mar 2023



ReACT

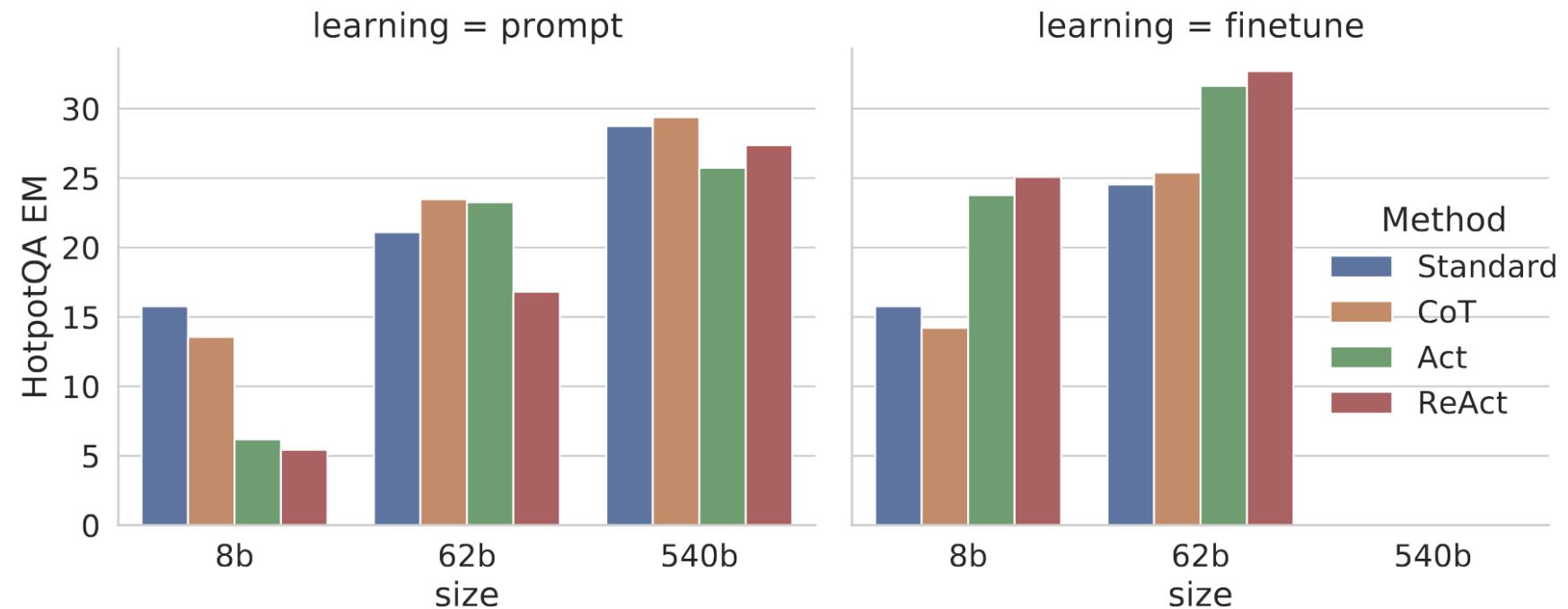


Scaling results for prompting and finetuning on HotPotQA with ReAct and baselines

* ReAct: Synergizing Reasoning and Acting in Language Models, Yao et. al., Mar 2023



ReACT



Scaling results for prompting and finetuning on HotPotQA with ReAct and baselines

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SWE-Agent uses ReACT

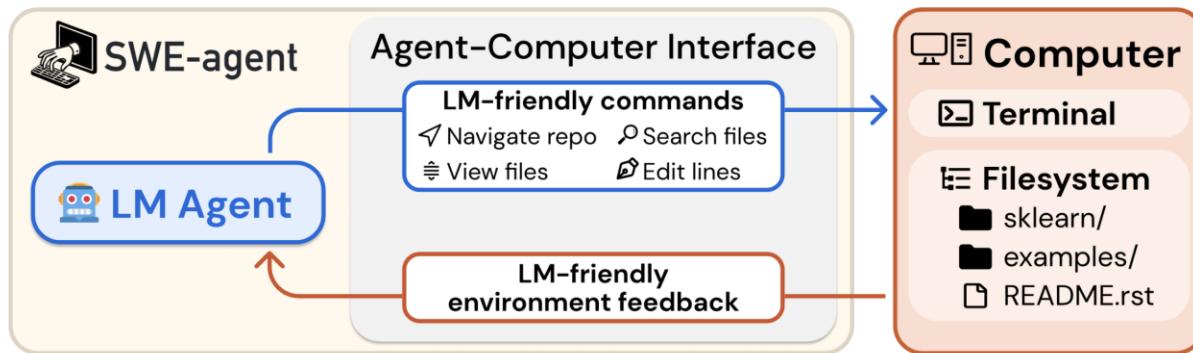


Image credits: <http://www.swebench.com>; SWE-agent: Agent-Computer Interfaces Enable Automated Software Engineering, 2024



LLMs: Introduction and Recent Advances



Dinesh Raghu

SWE-Agent* uses ReACT

System Prompt

- Describe environment and commands
- Specify response format

Demonstration

Full trajectory of a successful example

Issue statement

- Give reported issue description
- Instructions to resolve issue
- High-level strategy tips

Thought & Action

Environment Response (collapsed)

Thought & Action

Environment Response

:

Thought & Action

Environment Response

Submit

Patch File

```
diff --git a/src/sqlfluff/rules/L060.py
b/src/sqlfluff/rules/L060.py
--- a/src/sqlfluff/rules/L060.py
+++ b/src/sqlfluff/rules/L060.py
```

*SWE-agent: Agent-Computer Interfaces Enable Automated Software Engineering, 2024



SWE-Agent* uses ReACT

File Viewer

```
open atmosphere.py
```

```
(255 more lines above)
256: def gueymard94_pw(temp_air, relative_humidity):
257:     """
258:     Calculates precipitable water (cm) from ambient air temperature (C)
259:     and relatively humidity (%) using an empirical model. The
260:     accuracy of this method is approximately 20% for moderate PW (1-3
261:     cm) and less accurate otherwise.
262:
263:     The model was developed by expanding Eq. 1 in [2]_:
264:
265:     .. math::
266:
267:         Pw = 0.1 H_v \rho_v

(76 lines omitted)

343:
344:
345: def bird_hulstrom80_aod_bb(aod380, aod500):
346:     """
347:     Approximate broadband aerosol optical depth.
348:
349:     Bird and Hulstrom developed a correlation for broadband aerosol
350:     depth (AOD) using two wavelengths, 380 nm and 500 nm.
351:
352:     Parameters
353:     -----
354:     aod380 : numeric
355:         AOD measured at 380 nm. [unitless]
(180 more lines below)
```

Find Files

```
find_file atmosphere.py
```

```
Found 2 matches for "atmosphere.py" in /pvlib_pvlib-python/pvlib:
/pvlib_pvlib-python/pvlib/tests/atmosphere.py
/pvlib_pvlib-python/pvlib/atmosphere.py
```

Search Directory

```
search_dir APPARENT_ZENITH_MODELS
```

```
Found 4 matches for "APPARENT_ZENITH_MODELS" in /pvlib_pvlib-
python:
/pvlib_pvlib-python/docs/sphinx/source/whatsnew/v0.3.0.txt (1
matches)
/pvlib_pvlib-python/pvlib/atmosphere.py (2 matches)
/pvlib_pvlib-python/pvlib/location.py (1 matches)
End of matches for "APPARENT_ZENITH_MODELS" in /pvlib_pvlib-
python
```

Search File

```
search_file APPARENT_ZENITH_MODELS
```

```
Found 2 matches for "APPARENT_ZENITH_MODELS" in /pvlib_pvlib-
python/pvlib/atmosphere.py:
Line 12:APPARENT_ZENITH_MODELS = ('simple', 'kasten1966',
'kastenyoung1989',
Line 15:AIRMASS_MODELS = APPARENT_ZENITH_MODELS +
TRUE_ZENITH_MODELS
End of matches for "APPARENT_ZENITH_MODELS" in /pvlib_pvlib-
python/pvlib/atmosphere.py
```

System Prompt

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```

*SWE-agent: Agent-Computer Interfaces Enable Automated Software Engineering, 2024



SWE-Agent* uses ReACT

Response (Thought + Edit Action)

We need to add a check to ensure that all powers are the same. Let's edit the code to include this check.

```
edit 404:407
    elif (total_degree > 3 and
        len(set(k.exp[k.is_Pow])) == 1):
        if all(coeff[k] == 1):
            diop_type = 'general_sum_even'
end_of_edit
```

System Prompt

- Describe environment and commands
- Specify response format

Demonstration

Full trajectory of a successful example

Issue statement

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Thought & Action

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*SWE-agent: Agent-Computer Interfaces Enable Automated Software Engineering, 2024

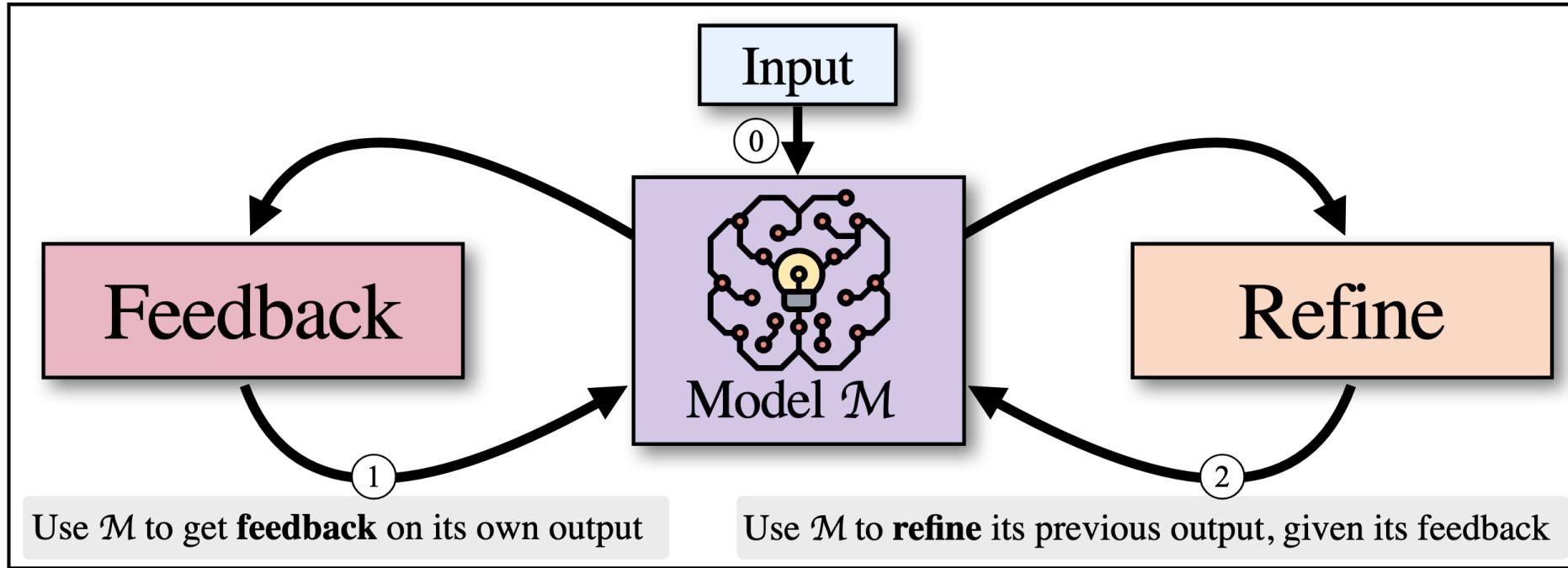


Outline

- ReACT
 - reasoning + act to arrive at the final answer
- Self-Refine
- Reflexion
- ReWoo & HuggingGPT



Self-Refine



* SELF-REFINE: Iterative Refinement with Self-Feedback, Madaan et. al., May 2023



Self-Refine

(a) Dialogue: x, y_t

User: I am interested in playing Table tennis.

Response: I'm sure it's a great way to socialize, stay active

(b) FEEDBACK \mathbf{fb}

Engaging: Provides no information about table tennis or how to play it.

User understanding: Lacks understanding of user's needs and state of mind.

(c) REFINE y_{t+1}

Response (refined): That's great to hear (...) ! It's a fun sport requiring quick reflexes and good hand-eye coordination.
Have you played before, or are you looking to learn?

(d) Code optimization: x, y_t

```
Generate sum of 1, ..., N
def sum(n):
    res = 0
    for i in range(n+1):
        res += i
    return res
```

(e) FEEDBACK \mathbf{fb}

This code is slow as it uses brute force. A better approach is to use the formula ... $(n(n+1))/2$.

(f) REFINE y_{t+1}

Code (refined)

```
def sum_faster(n):
    return (n*(n+1))/2
```

* SELF-REFINE: Iterative Refinement with Self-Feedback, Madaan et. al., May 2023



Self-Refine

Task	GPT-3.5		ChatGPT		GPT-4	
	Base	+SELF-REFINE	Base	+SELF-REFINE	Base	+SELF-REFINE
Sentiment Reversal	8.8	30.4 (\uparrow 21.6)	11.4	43.2 (\uparrow 31.8)	3.8	36.2 (\uparrow 32.4)
Dialogue Response	36.4	63.6 (\uparrow 27.2)	40.1	59.9 (\uparrow 19.8)	25.4	74.6 (\uparrow 49.2)
Code Optimization	14.8	23.0 (\uparrow 8.2)	23.9	27.5 (\uparrow 3.6)	27.3	36.0 (\uparrow 8.7)
Code Readability	37.4	51.3 (\uparrow 13.9)	27.7	63.1 (\uparrow 35.4)	27.4	56.2 (\uparrow 28.8)
Math Reasoning	64.1	64.1 (0)	74.8	75.0 (\uparrow 0.2)	92.9	93.1 (\uparrow 0.2)
Acronym Generation	41.6	56.4 (\uparrow 14.8)	27.2	37.2 (\uparrow 10.0)	30.4	56.0 (\uparrow 25.6)
Constrained Generation	28.0	37.0 (\uparrow 9.0)	44.0	67.0 (\uparrow 23.0)	15.0	45.0 (\uparrow 30.0)

* SELF-REFINE: Iterative Refinement with Self-Feedback, Madaan et. al., May 2023



Outline

- ReACT
 - reasoning + act to arrive at the final answer
- Self-Refine
 - iteratively improving initial results based on model feedback
 - can be combined with ReACT
- Reflexion
- ReWoo & HuggingGPT



Reflexion

	1. Decision making	2. Programming	3. Reasoning
(a) Task ↓ (b) Trajectory ↓ (c) Evaluation (internal / external) ↓ (d) Reflection ↓ (e) Next Trajectory	You are in the middle of a room [...] Task: clean some pan and put it in countertop.	Task: You are given a list of two strings [...] of open '(' or close ')' parentheses only [...]	Task: What profession does John Lanchester and Alan Dean Foster have in common?
	[...] Action: take pan1 from stoveburner1 Obs: Nothing happens. [...] Action: clean pan1 with sinkbasin1 Obs: Nothing happens. [...]	def match_parens(lst): if s1.count('(') + s2.count('(') == s1.count(')') + s2.count(')'): [...] return 'No'	Think: [...] novelist, journalist, critic [...] novelist, screenwriter [...] common is novelist and screenwriter. Action: "novelist, screenwriter"
	Rule/LM Heuristic: Hallucination.	Self-generated unit tests fail: assert match_parens(...)	Environment Binary Reward: 0
	[...] tried to pick up the pan in stoveburner 1 [...] but the pan was not in stoveburner 1. [...]	[...] wrong because it only checks if the total count of open and close parentheses is equal [...] order of the parentheses [...]	[...] failed because I incorrectly assumed that they both had the same multiple professions [...] accurately identifying their professions.
	[...] Action: take pan 1 from stoveburner 2 [...] Obs: You put the pan 1 in countertop 1.	[...] return 'Yes' if check(S1) or check(S2) else 'No'	Think: [...] So the profession John Lanchester and Alan Dean Foster have in common is novelist. Action: "novelist"

* Reflexion: Language Agents with Verbal Reinforcement Learning, Noah et. al., Oct 2023



Reflexion

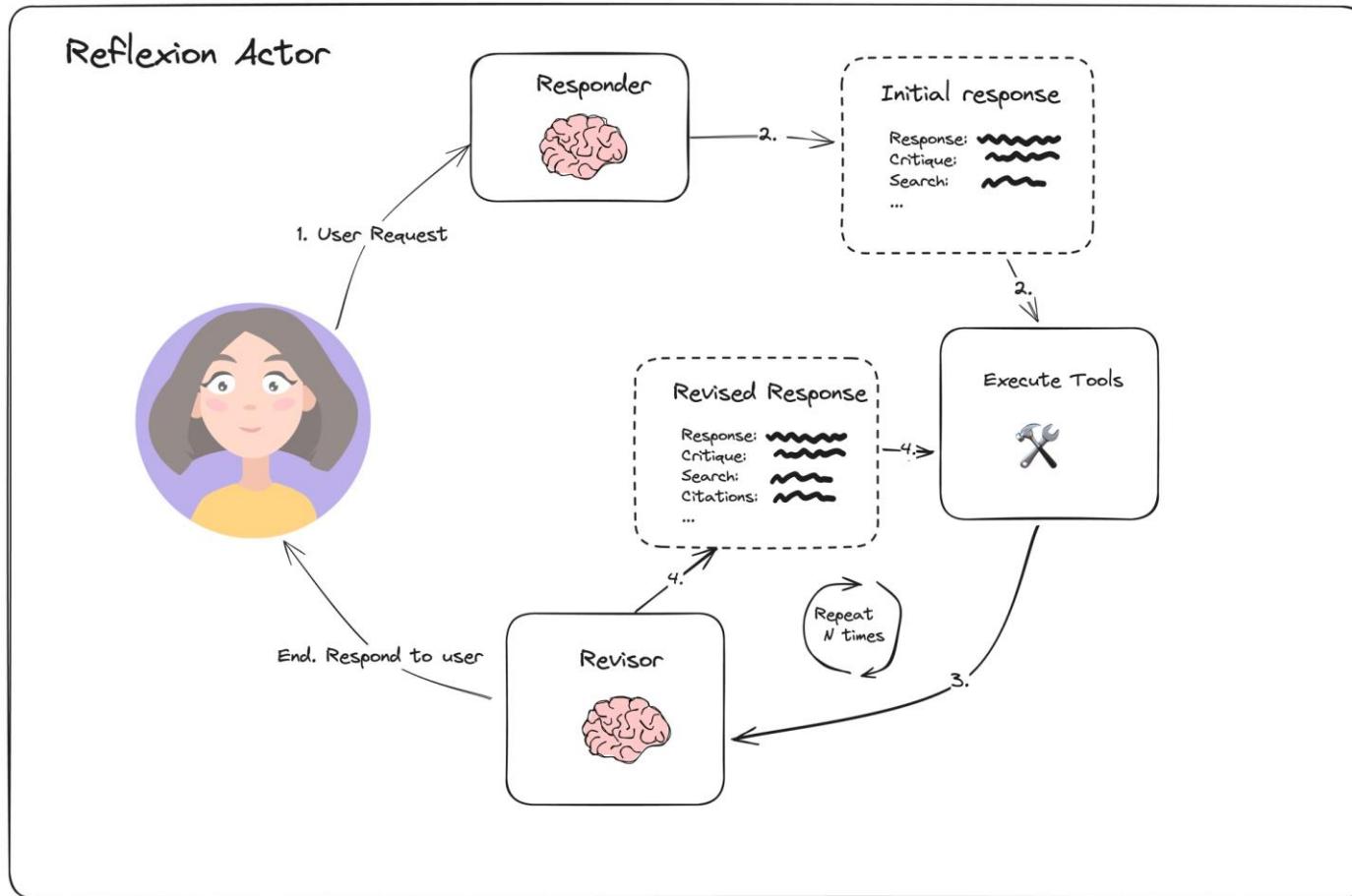
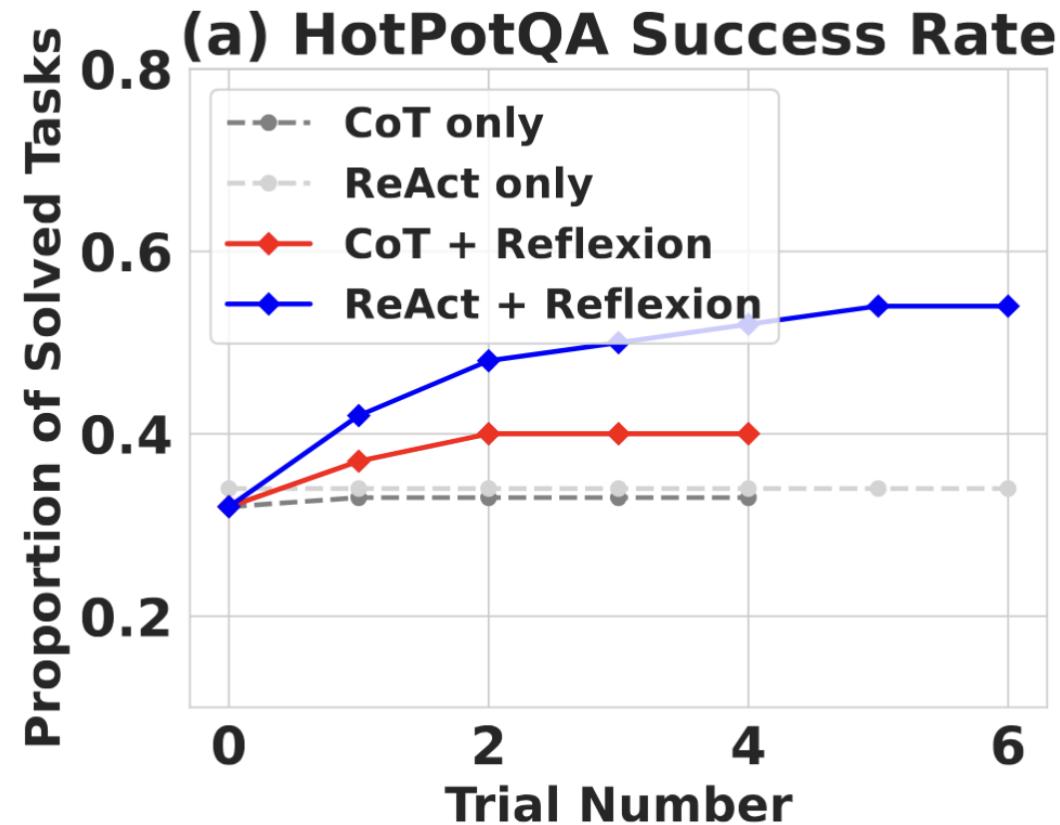


Image source: <https://langchain-ai.github.io/langgraph/tutorials/reflexion/reflexion/>



Reflexion



* Reflexion: Language Agents with Verbal Reinforcement Learning, Noah et. al., Oct 2023



Reflexion

Trial #1: Question: Grown-Ups starred the actor who was best known for which role on "'Allo 'Allo!"?

Thought 1: I need to search Grown-Ups and "'Allo 'Allo!", find the actor who starred in Grown-Ups, then find the role he was best known for in "'Allo 'Allo!".

Action 1: Search[Grown-Ups]

Observation 1: Grown-Ups is a 1980 British BBC television film devised and directed by Mike Leigh. It stars Lesley Manville, Philip Davis, Brenda Blethyn, Janine Duvitski, Lindsay Duncan and Sam Kelly. It was edited by Robin Sales and produced by Louis Marks for the BBC, and originally shown on BBC 2 on 28 November 1980.

Thought 2: Grown-Ups starred Lesley Manville, Philip Davis, Brenda Blethyn, Janine Duvitski, Lindsay Duncan and Sam Kelly. I need to search "'Allo 'Allo!" and find which actor was best known for which role.

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Thought 2: Grown-Ups starred Lesley Manville, Philip Davis, Brenda Blethyn, Janine Duvitski, Lindsay Duncan and Sam Kelly. I need to search "'Allo 'Allo!" and find which actor was best known for which role.

Action 2: Search["'Allo 'Allo!"]

Observation 2: Could not find ["'Allo 'Allo!"].
Similar: ["'Allo 'Allo!", "List of 'Allo 'Allo! characters", 'Gorden Kaye', "'Allo 'Allo! (series 2)", 'Allô, allô', 'Francesca Gonshaw', "'Allo 'Allo! (series 4)", 'Kim Hartman', "'Allo 'Allo! (series 6)", 'Jeremy Lloyd']

Thought 3: To find the actor who was best known for which role on "'Allo 'Allo!", I can search Gorden Kaye.

Action 3: Search[Gorden Kaye]

Observation 3: Gordon Irving Kaye (7 April 1941 – 23 January 2017), known professionally as Gorden Kaye, was an English actor, best known for playing womanising café owner René Artois in the television comedy series 'Allo 'Allo!.

Thought 4: Gorden Kaye was best known for playing womanising café owner René Artois in the television comedy series "'Allo 'Allo!". So the answer is Rene Artois.

Action 4: Finish[Rene Artois]

* Reflexion: Language Agents with Verbal Reinforcement Learning, Noah et. al., Oct 2023



Reflexion

Action 4: Finish[Rene Artois]

Observation 4: Answer is INCORRECT

Reflection: I searched the wrong title for the show, "'Allo 'Allo!", which resulted in no results. I should have searched the show's main character, Gorden Kaye, to find the role he was best known for in the show.

Trial #1: Question: Grown-Ups starred the actor who was best known for which role on "'Allo 'Allo!"?

Thought 1: I need to search Grown-Ups and "'Allo 'Allo!", find the actor who starred in Grown-Ups, then find the role he was best known for in "'Allo 'Allo!".

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Thought 2: Grown-Ups starred Lesley Manville, Philip Davis, Brenda Blethyn, Janine Duvitski, Lindsay Duncan and Sam Kelly. I need to search "'Allo 'Allo!" and find which actor was best known for which role.

Action 2: Search["'Allo 'Allo!"]

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Reflexion

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Trial #2: Question: Grown-Ups starred the actor who was best known for which role on "'Allo 'Allo!"?

Thought 1: I need to search the actor who was best known for a role on "'Allo 'Allo!" and find out what role they were best known for.

Action 1: Search[Grown-Ups]

Observation 1: Grown-Ups is a 1980 British BBC television film devised and directed by Mike Leigh. It stars Lesley Manville, Philip Davis, Brenda Blethyn, Janine Duvitski, Lindsay Duncan and Sam Kelly. It was edited by Robin Sales and produced by Louis Marks for the BBC, and originally shown on BBC 2 on 28 November 1980.

Thought 2: The paragraph does not mention the actor who was best known for a role on "'Allo 'Allo!". I need to search the actor's name instead.

Action 2: Search[Sam Kelly]

Observation 2: Roger Michael Kelly (19 December 1943 – 14 June 2014), known by the stage name Sam Kelly, was an English actor who appeared in film, television, radio and theatre. He is best known for his roles as Captain Hans Geering in 'Allo 'Allo!, Warren in Porridge, Sam in On the Up, and Ted Liversidge in Barbara.

Thought 3: Sam Kelly is best known for his role as Captain Hans Geering in "'Allo 'Allo!", so the answer is Captain Hans Geering.

Action 3: Finish[Captain Hans Geering]

Observation 3: Answer is CORRECT

* Reflexion: Language Agents with Verbal Reinforcement Learning, Noah et. al., Oct 2023



Reflexion

Benchmark + Language	Base	Reflexion
HumanEval (PY)	0.80	0.91
MBPP (PY)	0.80	0.77
HumanEval (RS)	0.60	0.68
MBPP (RS)	0.71	0.75

Overall accuracy for HumanEval and MBPP

* Reflexion: Language Agents with Verbal Reinforcement Learning, Noah et. al., Oct 2023

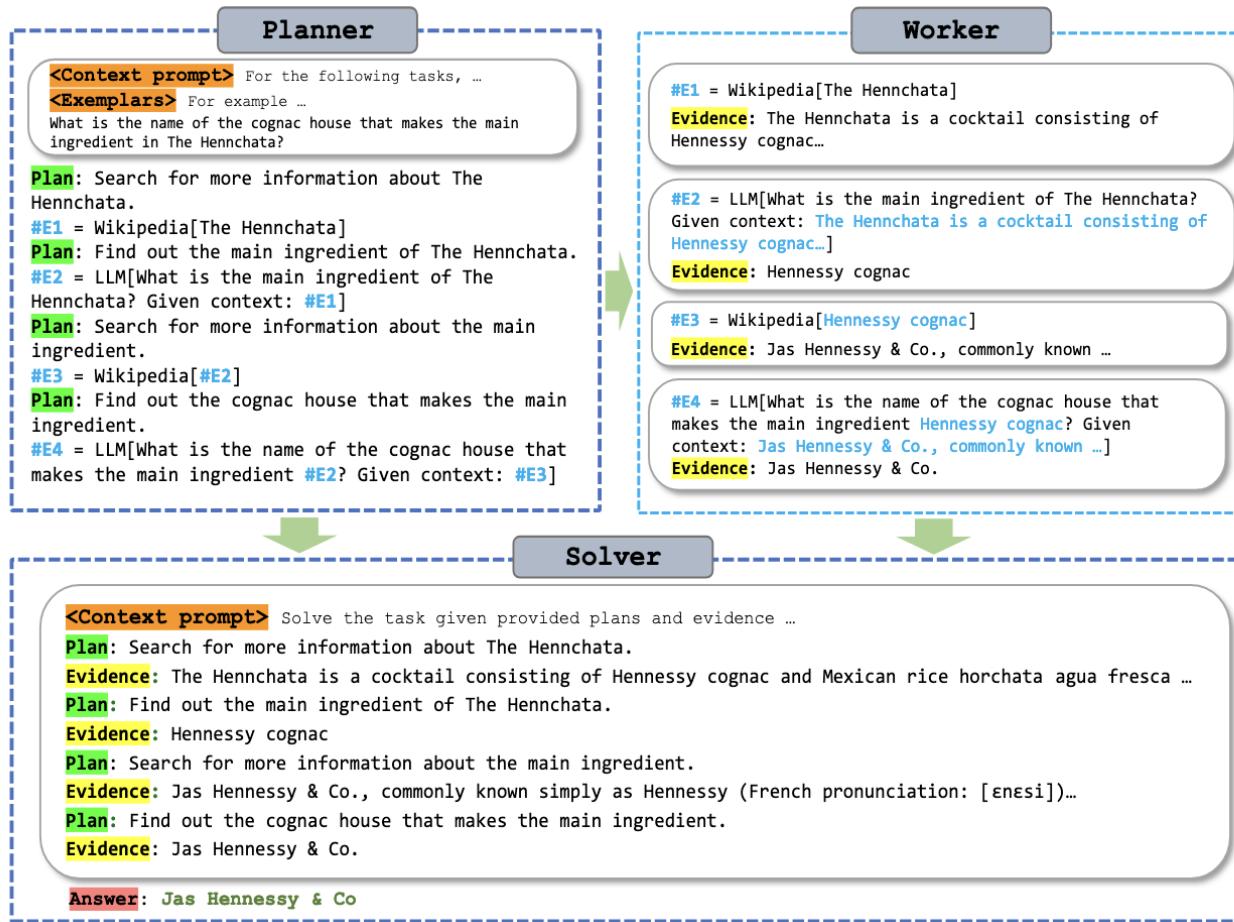


Outline

- ReACT
 - Reasoning + act to arrive at the final answer
- Self-Refine
 - iteratively improving initial results based on model feedback
 - can be combined with ReACT
- Reflexion
 - iteratively improving initial results based on model feedback
 - uses of tools and LLMs for reflection
 - can be combined with ReACT
- ReWoo & HuggingGPT



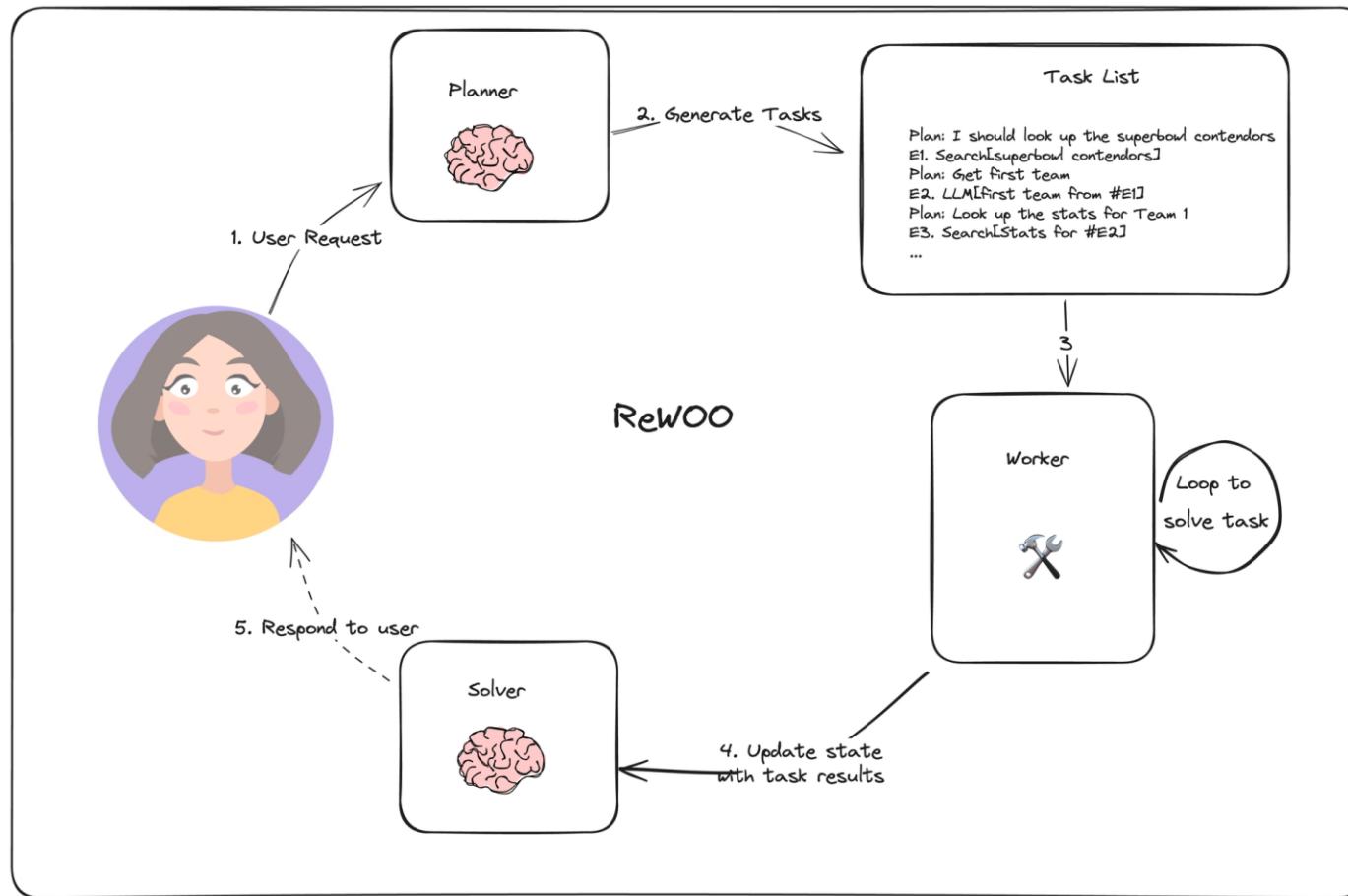
ReWOO



* ReWOO: Decoupling Reasoning from Observations for Efficient Augmented Language Models, Binfeng et. al., May 2023



ReWOO

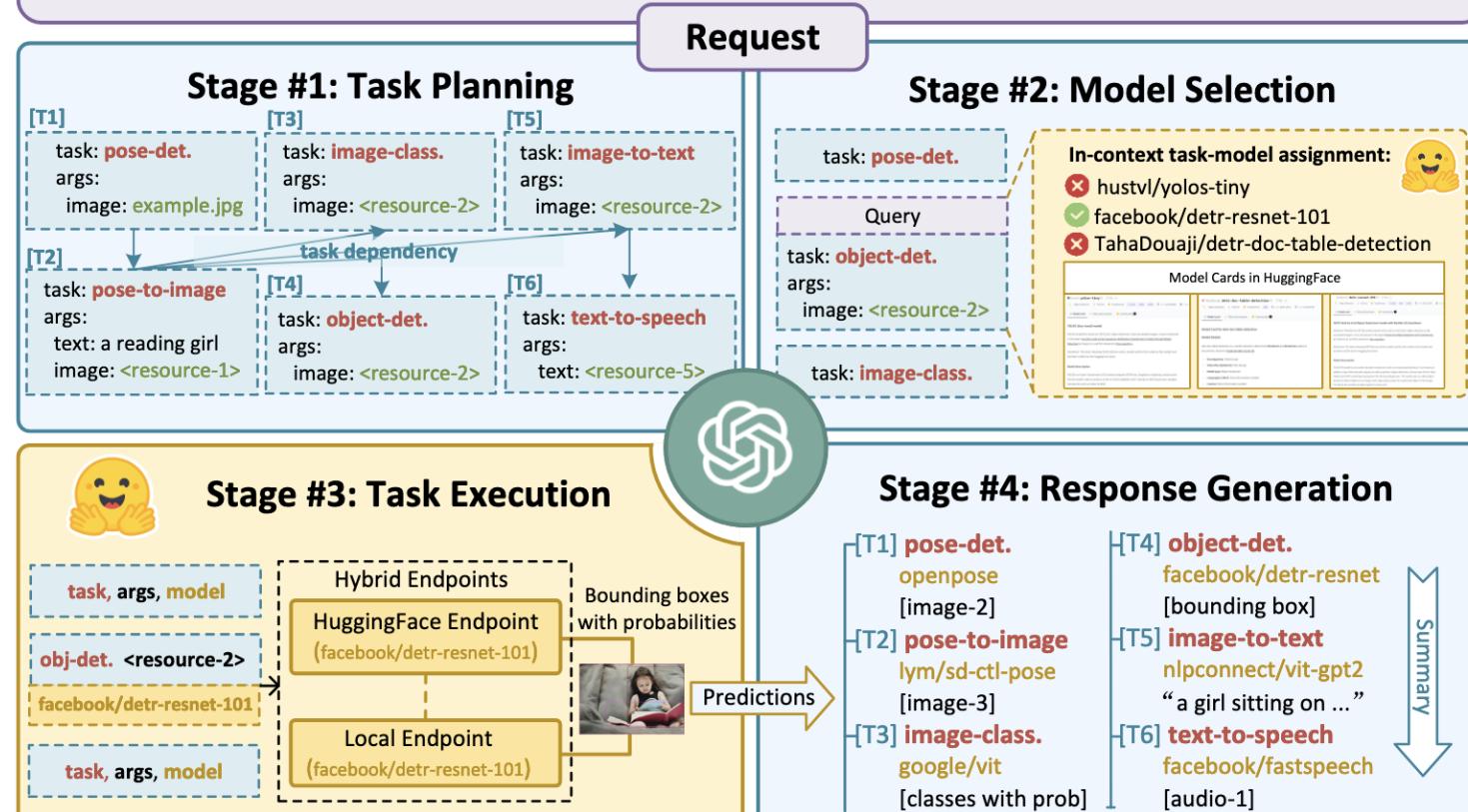


* ReWOO: Decoupling Reasoning from Observations for Efficient Augmented Language Models, Binfeng et. al., May 2023



HuggingGPT

Please generate an image where a girl is reading a book, and her pose is the same as the boy in the image example.jpg, then please describe the new image with your voice.



* HuggingGPT: Solving AI Tasks with ChatGPT and its Friends in Hugging Face, Shen et. al., Dec 2023



HuggingGPT



[Image-1] = example.jpg [Image-2] = <resource-1> [Image-3] = <resource-2>

[Image-4]

a girl sitting on a bed
reading a book

[Text-1] = <resource-5>



[Audio-1]

The image you gave me is of "boy". The first thing I did was use 😊 **OpenCV's openpose model** to analyze the pose of the boy in the image. I fed that image, specifically located at [Image-1], into the model to get an output image of the pose, located at [Image-2]. Then I take that pose and generate a new image, located at [Image-3], using 😊 **Ilyasviel/sd-controlnet-openpose** and the instruction "a girl is reading". Next, I ran object detection on the image generated in the previous step, to get predictions of the objects present in the image, including the box location. These predictions were run through the 😊 **facebook/detr-resnet-101** model. The box was drawn on the image, which is located at [Image-4]. Then, I used the predictions of a image classification model 😊 **google/vit-base-patch16-224** and a image caption model a 😊 **nlpconnect/vit-gpt2-image-captionin** model to generate the caption for newly generated image. It generated text: "a girl sitting on a bed reading a book". Lastly, I ran the 😊 **facebook/fastspeech2-en-ljspeech** model to convert the generated text into audio, located at [Audio-1].

* HuggingGPT: Solving AI Tasks with ChatGPT and its Friends in Hugging Face, Shen et. al., Dec 2023



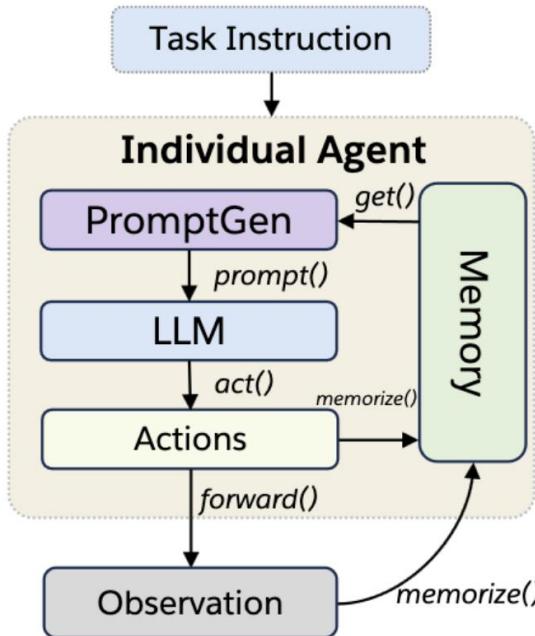
Outline

- ReACT
 - reasoning + act to arrive at the final answer
- Self-Refine
 - iteratively improving initial results based on model feedback
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 - iteratively improving initial results based on model feedback
 - uses of tools and LLMs for reflection
 - can be combined with ReACT
- ReWoo & HuggingGPT
 - decouples reasoning from observation
 - reduce token consumption and execution



Multi Agent Systems

Individual Agent



Multi Agent System

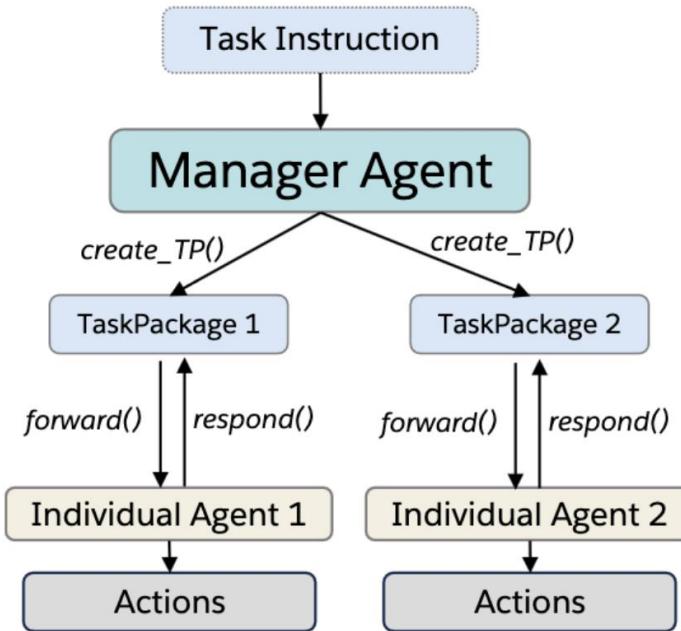
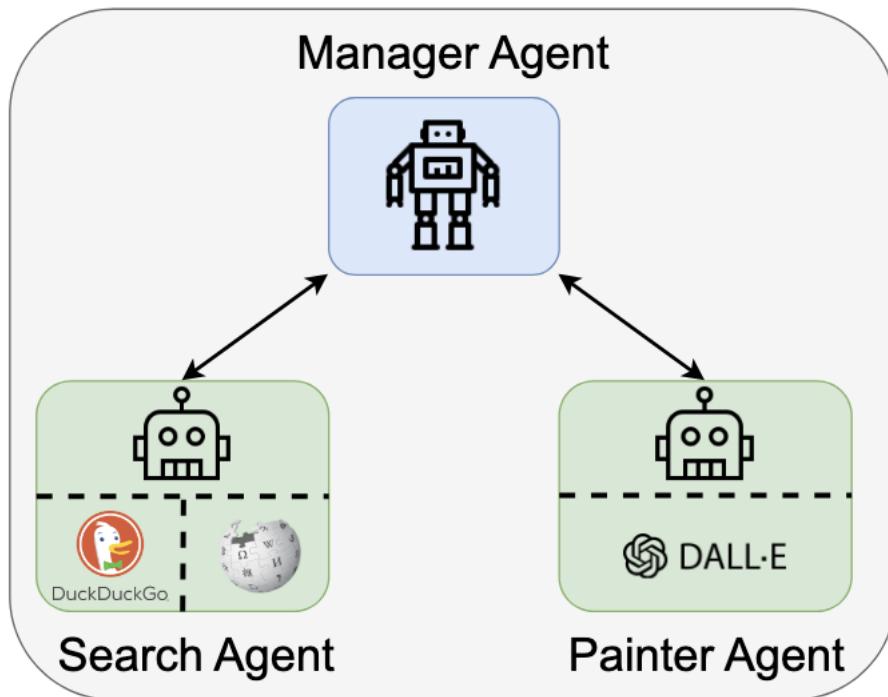


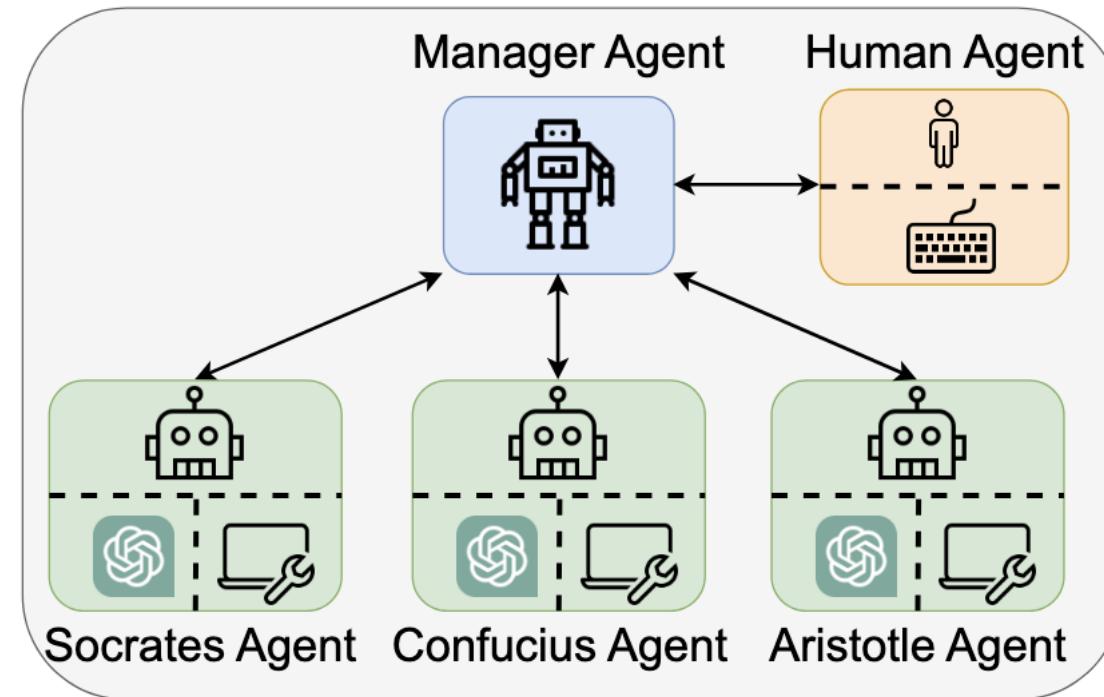
Image credits: AgentLite: A Lightweight Library for Building and Advancing Task-Oriented LLM Agent System, 2024



Multi Agent Systems



Online Painter



Philosophers Chatting

Image credits: AgentLite: A Lightweight Library for Building and Advancing Task-Oriented LLM Agent System, 2024

