

Generative Agents: Interactive Simulacra of Human Behavior

[\[UIST'23 - Full Paper - Best Paper Award \]](#)

[Github:joonspk-research/generative_agents: Generative Agents: Interactive Simulacra of Human Behavior \(github.com\)](#)

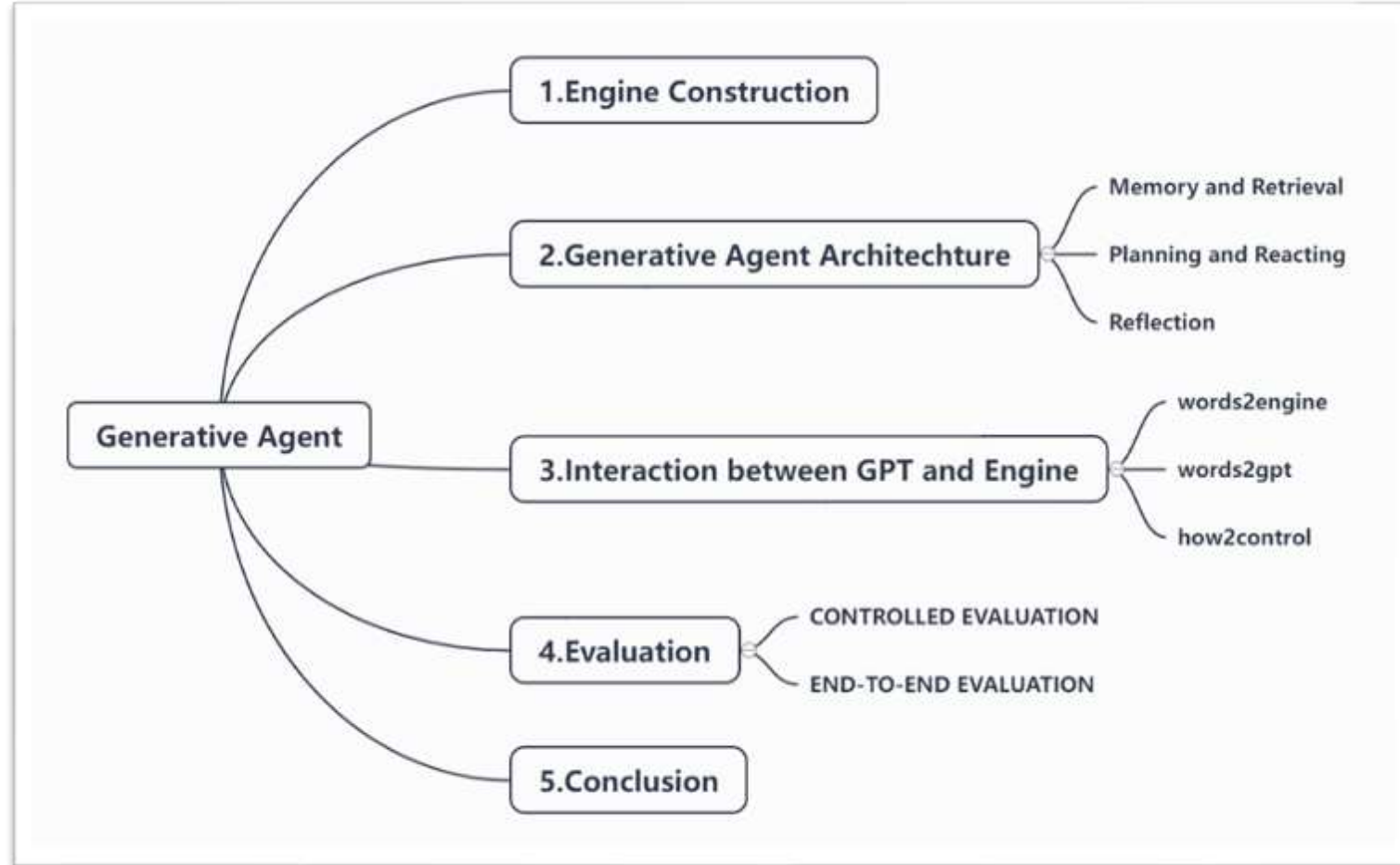
[Demo:Reverie](#)

Overview



In this work, we demonstrate generative agents by populating a sandbox environment, reminiscent of The Sims, with twenty-five agents. Users can observe and intervene as agents plan their days, share news, form relationships, and coordinate group activities.

Overview

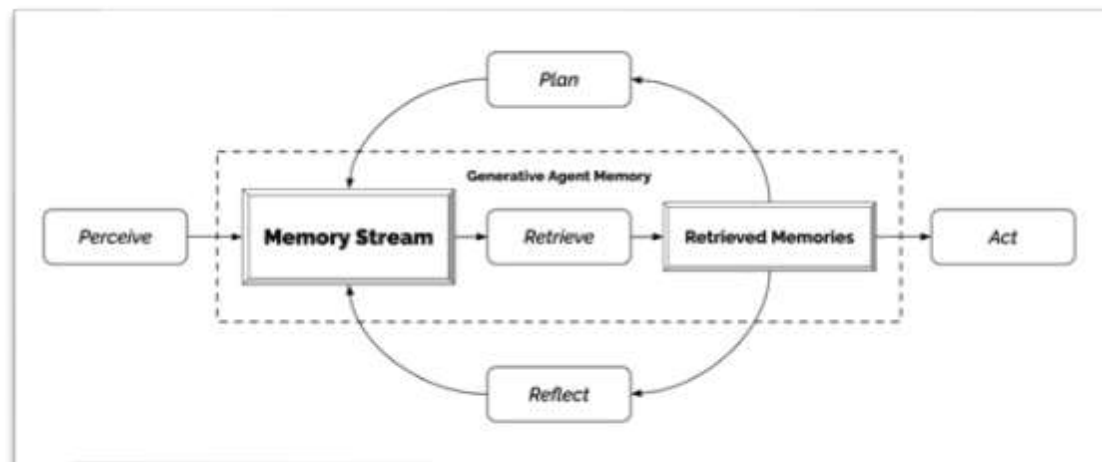


Structure of this paper

Focus



there is a door). However, believable agents require conditioning not only on their current environment but also on a **vast** amount of past experience, which is a poor fit (and as of today, impossi-



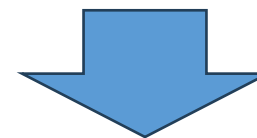
Q1:How to simulate believable behaviors ?

A1:current environment & vast amount past experience.

Q2:How to describe the current environment using llms?

A2: narrowly defined context .

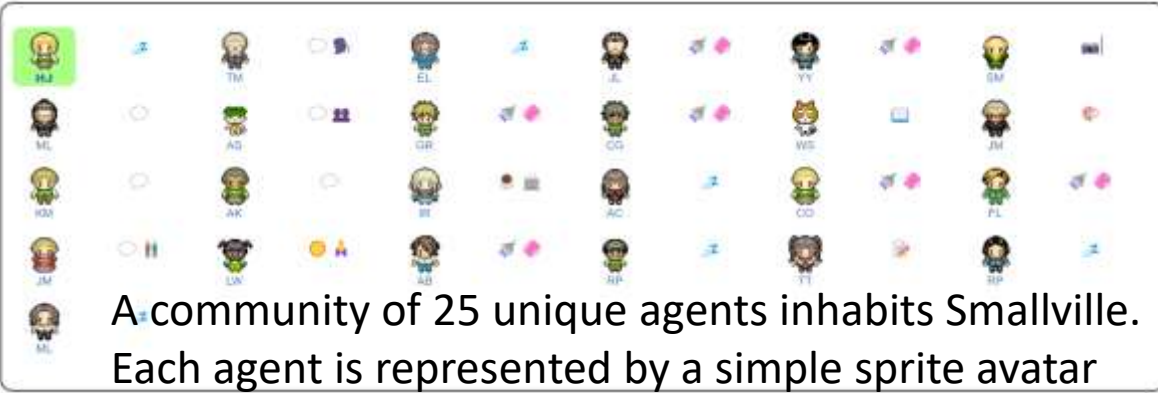
Q3:How to stimulate the vast amount past experience?



**LIMITED TOKEN
VS
BIG DATA**



Engine Construction

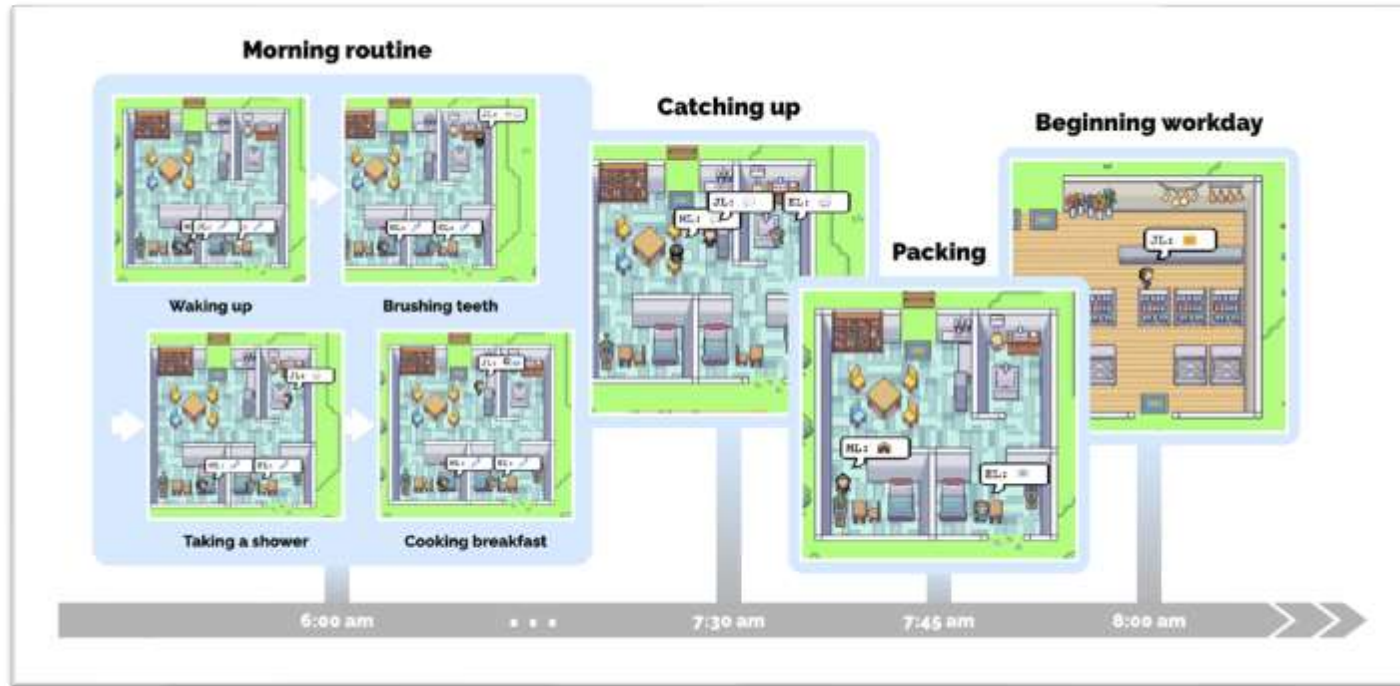


John Lin is a pharmacy shopkeeper at the Willow Market and Pharmacy who loves to help people. He is always looking for ways to make the process of getting medication easier for his customers; John Lin is living with his wife, Mei Lin, who is a college professor, and son, Eddy Lin, who is a student studying music theory; John Lin loves his family very much; John Lin has known the old couple next-door, Sam Moore and Jennifer Moore for a few years; John Lin thinks Sam Moore is a kind and nice man; John Lin knows his neighbor Yuriko Yamamoto, well; John Lin knows of his neighbors, Tamara Taylor and Carmen Ortiz, but has not met them before; John Lin and Tom Morenc are colleagues at The Willows Market and Pharmacy; John Lin and Tom Moreno are friends and like to discuss local politics together; John Lin knows the Moreno family somewhat well – the husband Tom Moreno and the wife Jane Moreno.

We authored one paragraph of natural language description to depict each agent's identity, including their occupation and relationship with other agents, as seed memories



Engine Construction

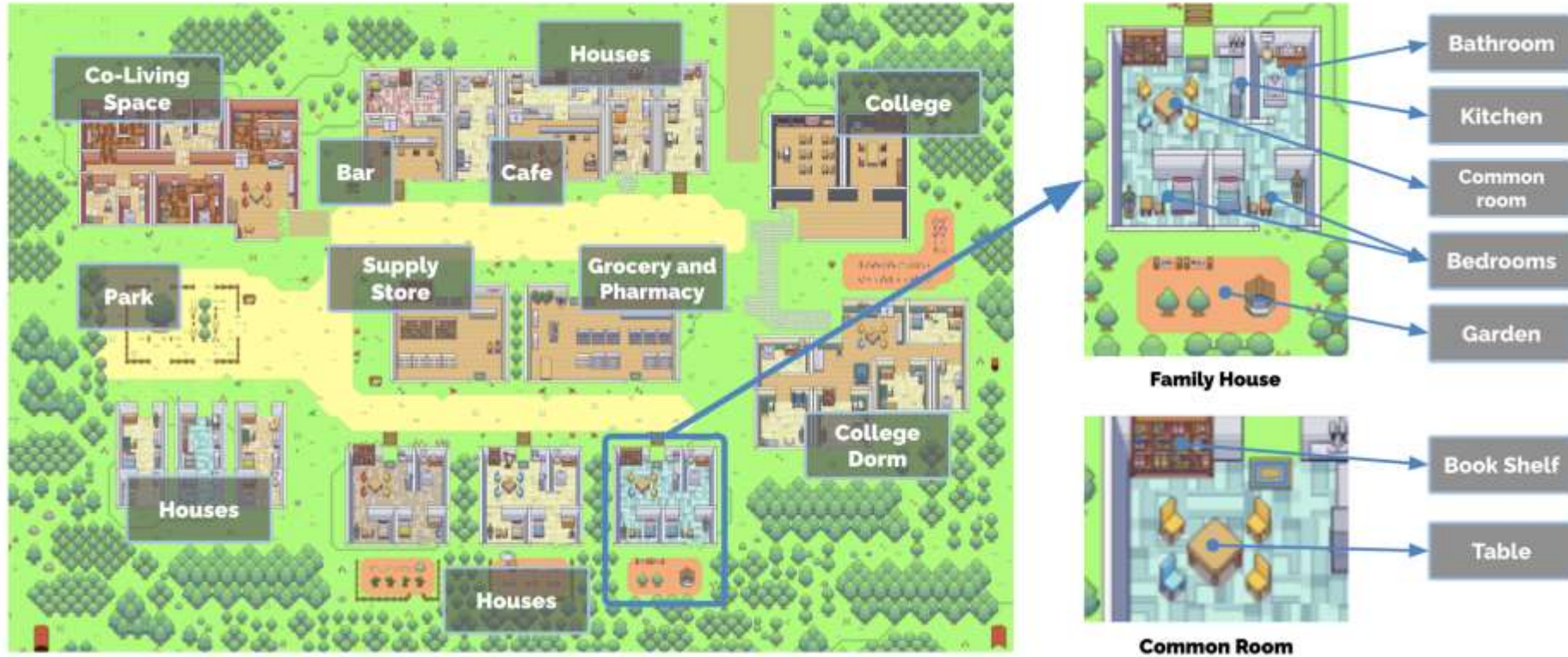


A morning in the life of a generative agent, John Lin. John wakes up around 6 am and completes his morning routine, which includes brushing his teeth, taking a shower, and eating breakfast. He briefly catches up with his wife, Mei, and son, Eddy, before heading out to begin his workday



Information Diffusion: elction
Relationship Memory:new friend
Coordination:party

Interaction



Environment: The root node describes the entire world, children describe areas (e.g., houses, cafe, stores), and leaf nodes describe objects (e.g., table, bookshelf). Agents remember a subgraph that reflects the parts of the world they have seen, maintaining the state of those parts as they observed them

We convert this tree into natural language to pass to the generative agents. For instance, “stove” being a child of “kitchen” is rendered into “there is a stove in the kitchen.”

John Lin [State Details](#)



Current Action:
waking up and completing his morning routine (taking a shower)

Location:
the Ville:Lin family's house:bathroom:shower

Current Conversation:
None at the moment



Interaction

To determine the appropriate location for each action, we traverse the agent's stored environment tree and flatten a portion of it into natural language to prompt the language model

Current area

[Agent's Summary Description]

Eddy Lin is currently in The Lin family's house: Eddy Lin's bedroom: desk) that has Mei and John Lin's

bedroom, Eddy Lin's bedroom, common room, kitchen, bathroom, and garden.

Known areas

Eddy Lin knows of the following areas: The Lin family's house, Johnson Park, Harvey Oak Supply Store, The Willows Market and Pharmacy, Hobbs Cafe, The Rose and Crown Pub.

* Prefer to stay in the current area if the activity can be done there.

Ask Destination

Eddy Lin is planning to take a short walk around his workspace. Which area should Eddy Lin go to?

Interaction

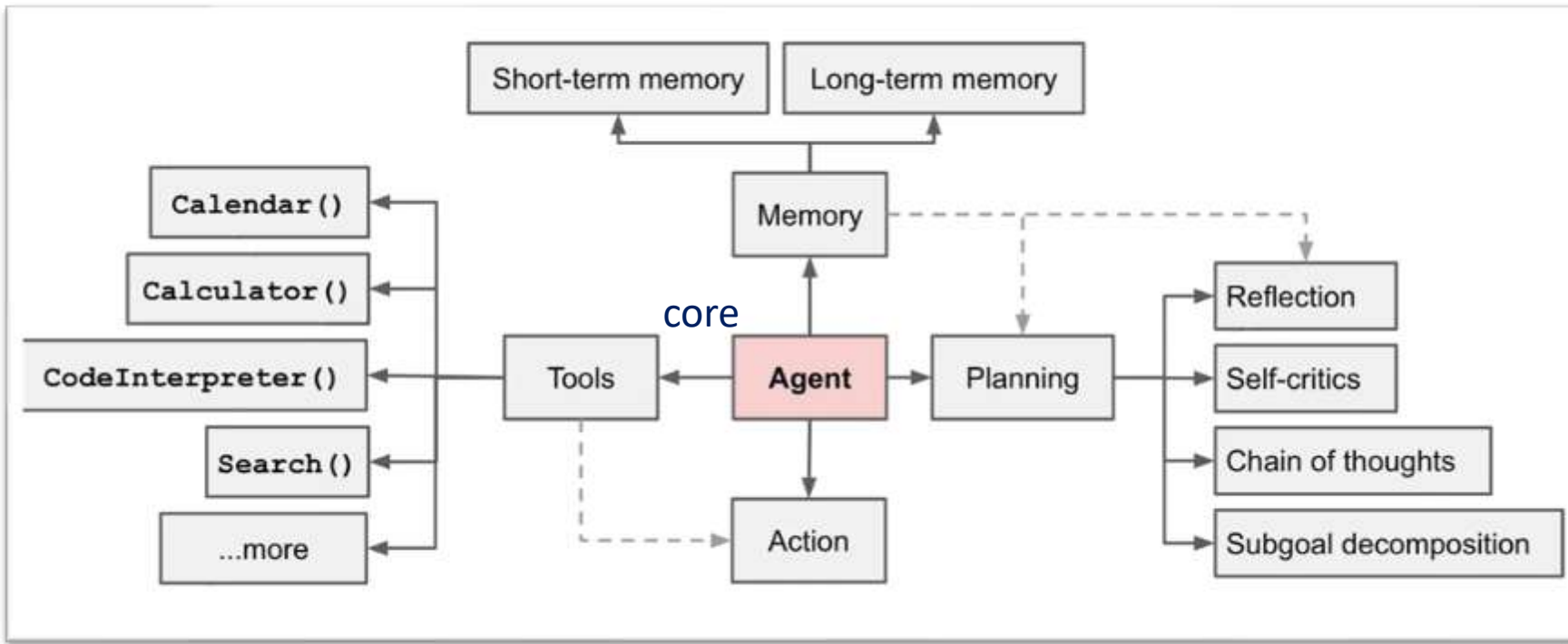
3.1.2 User Controls. The user communicates with the agent through natural language by specifying a persona that the agent should perceive them as. For example, if the user specifies that they are a news “reporter” and asks about the upcoming election by saying, “Who is running for office?”, the John agent replies:

John: My friends Yuriko, Tom and I have been talking about the upcoming election and discussing the candidate Sam Moore. We have all agreed to vote for him because we like his platform.

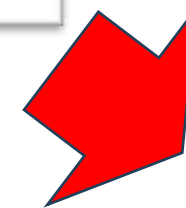
To directly command one of the agents, the user takes on the persona of the agent’s “inner voice”—this makes the agent more likely to treat the statement as a directive. For instance, when told “You are going to run against Sam in the upcoming election” by a user as John’s inner voice, John decides to run in the election and shares his candidacy with his wife and son.



GENERATIVE AGENT ARCHITECTURE

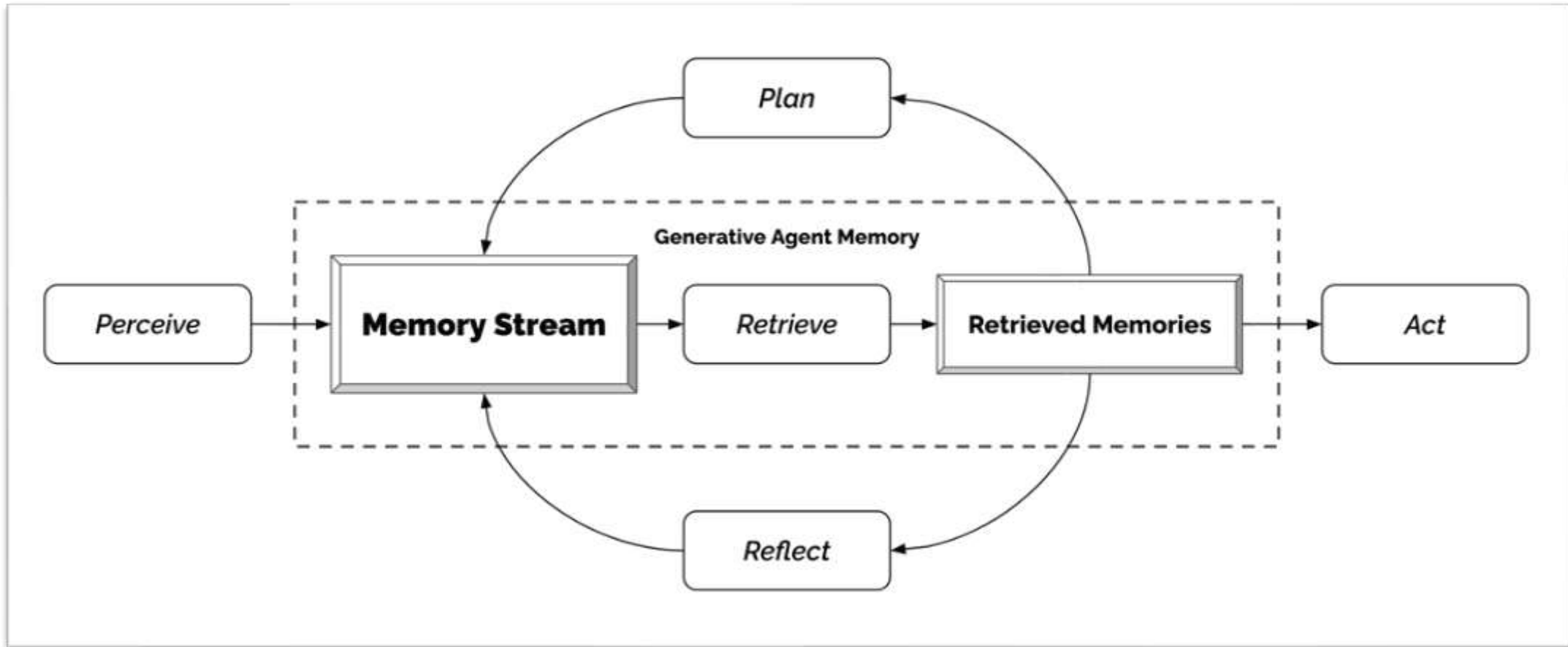


Universal diagram



Token
Project

GENERATIVE AGENT ARCHITECTURE



Arrow1:What can we get?

when, where, who, what

Arrow2:What should we keep in this database?

Arrow3,4,5.....

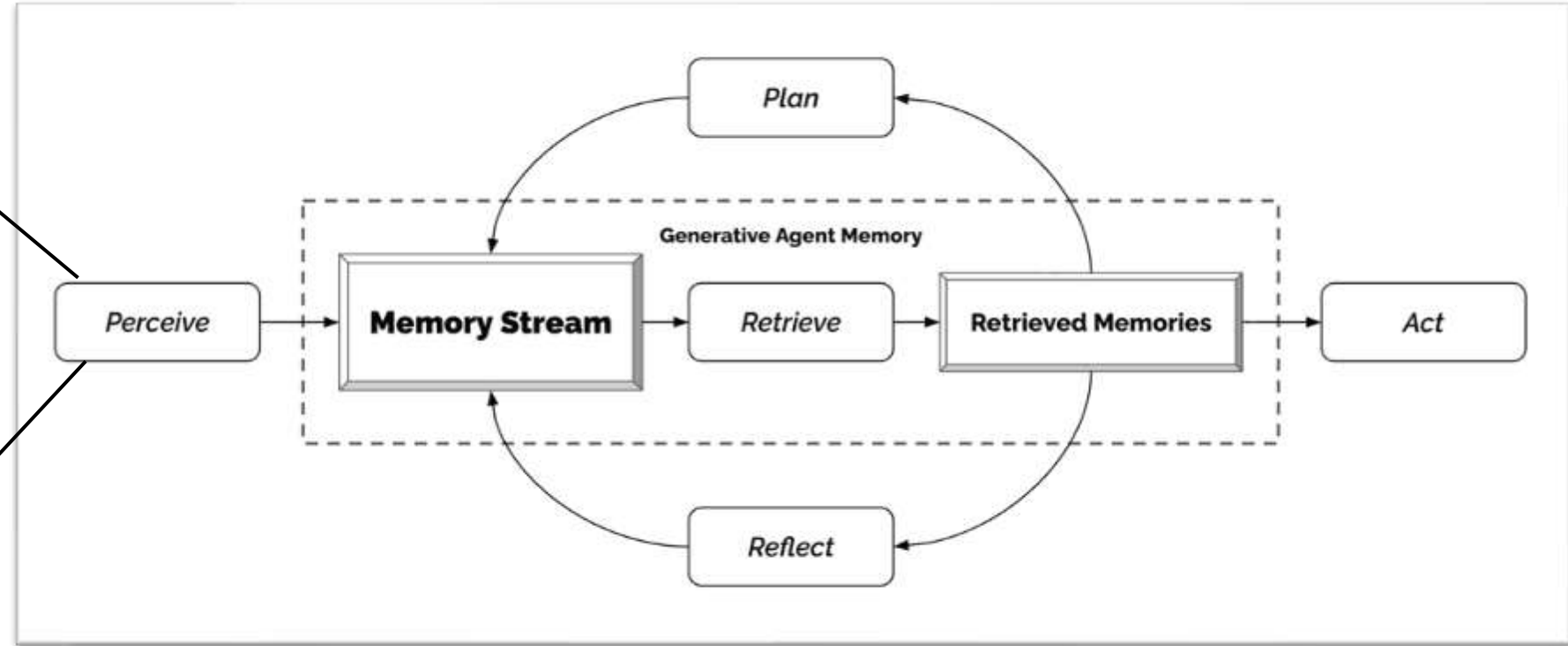
GENERATIVE AGENT ARCHITECTURE

John Lin [State Details](#)

 **Current Action:**
getting ready for work (taking a shower)

Location:
the VilleLin family's house:bathroom:shower

Current Conversation:
None at the moment



[node_856] 2023-02-13 20:18:10: Eddy Lin is Exploring new architecture

[node_853] 2023-02-13 20:13:10: Tamara Taylor is reading the book

[node_837] 2023-02-13 20:12:50: Tom Moreno is conversing about discussing collaborating to create innovative projects incorporating mathematical patterns in nature, including a voter registration planning to grab lunch together with Carlos, Tamara, and Giorgio later to talk more about it.

[node_836] 2023-02-13 20:12:50: Eddy Lin is conversing about discussing collaborating to create innovative projects incorporating mathematical patterns in nature, including a voter registration planning to grab lunch together with Carlos, Tamara, and Giorgio later to talk more about it.

[node_834] 2023-02-13 20:12:40: Tom Moreno is making a plan to vote

[node_833] 2023-02-13 20:12:10: Tamara Taylor is conversing about Eddy Lin asking Tamara Taylor if her book is good and then Tamara asking what brought Eddy over

[node_830] 2023-02-13 20:10:50: Tamara Taylor is conversing about Eddy Lin asking Tamara Taylor if her book is good and then Tamara asking what brought Eddy over

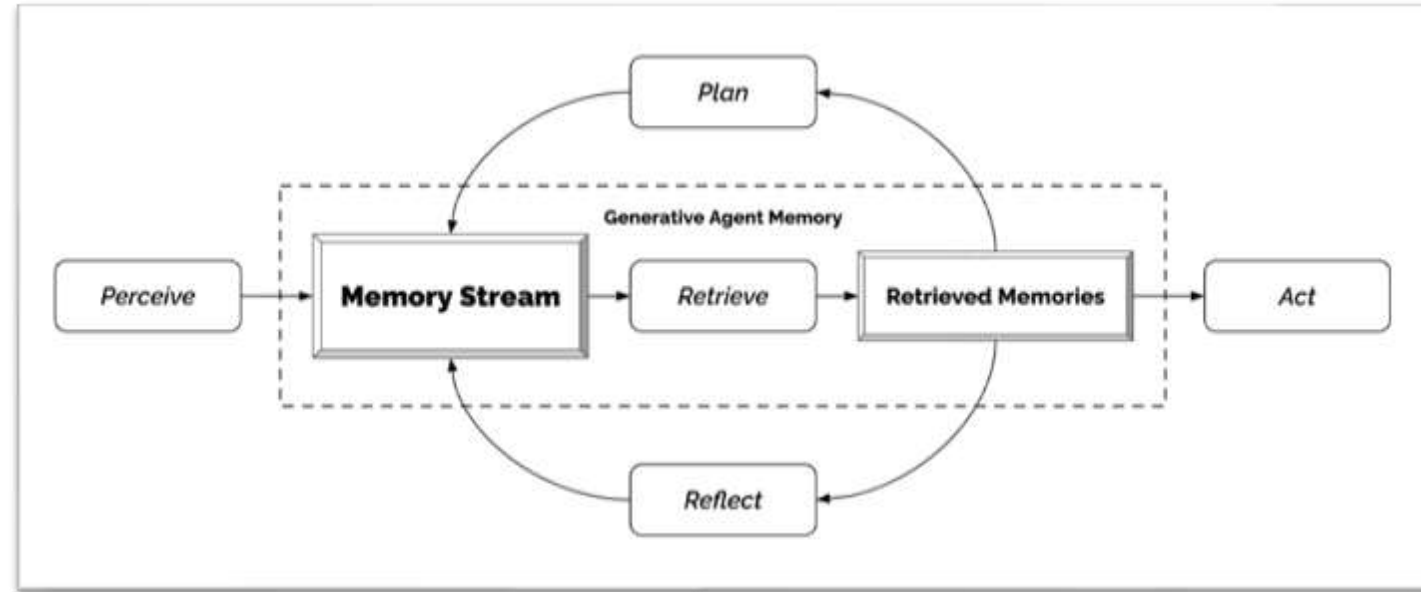
CORE OF THE AGENT

Memory Stream



2023-02-13 22:48:20: desk is idle
2023-02-13 22:48:20: bed is idle
2023-02-13 22:48:10: closet is idle
2023-02-13 22:48:10: refrigerator is idle
2023-02-13 22:48:10: Isabella Rodriguez is stretching
2023-02-13 22:33:30: shelf is idle
2023-02-13 22:33:30: desk is neat and organized
2023-02-13 22:33:10: Isabella Rodriguez is writing in her journal
2023-02-13 22:18:10: desk is idle
2023-02-13 22:18:10: Isabella Rodriguez is taking a break
2023-02-13 21:49:00: bed is idle
2023-02-13 21:48:50: Isabella Rodriguez is cleaning up the kitchen
2023-02-13 21:48:50: refrigerator is idle
2023-02-13 21:48:50: bed is being used
2023-02-13 21:48:10: shelf is idle
2023-02-13 21:48:10: Isabella Rodriguez is watching a movie
2023-02-13 21:19:10: shelf is organized and tidy
2023-02-13 21:18:10: desk is idle
2023-02-13 21:18:10: Isabella Rodriguez is reading a book
2023-02-13 21:03:40: bed is idle
2023-02-13 21:03:30: refrigerator is idle
2023-02-13 21:03:30: desk is in use with a laptop and some papers on it

...



Agent's Conversation History

Created: 2023-02-13 20:26:10

Description: conversing about Mei Lin and John are discussing a variety of topics including keeping up to date on pharmacy knowledge, promoting local artists and businesses, ways to support friend Eddy's music composition project.

Filling:

Mei Lin: Hey, John. What are you listening to?

John Lin: Oh, just a podcast on new medications and treatments. I'm keeping up to date on my pharmacy knowledge.

Mei Lin: That's great. You're always learning something new.

John Lin: Yeah, I want to provide the best service to our customers.

Mei Lin: Speaking of service, I was thinking about ways we can support our local artists and businesses. Maybe we could promote creativity and innovation in the community.

John Lin: I like that idea. We could showcase their work in our store and social media.

Mei Lin: Exactly. I also wanted to discuss the upcoming mayoral election. Have you heard anything about who's running?

John Lin: Not yet, but I've been asking around. I think it's important to be informed and vote for the right candidate.

Mei Lin: Agreed. We could also brainstorm ways to support our troubled neighbor and the elderly neighbors.

John Lin: Yes, they could use some help. We could offer to do some grocery shopping for them.

Mei Lin: That's a great idea. On a different note, have you ever considered trying improv classes? It could be a fun way to step out of our comfort zones and improve our communication skills.

John Lin: Huh, I haven't thought about that before. It could be interesting. And speaking of communication, do you have any advice on how I can improve our relationship communication?

Mei Lin: Well, we could make sure to listen to each other and express our feelings more openly. Communication is key, especially in any relationship.

John Lin: You're right. I will definitely work on that. Thanks for the advice.

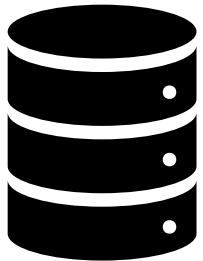
Mei Lin: Of course. And one more thing, I heard about Eddy's music composition project and his collaborations with Maris, Ayesha, and Ryan Park. I'm so proud of him for following his passion.

Everything in the architecture is recorded and reasoned over as a *natural language description*, allowing the architecture to leverage a large language model

Memory & Retrieval

Challenge: Creating generative agents that can simulate human behavior requires reasoning about a set of experiences that is far larger than what should be described in a prompt, as the full memory stream can distract the model and does not even currently fit into the limited context window. Consider the Isabella agent an-

**LIMITED TOKEN
VS
BIG DATA**

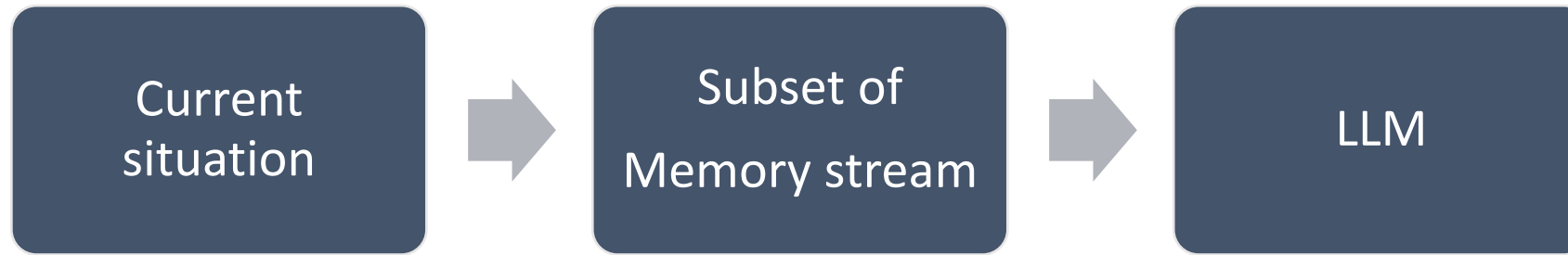


Retrieve rule



Input

How we retrieval



Core challenge: ensure that the most relevant pieces of the agent's memory are retrieved and synthesized when needed

Recency assigns a higher score to memory objects that were recently accessed, so that events from a moment ago or this morning are likely to remain in the agent's attentional sphere. In our implementation, we treat recency as an exponential decay function over the number of sandbox game hours since the memory was last retrieved. Our decay factor is 0.995.

Importance distinguishes mundane from core memories by assigning a higher score to memory objects that the agent believes to be important. For instance, a **mundane event**, such as eating breakfast in one's room, would yield a low importance score, whereas a **breakup with one's significant other** would yield a high score.

Relevance assigns a higher score to memory objects that are related to the current situation. What is relevant depends on the answer to, "Relevant to what?", so we condition relevance on a

query memory. If the query, for example, is that a student is discussing what to study for a chemistry test with a classmate, memory objects about their breakfast should have low relevance, whereas memory objects about the teacher and schoolwork should have high relevance. In our implementation, we use the language model to generate an embedding vector of the text description of each memory. Then, we calculate relevance as the cosine similarity between the memory's embedding vector and the query memory's embedding vector.

$$score = \alpha_{recency} \cdot recency + \alpha_{importance} \cdot importance + \alpha_{relevance} \cdot relevance$$

Memory & Retrieval

On the scale of 1 to 10, where 1 is purely mundane (e.g., brushing teeth, making bed) and 10 is extremely poignant (e.g., a break up, college acceptance), rate the likely poignancy of the following piece of memory.

Memory: buying groceries at The Willows Market and Pharmacy

Rating: <fill in>

Score:

cleaning up the room:2

asking your crush out on a date:8

Q. What are you looking forward to the most right now?

Isabella Rodriguez is excited to be planning a Valentine's Day party at Hobbs Cafe on February 14th from 5pm and is eager to invite everyone to attend the party.

retrieval		recency	importance	relevance
2.34	=	0.91	+ 0.63	+ 0.80

ordering decorations for the party

2.21	=	0.87	+ 0.63	+ 0.71
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researching ideas for the party

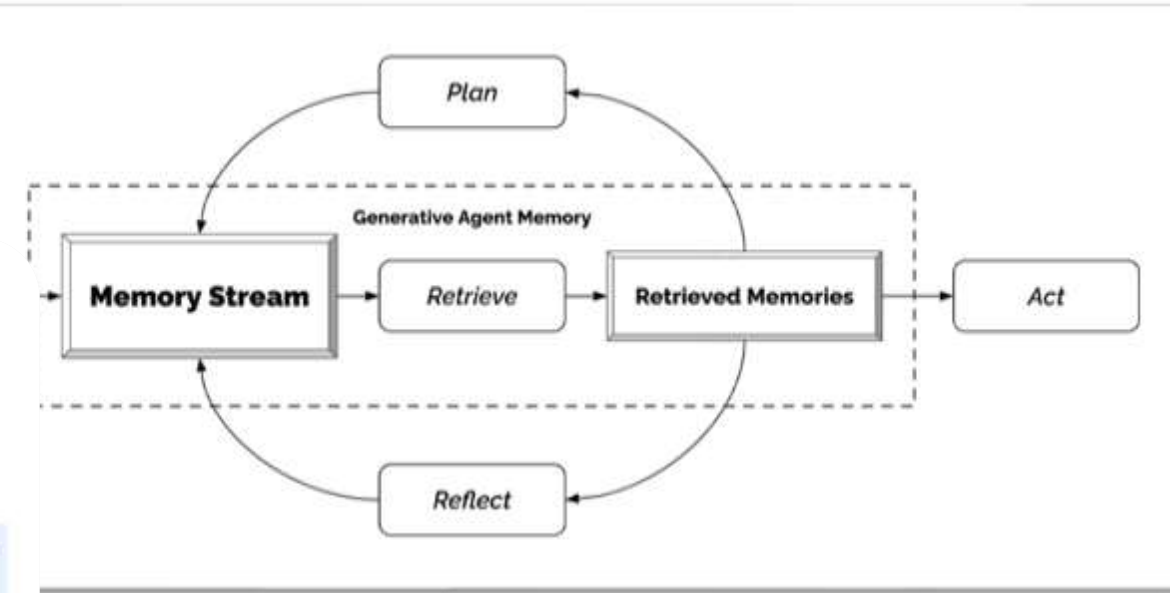
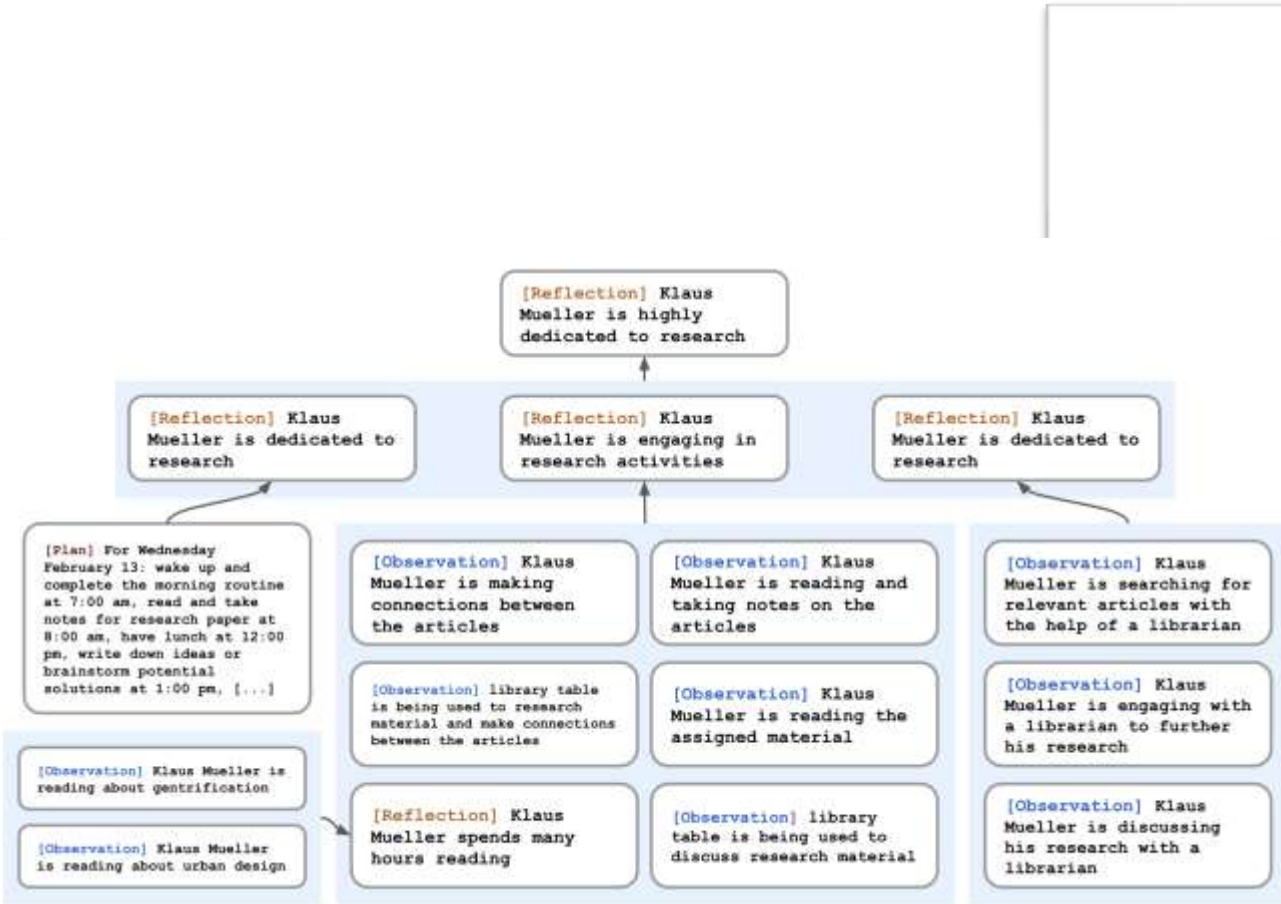
2.20	=	0.85	+ 0.73	+ 0.62
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...

I'm looking forward to the Valentine's Day party that I'm planning at Hobbs Cafe!



Reflect



Reflect

Challenge: Generative agents, when equipped with only raw observational memory, struggle to generalize or make inferences.

When to Reflect

- sum of the importance scores exceeds a threshold

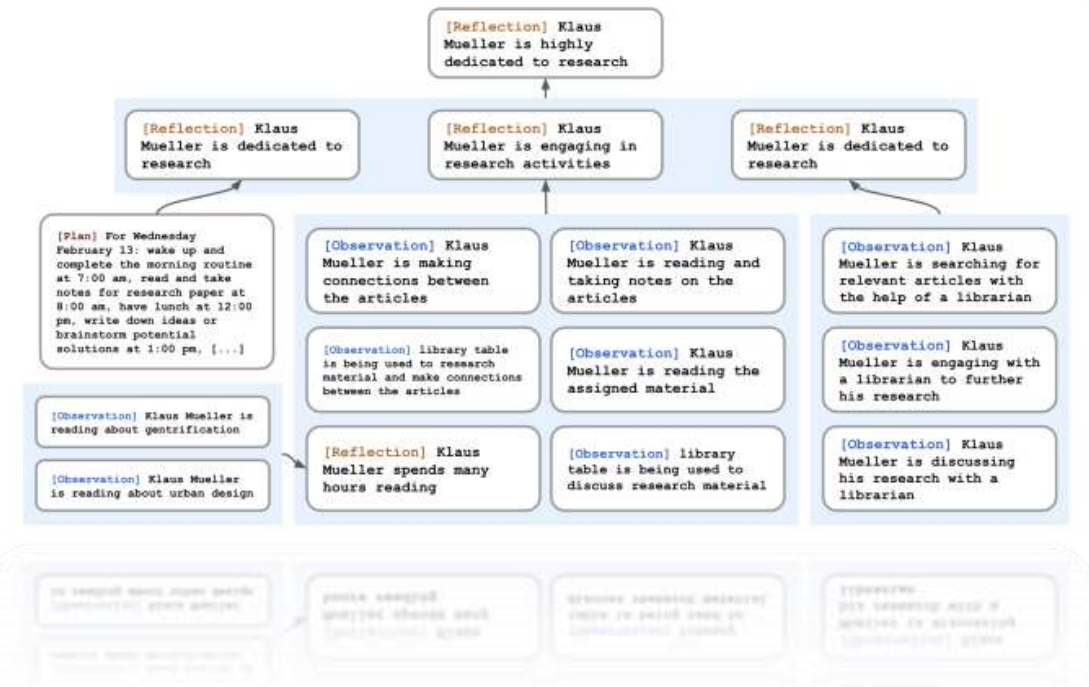
what to reflect on

- most recent records and prompt

extract insights and served

- prompt the Llm

“Given only the information above, what are 3 most salient high level questions we can answer about the subjects in the statements”



Statements about Klaus Mueller

1. Klaus Mueller is writing a research paper
2. Klaus Mueller enjoys reading a book on gentrification
3. Klaus Mueller is conversing with Ayesha Khan about exercising [...]

What 5 high-level insights can you infer from the above statements? (example format: insight (because of 1, 5, 3))

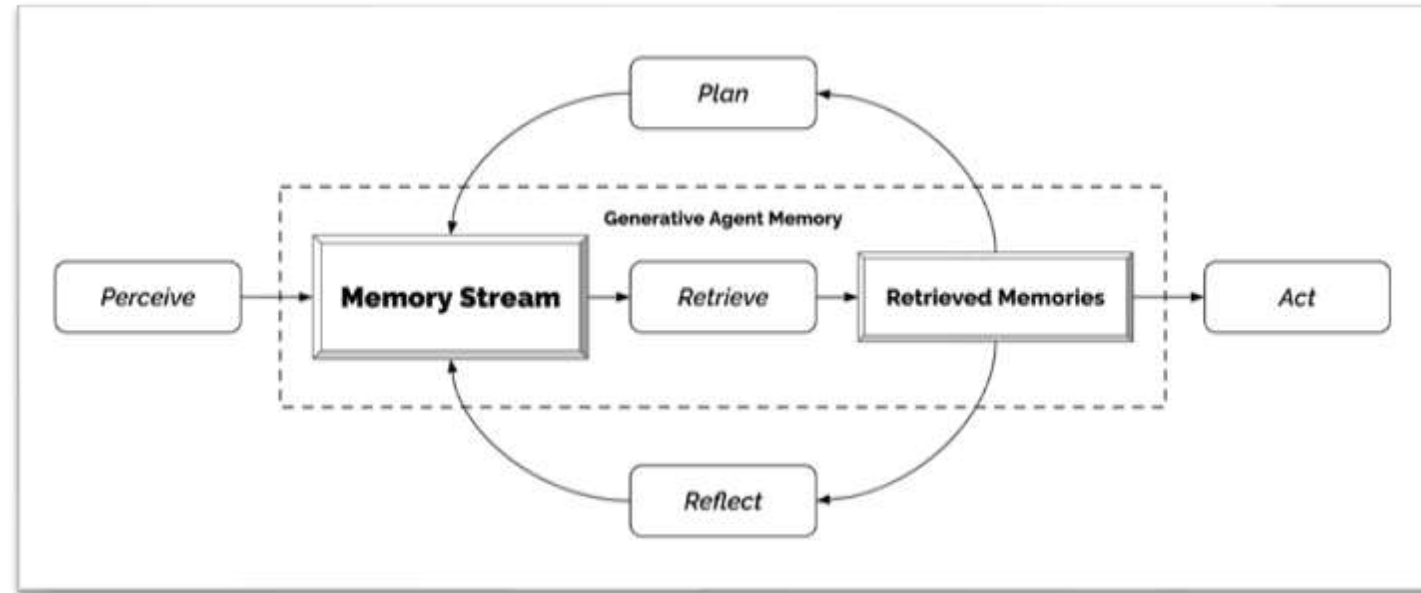
Plan & Act

[Challenge] While a large language model can generate plausible behavior in response to situational information (e.g., [46, 80]), agents need to **plan over a longer time horizon** to ensure that their **sequence of actions is coherent and believable**.

[Scene] If we prompt a language model with Klaus's background, describe the time, and ask what action he ought to take at the given moment, Klaus would eat lunch at 12 pm, but then again at 12:30 pm and 1 pm, despite having already eaten his lunch twice.

***Optimizing for believability in the moment sacrifices believability over time**

[Approach] Plans describe a future sequence of actions for the agent, and help keep the agent's behavior consistent over time. Our approach starts **top-down** and then **recursively** generates more detail.



Daily Requirement

1. wake up and complete the morning routine at 8:00 am
2. have breakfast at 8:30 am
3. go to Oak Hill College to take classes starting 10:00 am
4. have lunch at 11:45 am
5. continue classes until 2:00 pm
6. visit Hobbs Cafe to eat and study until 5:30 pm
7. have dinner at 5:30 pm
8. review his closest assignments until 7:00 pm

Plan & Act

Name: Eddy Lin (age: 19)

Innate traits: friendly, outgoing, hospitable

Eddy Lin is a student at Oak Hill College studying music theory and composition. He loves to explore different musical styles and is always looking for ways to expand his knowledge. Eddy Lin is working on a composition project for his college class. He is taking classes to learn more about music theory. Eddy Lin is excited about the new composition he is working on but he wants to dedicate more hours in the day to work on it in the coming days

On Tuesday February 12, Eddy 1) woke up and completed the morning routine at 7:00 am, [...]


6) got ready to sleep around 10 pm.

Today is Wednesday February 13. Here is Eddy's plan today in broad strokes: 1)

We prompt the language model with the agent's summary description (e.g., name, traits, and a summary of their recent experiences)

1. wake up and complete the morning routine at 8:00 am
2. have breakfast at 8:30 am
3. go to Oak Hill College to take classes starting 10:00 am
4. have lunch at 11:45 am
5. continue classes until 2:00 pm
6. visit Hobbs Cafe to eat and study until 5:30 pm
7. have dinner at 5:30 pm
8. review his closest assignments until 7:00 pm

Daily Requirement

 Eddy Lin	
Basic information	
First name	Eddy
Last name	Lin
Age	19
Current time	February 13, 2023, 20:58:20
Current tile	[110, 33]
Settings	
Vision Radius	8
Attention Bandwidth	8
Retention	8
Personality and Lifestyle	
Innate tendency	curious, analytical, musical
Learned tendency	Eddy Lin is a student at Oak Hill College studying music theory and composition. He loves to explore different musical styles and is always looking for ways to expand his knowledge.
Currently	Eddy Lin is working on a composition project for his college class. He is also taking classes to learn more about music theory.
Lifestyle	Eddy Lin goes to bed around 11pm, awakes up around 7amam, eats dinner around 5pm.

work on his new music composition
from 1:00 pm to 5:00 pm

1:00 pm: start by brainstorming some
ideas for his music composition [...]

4:00 pm: grab a light snack, such as a
piece of fruit, a granola bar, or some
nuts. 4:05 pm: take a short walk around
his workspace [...]

Hour long chunks

5-15min chunks

Plan & Act

[Agent's Summary Description]

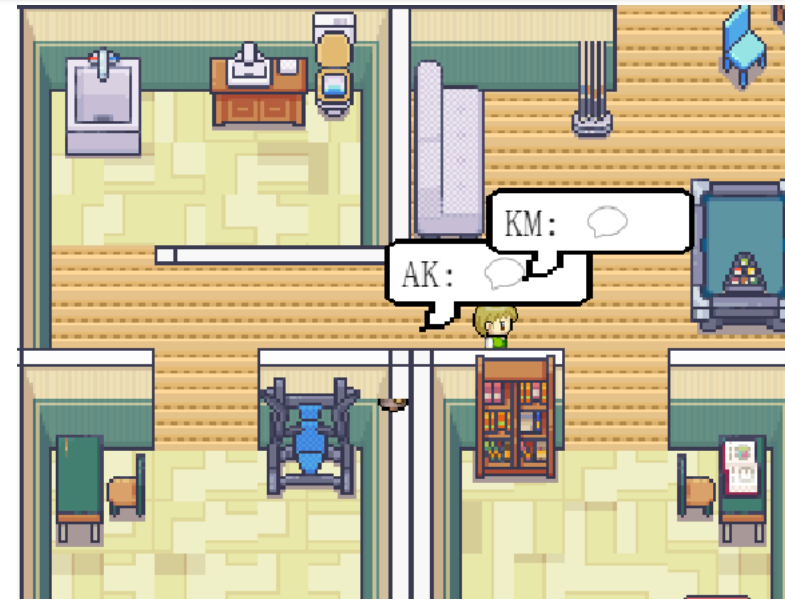
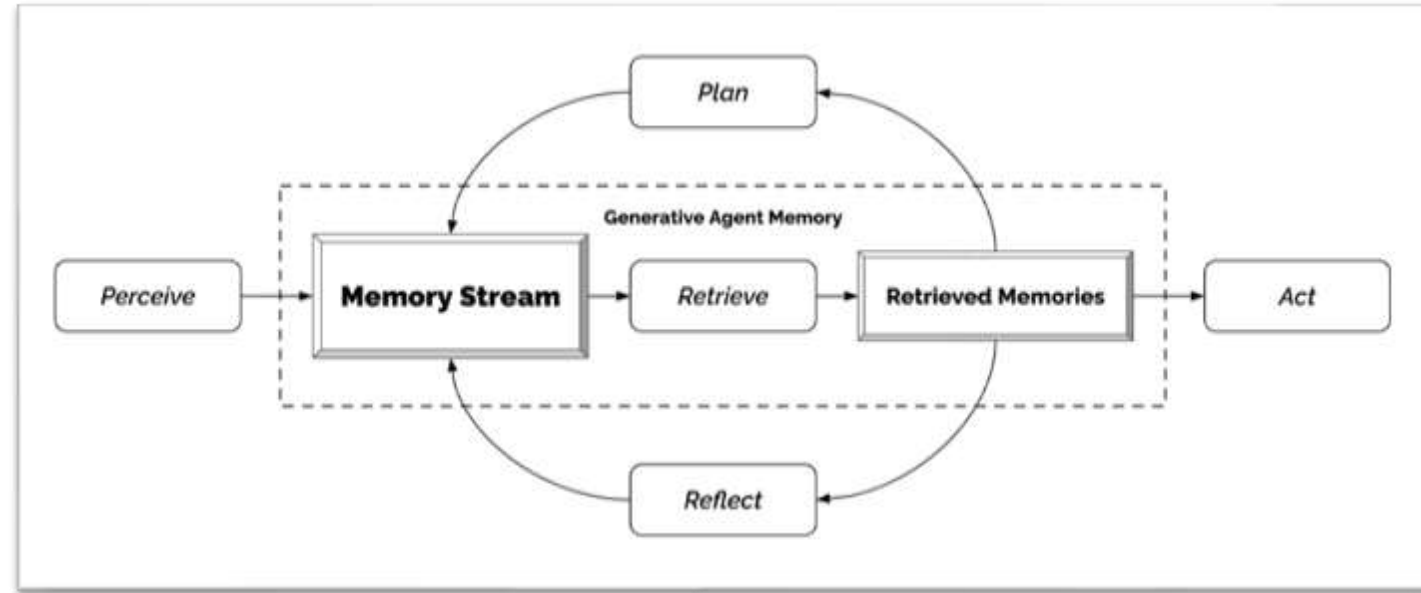
It is February 13, 2023, 4:56 pm.

John Lin's status: John is back home early from work.

Observation: John saw Eddy taking a short walk around his workplace.

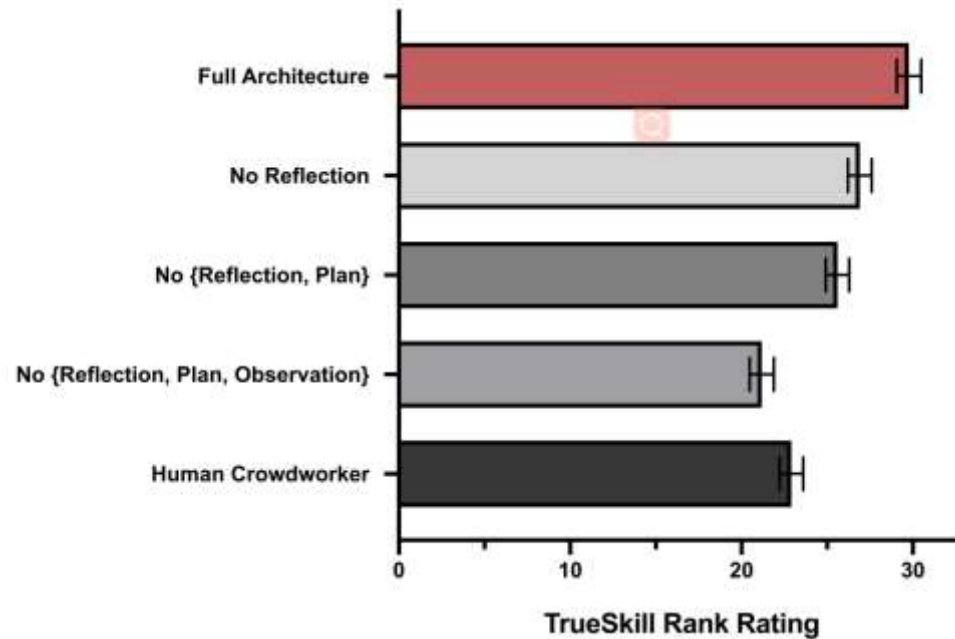
Summary of relevant context from John's memory: Eddy Lin is John's Lin's son. Eddy Lin has been working on a music composition for his class. Eddy Lin likes to walk around the garden when he is thinking about or listening to music.

Should John react to the observation, and if so, what would be an appropriate reaction?

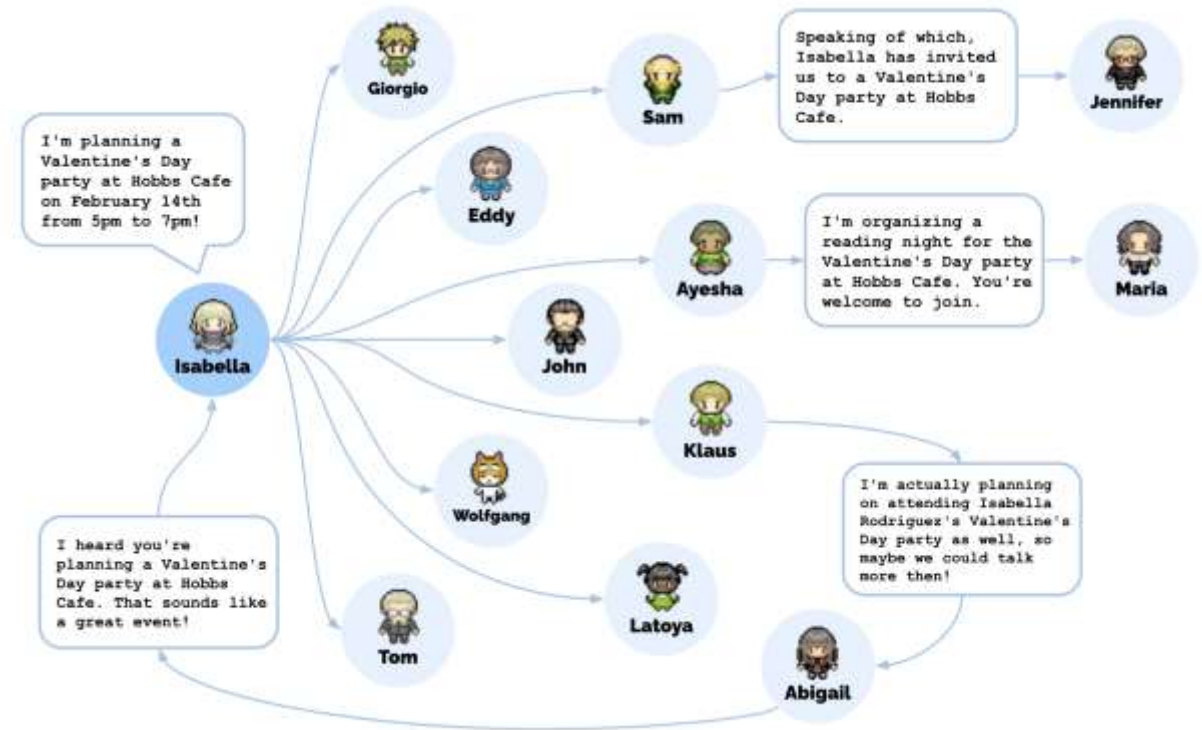


Evaluation

CONTROLLED EVALUATION(Single agent)
Ablation experiment



END-TO-END EVALUATION(Agents)
Information Relationship Coordination



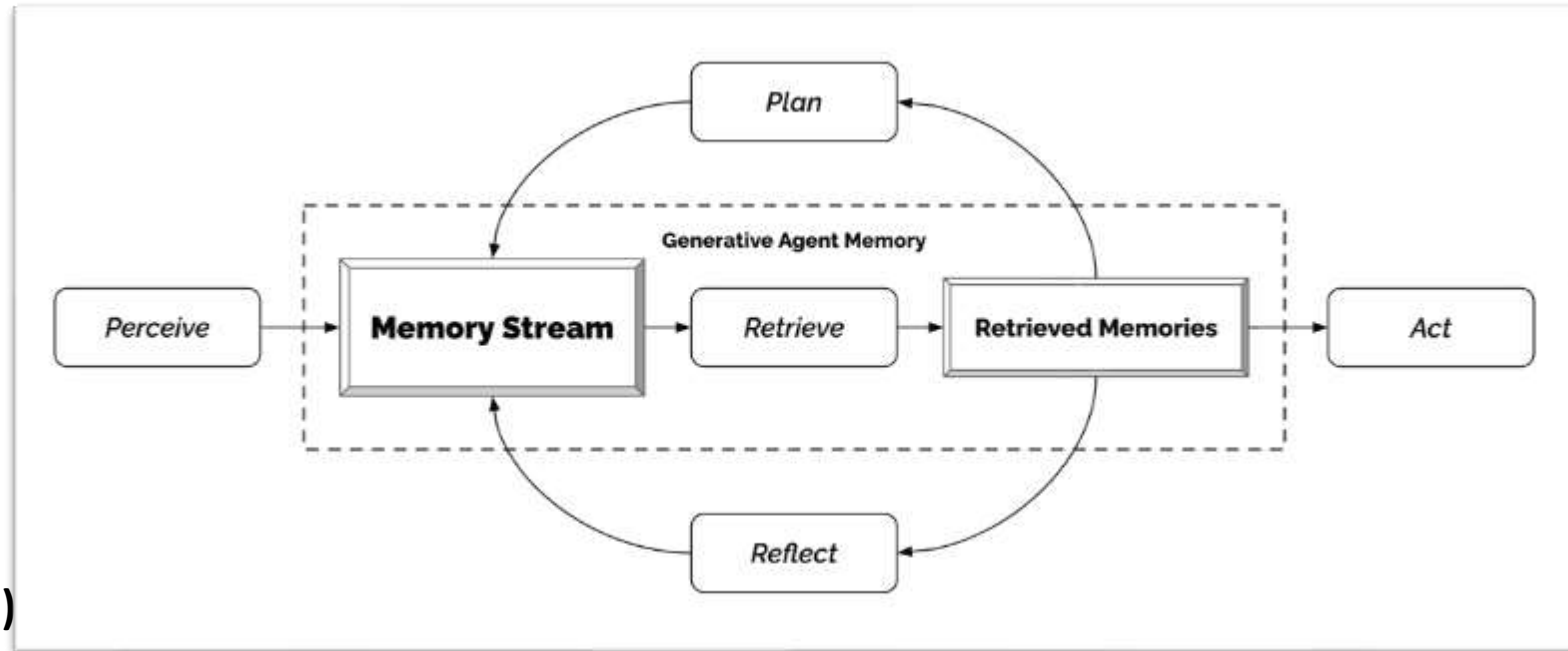
Conclusion

Merits :

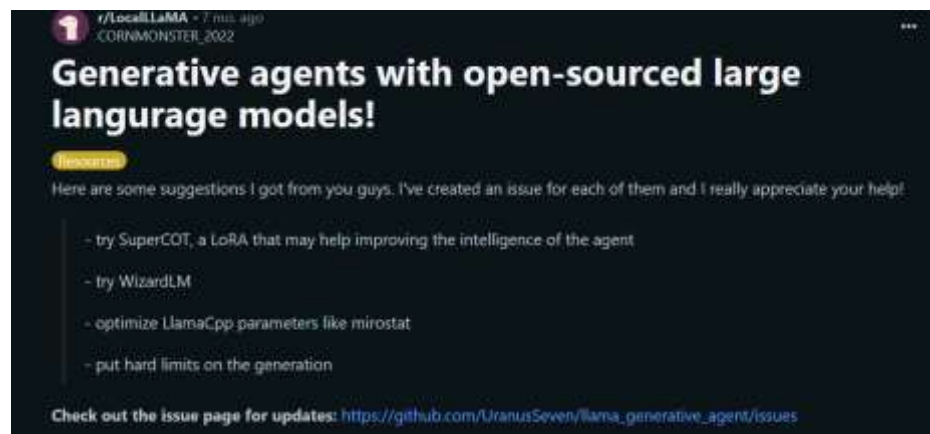
- Memory & Retrieval
- Emergent Behavior

Demerits:

- too Expensive
- Boundaries and Errors(formal,overcooperation)



One more step



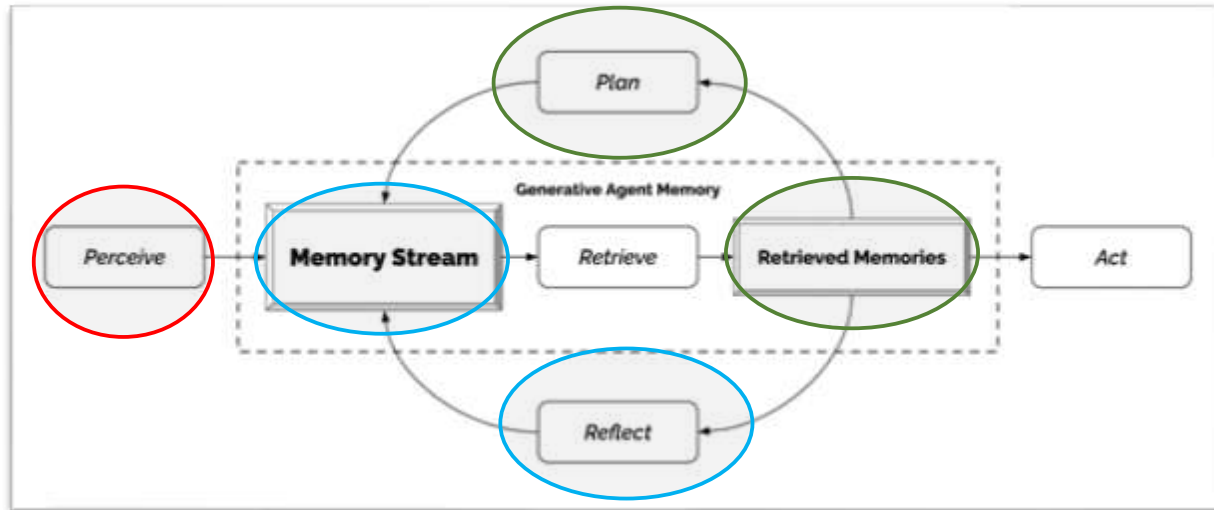
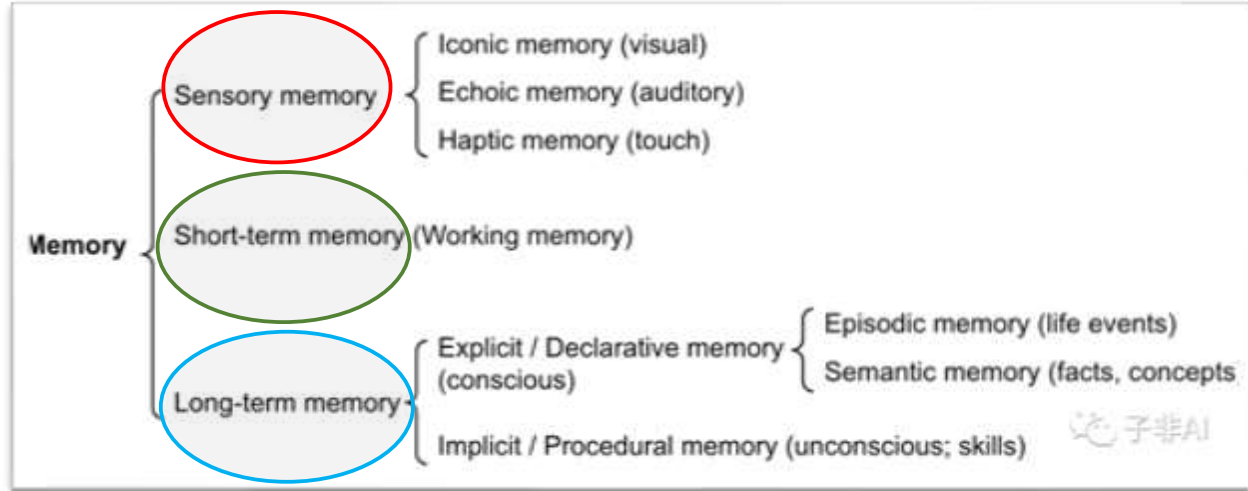
我只需要根据固定的提示词，就能让大语言模型扮演正反双方，在对抗中生成更高质量的答案。

0. 论题定义

训练监督学习模型 根据带有噪声的金融时间序列 预测未来某短时间价格的涨跌波动情况。请问使用什么模型更好？

- 正方：循环网络(LSTM, GRU) 比集成模型(XGBoost, LightGBM) 更好
- 反方：集成模型(XGBoost, LightGBM) 比循环网络(LSTM, GRU) 更好

Memory Of Agent



To improve memory ability:

- Extended **length limit** Improved on the sequence

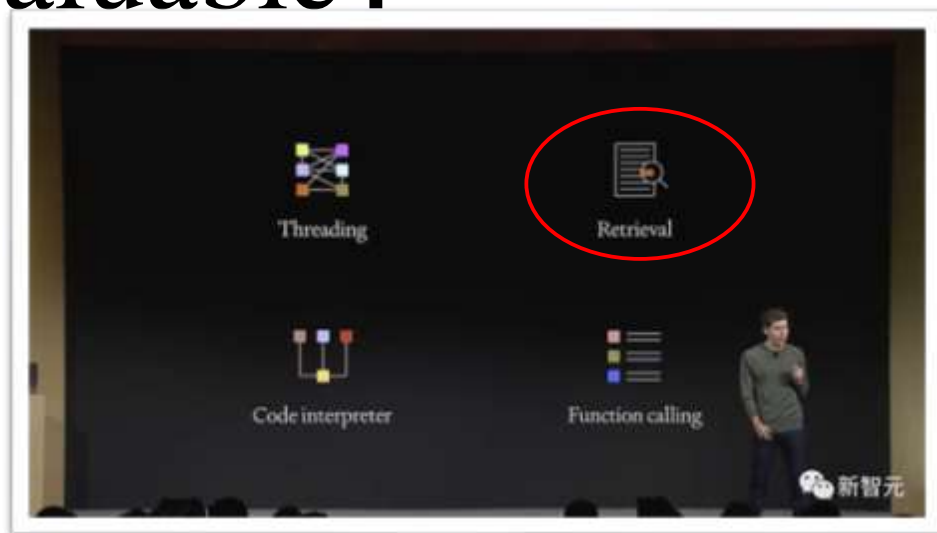
- **Summarizing memories**

Summarize memories to enhance the agent's ability to extract **key details** from them.

- **Compressing**

Memory retrieval can be improved by compressing memories using **vectors** or **appropriate data structures**

Valuable?



传递文件给代码解释器

代码解释器可以解析文件中的数据。当您想要向助手提供大量的数据或允许用户上传自己的文件进行分析时，这非常有用。

助手级别传递的文件可以被所有使用此助手的运行访问：

```
# Upload a file with an "assistants" purpose
file = client.files.create(
    file=open("speech.py", "rb"),
    purpose='assistants'
)

# Create an assistant using the file ID
assistant = client.beta.assistants.create(
    instructions="You are a personal math tutor. When asked a math question, write and r
    model="gpt-4-1106-preview",
    tools=[{"type": "code_interpreter"}],
    file_ids=[file.id]
)
```



All based on GPT-4! GPT-4! GPT-4!

- Other LLMS?
- Performance Overhead?
- Abstract Mind ---Higher memory system
- Stimulate Cooperation.....

over