

LLM-powered Agents in Social Network

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Background



RecAgent



S3



Conclusion



Agent Society



Human Society

**Agent-based
Social Network**



Connections

**Traditional
Social Network**

When Large Language Model based Agents meet User Behavior Simulation



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Conclusion

Building a user behavior simulator based LLM-based agents

- Borrowing the human-like capability of LLM

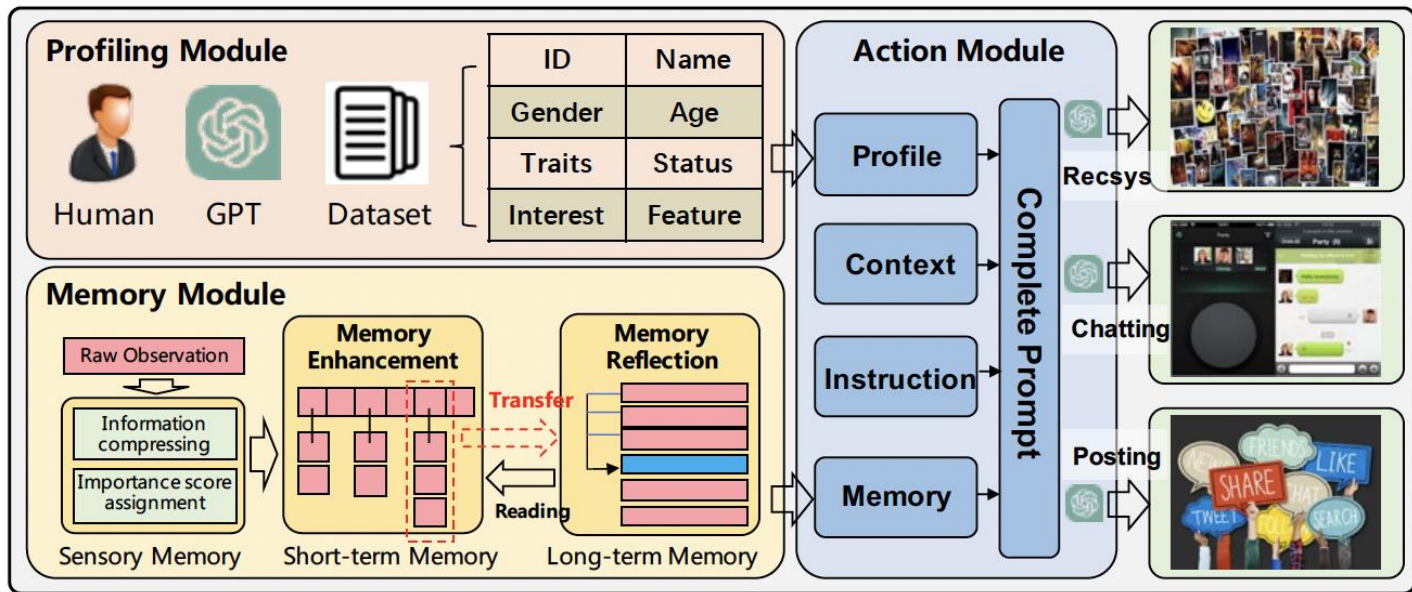
Simulating three online scenarios

- One to one chatting, one-to-many broadcasting and recommendation

Studying social phenomena based on the simulator

- information cocoon and conformity behaviors

Agent = LLM + Profiling Module + Memory Module + Action Module



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Profiling Module

ID	Name	Gender	Age	Traits	Career	Interest	Feature
0	David Smith	male	25	compassionate, caring, ambitious, optimistic	photographer	sci-fi movies, comedy movies	Watcher;Critic;Poster
1	David Miller	female	39	Funloving, creative, practical, energetic, patient	writer	action movies, scifi movies, classic movies	Watcher;Explorer;Poster
2	James Brown	male	70	independent, creative, patient, empathetic	engineer	comedy movies, familyfriendly movies, documentaries, thriller movies	Watcher;Critic;Poster
3	Sarah Miller	female	33	independent, compassionate	farmer	romantic movies, comedy movies, classic movies, family-friendly movies	Watcher;Critic;Poster
4	John Taylor	male	68	optimistic	doctor	action movies, thriller movies	Watcher;Poster
5	Sarah Williams	female	51	meticulous	musician	action movies, documentaries, scifi movies, familyfriendly movies	Watcher;Explorer;Chatter
6	James Jones	male	59	practical, funloving, creative, ambitious, caring	farmer	documentaries	Watcher;Poster
7	Jane Brown	female	30	patient, adventurous, funloving, optimistic	doctor	documentaries	Watcher;Explorer;Poster
8	David Jones	male	23	analytical, energetic, introspective, independent	scientist	familyfriendly movies, thriller movies, action movies, sci-fi movies	Poster
9	James Brown	female	20	ambitious, analytical, optimistic, energetic, meticulous	designer	familyfriendly movies, romantic movies	Critic; Chatter
10	James Garcia	male	20	practical, energetic, introspective, patient	engineer	documentaries, thriller movies, comedy movies, classic movies, romantic movie	Watcher; Explorer; Poster

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Profiling Module



Handcrafting Method

- ✓ More flexible
- ✗ Labor intensive
- ✗ Hard to scale up



GPT-generation Method

- ✗ Less flexible
- ✓ Lower expenses
- ✓ Easy to scale up



Dataset Alignment Method

- ✗ Less flexible
- ✓ Lower expenses
- ✓ More real



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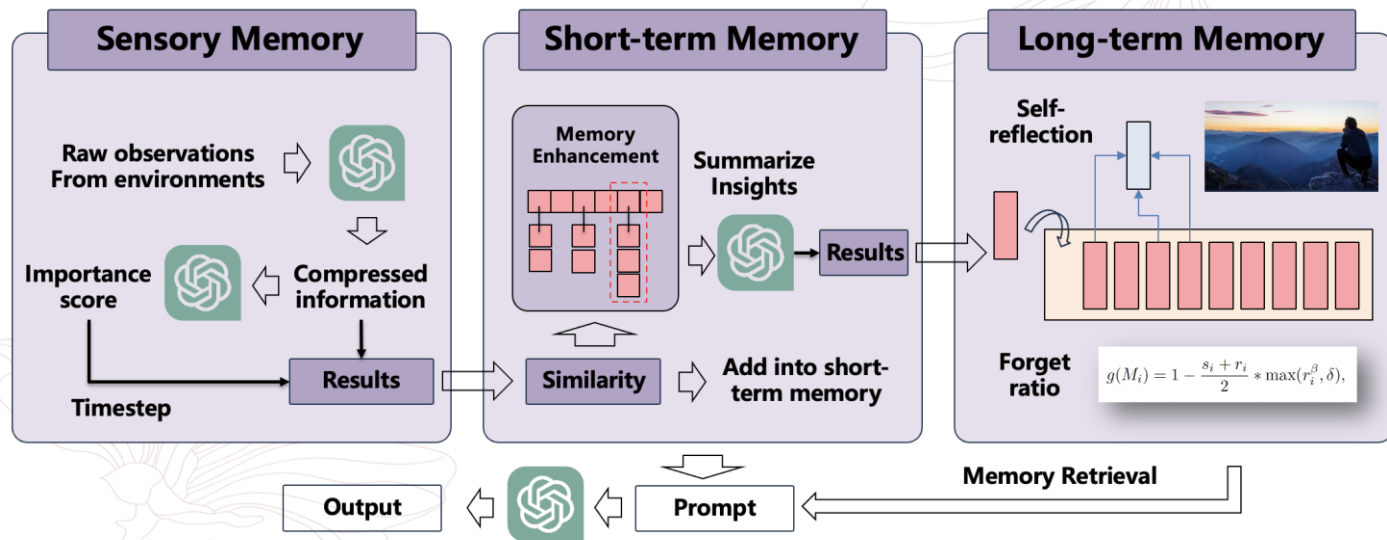


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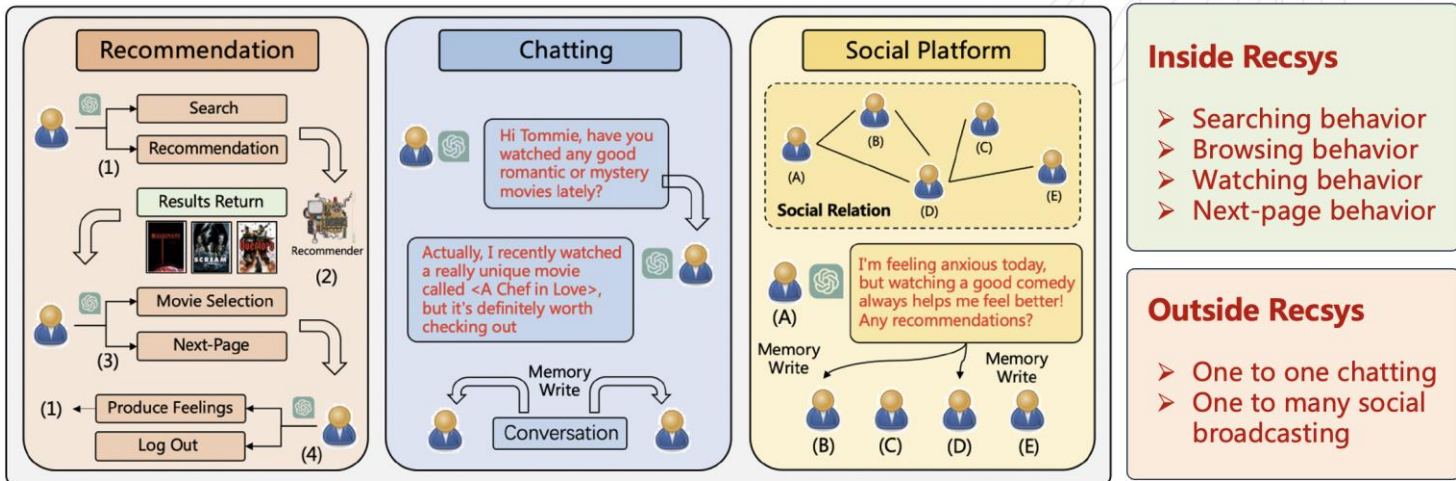
Memory Module



Richard C Atkinson and Richard M Shiffrin. **Human memory: A proposed system and its control processes.** In Psychology of learning and motivation, volume 2, pages 89–195. Elsevier, 1968.

Action Module

Simulate more complete recommendation ecosystem



Behavior Adaptive Prompt Generation

Name: David Smith (age: 25), David Smith, a 25-year-old male photographer, is compassionate, caring, ambitious, and optimistic. He enjoys watching sci-fi and comedy movies and provides feedback and ratings to the recommendation system. He demands high standards for movies and the recommendation system and may criticize both. The observation about David watching "The Neon Bible" aligns with his interest in drama films and explores themes of faith, family, and coming-of-age.

Profile

It is August 18, 2023, 12:00 AM.

Context

Most recent observations: David Smith enjoys and finds captivating films that have captivating plots, humorous elements, thought-provoking themes, delve into complexities of human nature and sexual desire, uplift viewers, and have vibrant and engaging performances by the cast.

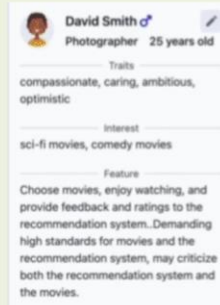
Observation: David Smith has just finished watching Neon Bible, The (1995): "The Neon Bible" is a drama film set in the 1940s in a small southern town in the United States. It follows the story of a young boy named David who is struggling to understand the complexities of the world around him. David's mother is mentally unstable and his father is absent, leaving him to navigate the challenges of adolescence on his own. As he tries to make sense of his surroundings, he turns to religion and finds solace in the teachings of his local preacher. However, his faith is tested when he discovers the secrets and hypocrisies of those around him. The film explores themes of faith, family, and coming-of-age in a poignant and powerful way.

Memory

All occurrences of movie names should be enclosed with <>. David Smith has not seen this movie before. Imagine you are David Smith, how will you feel about this movie just watched? Please share your personal feelings about the movie in one line. Please act as David Smith well.

Instruction

➤ **Simplified profile according to the current behavior**



➤ **Adaptive Memory based on the current behavior**

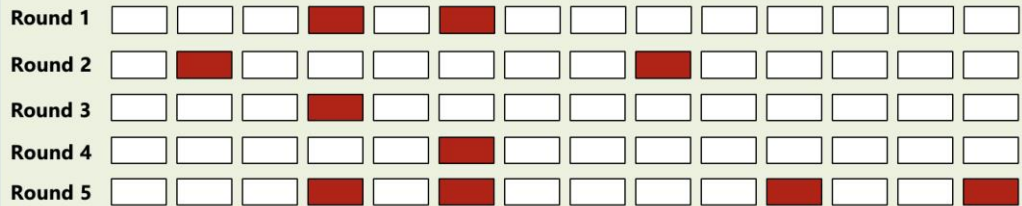
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Execution Protocol



Pareto distribution

$$p(x) = \frac{\alpha x_{min}^{\alpha}}{x^{\alpha+1}},$$



Figure 5: The results of using $p(x)$ to fit real-world datasets. The blue points are the real-world data, and the red lines are the fitted distributions.



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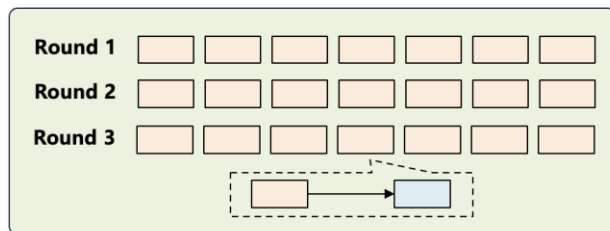


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Intervention



David Smith

Before Intervention

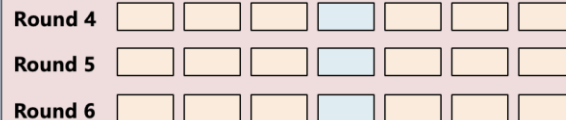
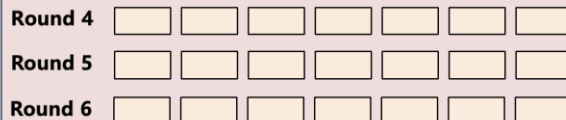
Traits: adventurous, energetic, ambitious, optimistic
Interest: sci-fi movies, thriller movies, suspense movies

After Intervention

Traits: introverted, cautious, quick-tempered
Interest: family-friendly movies, romantic movies, comedy movies

[David Smith]: I haven't come across any classics lately, but I did watch this amazing sci-fi thriller called <Inception>. It's mind-blowing! You should definitely check it out. ...

[David Smith]: I'll definitely keep an ear out for any exciting sci-fi movies and let you know. We both know how much we love that genre!



Original Branch

[David Smith]: That's great! I'm more into sci-fi, thriller, and suspense movies. They always keep me on the edge of my seat. Have you watched any good movies lately?

[David Smith]: Wow, that's quite a list! I'm glad you enjoyed them. Based on your interest in "The Matrix" and "Inception," I would recommend "Blade Runner" for its mind-bending concept and suspenseful elements.

Intervention Branch

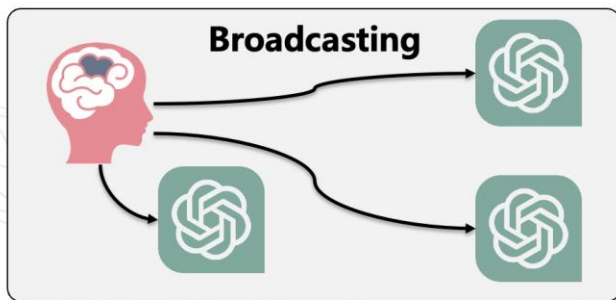
[David Smith]: I love movies that really make you think. I'm definitely going to check them out. By the way, have you come across any good family-friendly or romantic movies? I'm in the mood for something heartwarming.

[David Miller]: Absolutely! If you're looking for a heartwarming movie, I recently watched <Miracle on 34th Street> on the recommender system, and it was delightful.

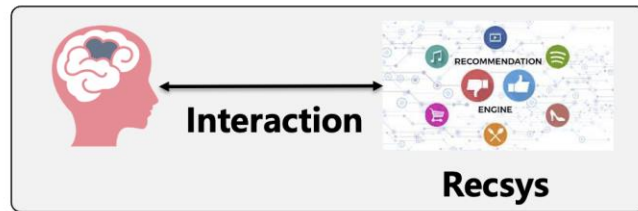
Human-Agent Collaborative Simulation



Human-agent Conversation



Human-agent social broadcasting



Human-system Interaction



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The interface displays a central map with several user avatars (red and yellow pins) indicating their locations. On the left, a user profile for David Smith (Photographer, 25 years old) is shown with traits (compassionate, caring, ambitious, optimistic), interests (sci-fi movies, comedy movies), and a feature (Choose movies, enjoy watching, and provide feedback and ratings to the recommendation). Below the profile is a chat window where David Smith says: "Hey, thanks for the movie recommendations! I'll definitely add <Casablanca> and <Gone with the Wind> to my watchlist."

On the right, the State Information panel shows:

Total Users	Total Movies	Algorithm
10	3883	Random
Interactions	Current Users	
1	1	
Most Popular Movie		
#1	Toy Story	
#2	Jumanji	
#3	Grumpier Old Men	

Below the state information is a Log Messages panel showing a message: "is a crime thriller movie released in 1991.", '<What About Bob?>;<What About Bob?> is a comedy film about a man named Bob Wiley (played by Bill Murray) who has multiple phobias and anxiety disorders.', '<Phantasm III: Lord of the Dead>;<Phantasm III: Lord of the Dead> is a horror movie that follows the story of Mike, who is on a mission to stop the Tall Man, a supernatural entity who is responsible for the death of his family.']."

Experiment Setting

Goal: whether the agent memory can produce reasonable results

- Let the agents and humans finish **the same** memory-related tasks
- Recruit another group of humans **to judge which one is more reasonable**

Results

Table 1: The results of evaluating sensory memory (T1), short-term memory (T2), and long-term memory (T3). A and B indicate the results generated by the agent and real human, respectively. “>>”, “>”, and “≈” mean significantly better, slight better and comparable, respectively.

	$A \gg B$	$A > B$	$A \approx B$	$B > A$	$B \gg A$
T1	0.6833	0.2500	0.0333	0.0333	0.0000
T2	0.3000	0.3000	0.1000	0.2500	0.0500
T3	0.2500	0.1167	0.2000	0.2500	0.1667



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Experiment Setting

Goal: whether the extracted memory are informative and relevant

- Randomly sample 15 agent behaviors
- Recruit three human annotators to evaluate the extracted information
- Consider both informativeness and relevance

Results

Table 2: The results of evaluating the memory module. We use bold fonts to label the best results.

Model	Informativeness	Relevance
Memory module (w/o short)	4.09	4.02
Memory module (w/o long)	4.55	3.75
Memory module (w/o reflection)	4.40	3.63
Memory module	4.42	4.09



Experiment Setting

Goal: whether the agents can separate real items from irrelevant ones

- 20 Users from Movielens-1M
- Combine the **a** ground truths with **b** negative items
- Comparing the selection accuracy

Results

Table 3: The results of evaluating different models based on different (a, b) 's.

Model	$(a, b) = (1, 5)$	$(a, b) = (3, 3)$	$(a, b) = (3, 6)$	$(a, b) = (1, 9)$
Embedding	0.2500	0.5500	0.4500	0.3000
RecSim	0.2500	0.5333	0.3667	0.1000
RecAgent	0.5500	0.7833	0.6833	0.5000
Real Human	0.6000	0.8056	0.7222	0.5833

Experiment Setting

Goal: whether the agents can generate reliable user behavior sequences

Results

Table 4: The results of evaluating the reliability of the generated user behavior sequences (N=5).

A v.s. B	$A \gg B$	$A > B$	$A \approx B$	$B > A$	$B \gg A$
RecAgent v.s. RecSim	0.1500	0.3167	0.1833	0.2667	0.0833
RecAgent v.s. GT	0.1333	0.2833	0.1667	0.2667	0.1500
RecSim v.s. GT	0.1167	0.2667	0.2667	0.2167	0.1333

Table 5: The results of evaluating the reliability of the generated user behavior sequences (N=10).

A v.s. B	$A \gg B$	$A > B$	$A \approx B$	$B > A$	$B \gg A$
RecAgent v.s. RecSim	0.1833	0.4333	0.0667	0.2000	0.1167
RecAgent v.s. GT	0.2000	0.4333	0.0000	0.2000	0.1667
RecSim v.s. GT	0.1333	0.3500	0.1500	0.3000	0.0667



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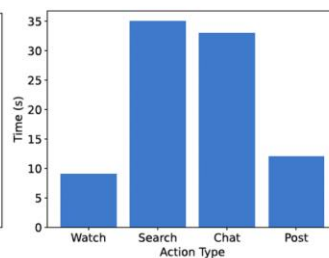
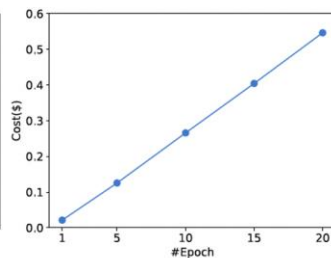
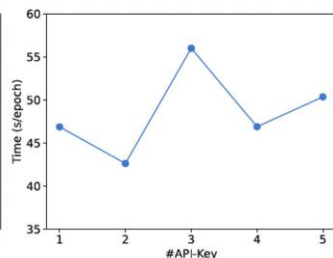
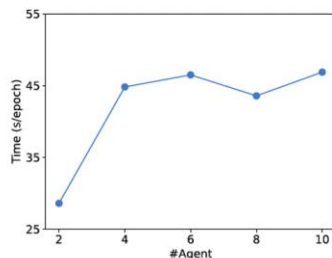


S3

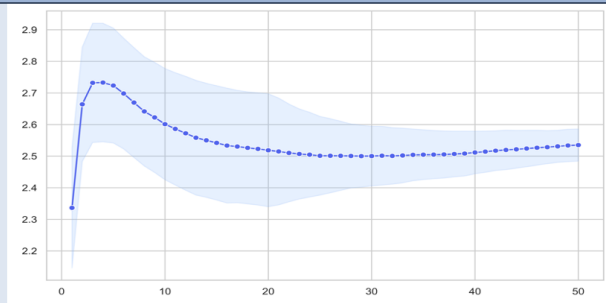


Conclusion

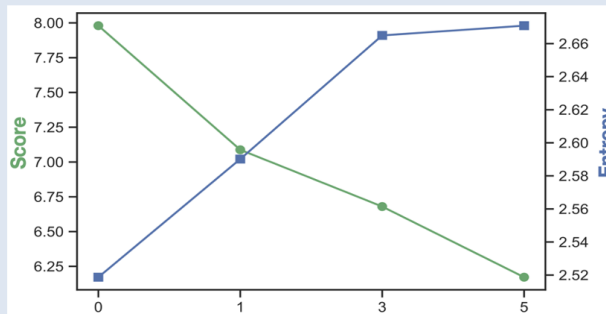
- How does the time cost increase as the number of agents become larger in each epoch?
- How does the time cost increase as the number of API keys become larger in each epoch?
- How does the time cost increase as the number epochs become larger?
- What are the time costs of different agent behaviors?



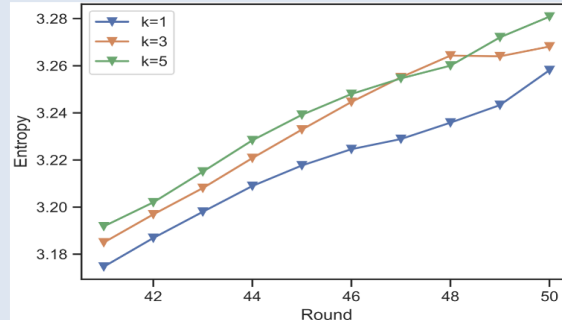
Information Cocoon Room



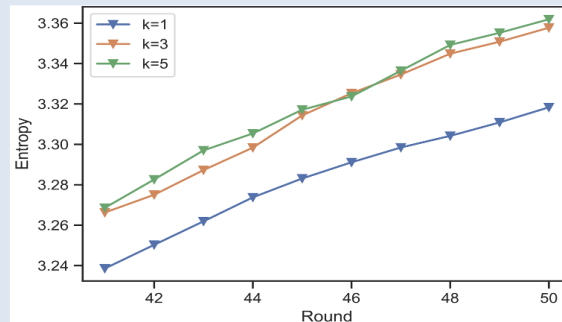
User Entropy



Rec Quality vs Entropy



Random Recommendation



Heterogeneous friends



Background



RecAgent

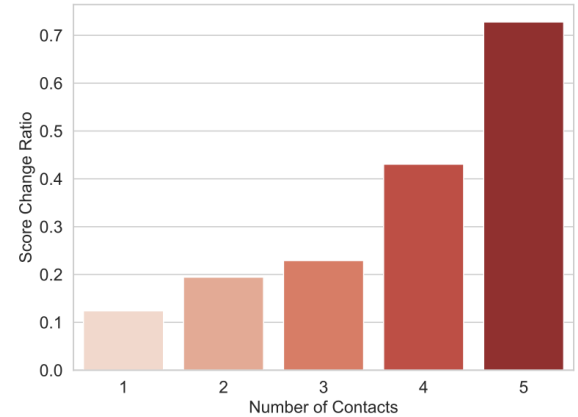
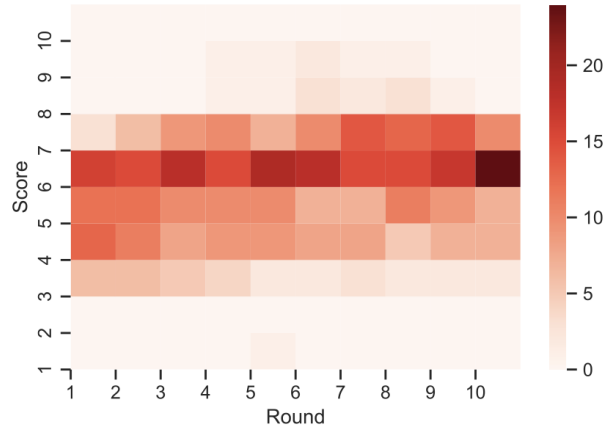


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Conclusion

➤ User Conformity Behaviors





Background



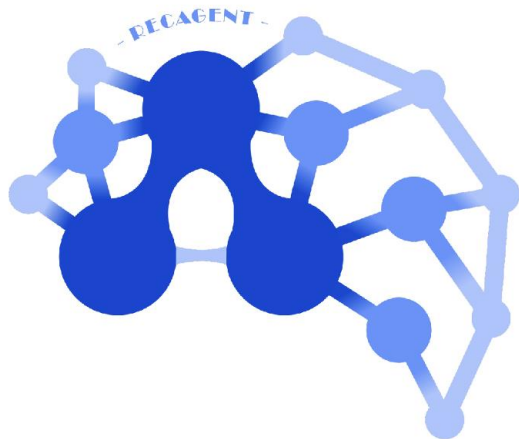
RecAgent



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Conclusion



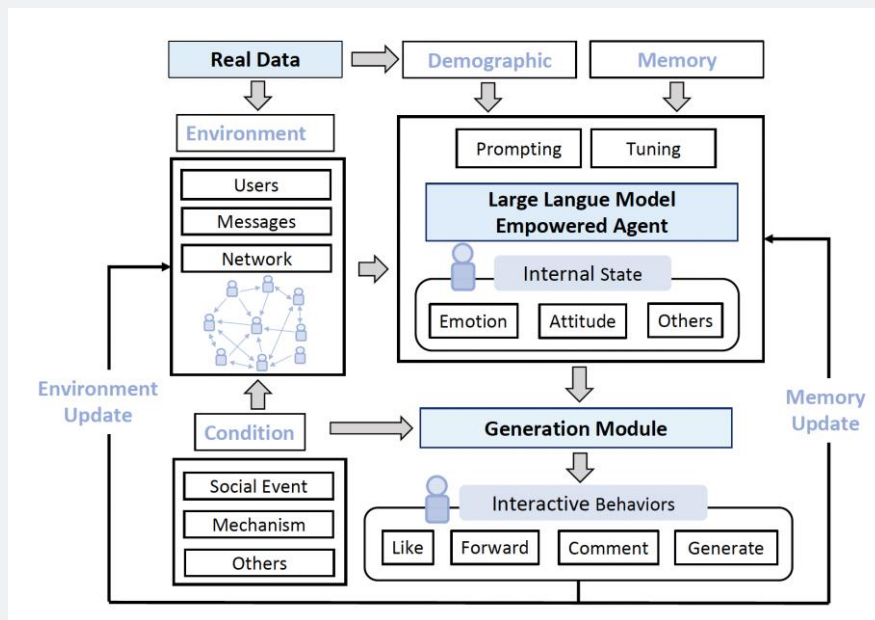
RECAGENT

Project Page: <https://github.com/RUC-GSAI/YuLan-Rec>

Paper Link: <https://arxiv.org/pdf/2306.02552.pdf>

Chinese Introduction: <https://mp.weixin.qq.com/s/bfES1ieY5pTtmVfdEgX6WQ>

S3: Social-network Simulation System with Large Language Model-Empowered Agents



- **Gender discrimination**
- **Nuclear energy**

Individual-level Simulation

Emotion Simulation

- *calm, moderate, and intense*

Attitude Simulation

- *negative and positive stances towards an event*

Content-generation Behavior Simulation

- *generate contents*

Interactive Behavior Simulation

- *forwarding, posting new content or do nothing*



Background



RecAgent



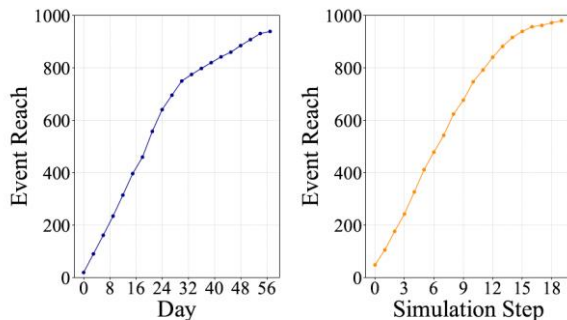
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Conclusion

Population-level Simulation

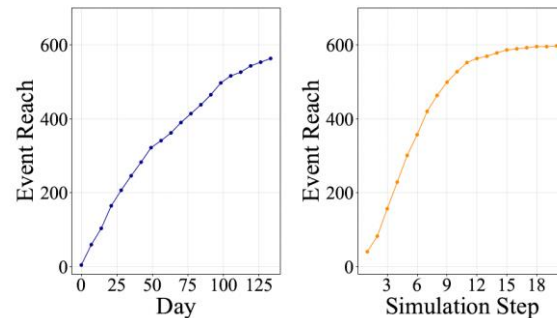
Information Propagation



(a) True spread

(b) Simulated spread

Eight-child Mother Event



(a) True spread

(b) Simulated spread

Japan Nuclear Wastewater Release Event

The overall number of people who have known the events at each time step



Background



RecAgent



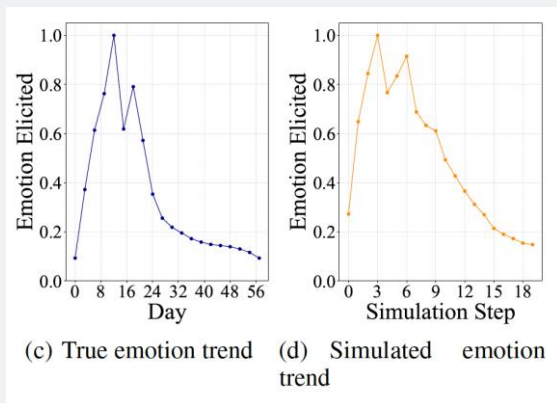
S3



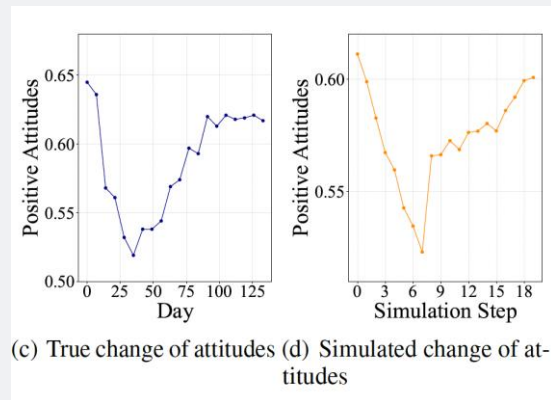
Conclusion

Population-level Simulation

Emotion Propagation



Eight-child Mother Event



Japan Nuclear Wastewater Release Event

Extract the emotional density from the textual interactions among agents

Challenges

└ Generalized Human Alignment

Agent based Simulation



Background



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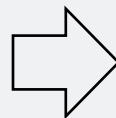


Conclusion

Challenges

└ Knowledge Boundary

Agent based Simulation



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Challenges

└─ Hallucination



The model erroneously outputs false information confidently



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Conclusion

Challenges

└ Efficiency

	#Agent: 100	#Agent: 200
#API key: 10	135.2258811 s	391.95364 s
#API key: 10	395.647825 s	517.9082 s
#API key: 10	333.9154 s	425.1331 s
Avg	288.2630354 s	444.9983133 s

Lei Wang, Jingsen Zhang, Xu Chen, Yankai Lin, Ruihua Song, Wayne Xin Zhao, Ji-Rong Wen:
RecAgent: A Novel Simulation Paradigm for Recommender Systems. [CoRR abs/2306.02552](#) (2023)



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Thanks & QA
