

A MULTI-AGENT SOCIAL SIMULATION FRAMEWORK BASED ON LARGE LANGUAGE MODELS: A CASE STUDY OF PUBLIC OPINION EVOLUTION ON THE FUKUSHIMA NUCLEAR WASTEWATER DISCHARGE

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ABSTRACT

Simulating public opinion evolution is a core focus of computational social science. Traditional agent-based models rely on predefined heuristic rules, failing to capture the semantic features and cognitive processes of human natural language interactions. While large language models offer new approaches for artificial society construction, existing frameworks have limitations in scalability and memory management. Taking the Fukushima nuclear wastewater discharge event as the background, this study uses an open-source multi-agent social simulation framework, designing four progressive intervention scenarios to analyze agents' cognitive synergy and public opinion trajectories. Results show the framework mitigates role drift and premature consensus, reproduces the public opinion evolution trajectory, providing empirical insights for policy testing and LLM-driven social computing.

KEYWORDS

Multi-agent simulation, Public opinion evolution, Nuclear wastewater discharge, Computational social science

1. INTRODUCTION

In the highly interconnected digital era, sudden public events easily trigger cross-regional collective public opinion. Understanding and predicting the evolutionary paths of collective cognition and emotion holds significant importance for public policy making and crisis management. Traditional research frequently aggregates micro-states to simulate macro-social phenomena, such as employing the susceptible-infected-recovered model to track information diffusion [1] or utilizing evolutionary game theory to analyze the strategic choices of

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stakeholders. These mathematical and statistical models demonstrate applicability in characterizing the topological structure of information dissemination [2,3], yet they exhibit limitations in reflecting the semantic features of human interactions. Opinion formation is not merely a state transition but is also influenced by individual characteristics, experiences, emotions, and natural language understanding processes. Classic models like the DeGroot model and bounded confidence models explore the convergence, polarization, and fragmentation of opinions within network topologies through mathematical iteration [4].

Large language models provide a new perspective on these issues. Serving as the cognitive core of agents, large language models instantiate generative agents equipped with specific personalities, memories, and reflection capabilities [5]. Such agents autonomously plan within sandbox environments and engage in multi-turn natural language interactions regarding social issues, which subsequently leads to the emergence of group-level norms and polarization based on individual interactions. However, integrating large language models into social simulation faces technical challenges. As simulation rounds increase, the expansion of the agent memory bank causes a decline in retrieval efficiency and hallucination issues. Furthermore, existing simulation frameworks mostly adopt tightly coupled designs, making them difficult to adapt to scenario transitions from online social networks to offline physical spaces.

To address the aforementioned issues, this study employs an object-oriented, modular multi-agent social simulation framework to simulate the evolution of public opinion concerning the Fukushima nuclear wastewater discharge event. This framework possesses strong architectural scalability and introduces a memory summarization mechanism to enhance the cognitive coherence of the agents. Through dialogue text analysis, this report examines the dynamic evolution patterns of internal cognition and external expression in generative agents when they face conditions including single events, intertwined multiple events, policy implementations, and real-time internet information interventions. This research aims to provide a reference for multi-agent simulation applications within the context of environmental issues.

2. RELATED WORK

2.1. Complex Social Simulation and Deficiency of Traditional Model

Complex social simulation aims to reproduce the internal dynamics of human social, economic, and ecological systems through computational methods. Early research predominantly relies on agent-based modeling and simulation, reproducing macroscopic phenomena such as urban segregation, market transaction fluctuations, and disease propagation by assigning behavioral rules and interaction protocols to computational nodes [6]. In the context of public opinion dynamics, existing classic models mostly characterize the evolutionary patterns of collective opinions through mathematical iterations.

However, traditional agent-based modeling and simulation makes simplified assumptions about human behavior. Lacking natural language understanding capabilities, these models struggle to process complex real-world debates that contain metaphors and logical leaps. Simultaneously, traditional models often assume individual preferences to be static or to follow fixed transition probabilities, making it difficult to adequately reflect the nonlinear cognitive reconstruction processes of humans during sudden crises.

2.2. Multi-Agent Simulation Frameworks Based on Large Language Models

To compensate for the semantic understanding deficiencies of traditional models, researchers introduce large language models into multi-agent systems. Park et al. propose a generative agent architecture that enables agents to exhibit human-like behavior in simulated sandboxes through three core modules including memory streams, reflection, and planning [5]. Subsequently, this method gradually expands to large-scale social simulations. For instance, the AgentSociety framework utilizes an asynchronous simulation engine and distributed computing to support the concurrent interaction of large-scale agents, successfully reproducing macroscopic social phenomena such as the impact of universal basic income policies.

In terms of model evaluation, benchmark datasets like RoleAgentBench are utilized to quantitatively assess the self-awareness accuracy, response consistency, and memory system efficacy of large language models in role-playing scenarios [7]. Research indicates that by extracting personality traits, large language models can simulate the values of specific demographic groups [8]. Regarding public opinion evolution, existing frameworks attempt to explore the co-evolutionary mechanisms of topics and stance dynamics, allowing agents to autonomously generate discussion subtopics and adjust their own stances based on peer feedback. In recent years, numerous studies systematically review the research progress and development prospects of agent-based modeling and simulation empowered by large language models [9], and related research also validates the feasibility of using large language models as simulated economic agents to reproduce human subject studies [10,11].

2.3. Social Impacts of the Fukushima Nuclear Wastewater Discharge Event

In August 2023, Japan initiated the plan to discharge nuclear wastewater from the Fukushima Daiichi Nuclear Power Plant into the ocean. This event not only involves the ecological environment but also triggers transnational public opinion attention. Textual analysis reveals differences in risk discourse construction among media outlets in different countries, with some emphasizing ecological risks and government responsibilities, while others lean towards technocratic discourse emphasizing the scientific assessments of the International Atomic Energy Agency. The evolution of public opinion and the propagation patterns of disinformation in sudden public health and environmental events have become research hotspots in related fields [12,13,14].

Relevant studies utilize evolutionary game theory models to analyze strategic interactions among multiple countries and fishery entities, pointing out that international cooperation and scientific monitoring are key intervention methods to address this event. On social media, public sentiment experiences an evolution from initial anxiety to subsequent opinion divergence including technology skepticism and environmental activism. Information propagation on social media is often accompanied by echo chamber effects and group opinion polarization phenomena [15,16]. Events of this nature possessing scientific uncertainty and broad social impact provide suitable testing scenarios for evaluating the capability of multi-agent simulation systems to handle complex cognitive conflicts.

3. EXPERIMENTAL DESIGN

This study is based on the open-source Generalized Multi-agent Social Simulation Framework developed by the DAI Laboratory at Zhejiang University (<https://github.com/LiGang1999/LLM-SocialSimulation-DAI>). The platform adopts an object-oriented design, optimizing the cognitive coherence of agents and system scalability in complex scenarios through a memory summarization mechanism. As shown in figure 1, the architecture employs a hierarchical membership model where an overarching Social Simulation module manages Tools and a customizable World, which in turn encapsulates Organizations, Resources (Stuff), and autonomous Personas operating via behavior-composed Workflows and specialized Memory components.

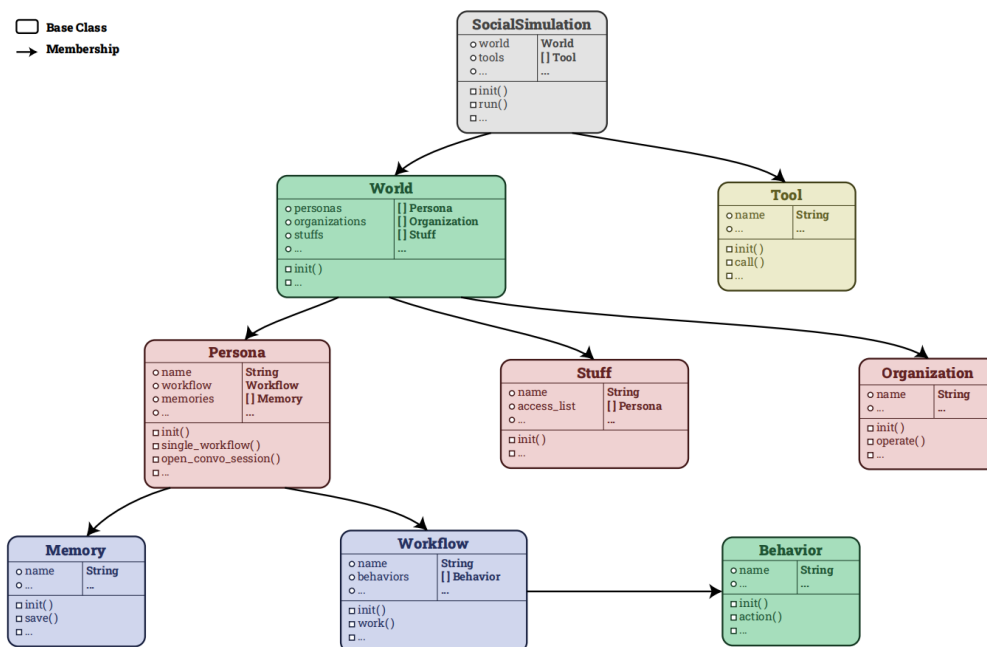


Figure 1. The diagram of the proposed framework

Based on this framework, the research designs a virtual online social media discussion experiment themed on nuclear wastewater discharge. The experiment selects three generative agents with different background settings to observe the interaction process of individual differences during crisis event discussions.

3.1. Agent Profile Design

Differences in individual prior knowledge and interest demands constitute the foundation of public opinion diversity. The three core participants set in the experiment are detailed as follows.

Table 1 Identity Settings of Experiment Participants

Agent Name	Age and Occupation	Core Personality Traits and Focuses	Current Environmental Background Setting
Isabella Rodriguez	34 years old, Hobbs cafe owner	Warm, hospitable, and highly affable. Focuses heavily on community well-being and interpersonal relationships, tending to understand macro events from the perspective of daily business and micro life experiences.	Actively preparing for a Valentine Day party at the cafe tomorrow night, hoping to create a relaxing community space for customers.
Maria Lopez	21 years old, physics student and Twitch game streamer	Energetic and full of curiosity. Possesses solid scientific thinking, tending to explore the technical details and physical mechanisms of events while having a massive online audience.	Attempting to strike a balance between heavy physics coursework and making money through game streaming.
Klaus Mueller	20 years old, sociology student	Kind and passionate. Holds a profound obsession with social equity and justice, excelling in macro structural critique and intersectional analysis.	Writing an academic paper on the negative impacts of gentrification in lower-class communities.

The configuration of the three aforementioned perspectives encompassing microeconomics, technical rationality, and macro social structures aims to prompt differentiated cognitive interactions in dialogues and avoid singular homogeneous discussions. Considering the dual requirements for inference efficiency and generation quality in large-scale multi-agent simulations, this study employs gpt-3.5-turbo as the foundational model to drive agent interactions.

3.2. Progressive Intervention Scenario Design

The simulation process comprises four progressive environmental conditions. Under each condition, the three agents conduct three consecutive rounds of interaction. The input settings are described below.

The first scenario involves basic public discussions on a single event, introducing original news regarding nuclear wastewater into the environment. The prompt setting is: "Recently, the Fukushima Daiichi Nuclear Power Plant in Japan initiated the discharge of contaminated water into the sea. Through a 1-kilometer underwater tunnel, nuclear contaminated water flows towards the Pacific Ocean. In the following decades, nuclear contaminated water will continue to be discharged into the ocean, affecting the entire Pacific and even global waters."

The second scenario focuses on parallel events caused by breaking news related to ecological significance within the context of the ocean discharge. The prompt setting is: "Marine biologists at the Oceanic Institute of Marine Sciences made a groundbreaking discovery this week, uncovering a previously unknown species of bioluminescent jellyfish in the depths of the Pacific Ocean. The newly identified species, named *Aurelia noctiluca*, emits a mesmerizing blue-green glow, illuminating the dark ocean depths where it resides."

The third scenario examines the structural evolution of public opinion under policy intervention, where a committee releases relevant protection and regulatory policies. The prompt setting is: "The Committee has issued the following policy measures: 1. Implement stricter regulations on nuclear power plants to prevent the discharge of contaminated water into the ocean. 2. Develop monitoring and mitigation policies to assess the impact of the contamination on marine life and ecosystems. 3. Establish cleanup and remediation policies to address the long-term consequences. 4. Collaborate with international organizations and neighboring countries to address the global impact. Additionally, implement strict regulations on fishing practices in the area where *Aurelia noctiluca* was discovered, establish marine protected areas, and collaborate with local communities."

The fourth scenario entails in-depth technical discussions guided by internet information, opening search engine permissions to enable agents to acquire external data. The prompt setting is: "Japan has implemented measures like the Advanced Liquid Processing System (ALPS) to treat the contaminated water before its release into the ocean. However, Japan has failed to prove that the discharge is harmless and plans to discharge nuclear contaminated water for 30 years. Furthermore, scientists discovered luminescence in deep-sea shrimp, highlighting how much more there is to learn about ocean ecosystems and gene expression."

The aforementioned first and second scenarios serve as a basic perception baseline. By comparing single and multiple information sources, the research examines the attention allocation mechanisms of agents under information conflict. The third scenario introduces macro policy constraints to evaluate the impact of institutional interventions on the discussion frameworks of

micro individuals, validating the applicability of the system in policy prototype testing. The fourth scenario opens external tool interfaces to break the limitations of static weights within the model. This progressive design reflects the evolutionary stages of real-world public crises from outbreak and fermentation to policy intervention and technical discussion.

4. EXPERIMENTAL RESULTS AND ANALYSIS OF PUBLIC OPINION EVOLUTION

Through qualitative analysis of multi-turn interactive texts generated by large language models, this study tracks the transformation of cognitive dimensions within the agent group across different scenarios.

4.1. Scenario One: Cognitive Discussion Under the Basic Single Event

Facing the news of nuclear wastewater discharge, the initial statements of the agents exhibit strong correlations with their predefined profiles. The reaction of Isabella is predominantly concerned, linking macroscopic ecological threats to microscopic daily life and considering discussing this matter with customers at her party. Maria approaches the issue from a technical perspective, raising feasibility questions regarding advanced filtration systems. Klaus directs the topic towards the social structure level, focusing on the economic stability of vulnerable communities dependent on marine resources.

During the second and third rounds of discussion, various topic threads begin to intersect. Integrating the viewpoints of Klaus, Maria explores the economic feasibility of large-scale filtration systems. Klaus further combines the ecological crisis with the gentrification issue to analyze the intersectional impact of environmental problems and social classes. The cognitive scope of Isabella expands from personal business to seeking organizational initiatives to support vulnerable communities. This stage reflects the transition process of public opinion from initial emotional reactions to structural analysis.

Table 2 Discussion Under the Basic Single Event

Round	Key Comments
Round 1	<p>Isabella Rodriguez: I'm really concerned about this news... the long-term effects this could have on our planet... I should probably check if any of my customers are planning to come in tomorrow for Valentine's Day and discuss this news further with them.</p> <p>Maria Lopez: I completely agree with Isabella's concerns... As a physics student... I wonder if there are any alternative solutions being explored to mitigate the damage? Have they considered using advanced filtration systems...</p> <p>Klaus Mueller: I share Isabella's concerns... As someone studying sociology, I'm also worried about the impact on vulnerable communities that rely heavily on</p>

	marine resources... How will this affect their economic stability and access to clean food?
Round 2	<p>Isabella Rodriguez: I completely agree with Maria's suggestion... Klaus also raises a very valid point about the impact on vulnerable communities...</p> <p>Maria Lopez: I'm glad Isabella agrees with my suggestion... has anyone considered the potential economic impacts on these communities and how they can be mitigated?</p> <p>Klaus Mueller: I appreciate Isabella's emphasis on supporting vulnerable communities... What measures are being taken to ensure that the voices of these communities are heard in the decision-making process?</p>
Round 3	<p>Isabella Rodriguez:... I appreciate Klaus' point about considering the intersectionality... are there any organizations or initiatives that we can support to help amplify the voices of vulnerable communities affected by this disaster?</p> <p>Maria Lopez:... I'd like to know more about the 1-kilometer underwater tunnel... has there been any update on exploring alternative solutions like advanced filtration systems that we discussed earlier?</p> <p>Klaus Mueller: I appreciate how our discussion has highlighted the need for intersectional consideration in addressing environmental disasters... I'm now wondering if there are any existing frameworks or policies... and whether they're being effectively implemented?</p>

4.2. Scenario Two: Information Processing Under Parallel News Events

When the news regarding the discovery of the bioluminescent jellyfish is introduced, agents need to reconstruct information between environmental threats and new ecological discoveries.

The news of the bioluminescent jellyfish attracts the attention of Isabella, who proposes using luminescent decorations at the party while simultaneously expressing concerns about nuclear pollution. Maria proposes a hypothesis exploring whether the new species serves as a potential indicator of marine adaptability to pollution, suggesting the organization of an ocean-themed live broadcasting event. Klaus conducts an ethical examination of the biological adaptability hypothesis, pointing out that marine resilience cannot justify ignoring environmental protection responsibilities. In the third round of discussion, the three individuals plan to establish a science popularization and fundraising station in the cafe, achieving the integration of environmental education and action initiatives.

Table 3 Multiple Event Discussion After News Introduction

Round	Key Comments
Round 1	<p>Isabella Rodriguez:... We just heard about that amazing new species of bioluminescent jellyfish discovered in the Pacific Ocean... Wow, I'm so amazed by this discovery!... On a lighter note, I wish we could have some bioluminescent decorations for our Valentine's Day party...</p> <p>Maria Lopez: I completely understand Isabella's concerns... As a physics student... it's heartbreaking... But at the same time, I'm also amazed by the discovery of that new bioluminescent jellyfish... Do you think there's any connection between the nuclear contamination and the discovery of this new species?... maybe we could organize a gaming stream with an ocean-themed twist tomorrow?</p> <p>Klaus Mueller: I'm deeply troubled... It makes me wonder if there are any potential connections between the nuclear contamination and the emergence of this new species. As someone studying sociology, I'm also curious about how this might affect the livelihoods of people who depend on the ocean...</p>
Round 2	<p>Isabella Rodriguez:... Klaus Mueller's question about a possible connection... could this new species be an indicator of how our oceans are adapting to pollution?... Maybe we can even have a small fundraiser for ocean conservation efforts?</p> <p>Maria Lopez: I've been thinking about Klaus's comment... I'm intrigued by the possibility that this new species could be an indicator of ocean adaptation to pollution... I should start planning the stream's content - maybe we can include some games that highlight the impact of pollution on marine life?</p> <p>Klaus Mueller:... I'm also concerned about the potential impact on communities that depend on the ocean for their livelihoods... could this be a sign of the ocean's resilience, or is it a warning sign? I'd love to explore this topic further in my research paper on gentrification...</p>
Round 3	<p>Isabella Rodriguez:... Maybe we can even have a special 'glow-in-the-dark' station with information about bioluminescent creatures like <i>Aurelia noctiluca</i>, and discuss ways our customers can make a positive impact on ocean conservation.</p> <p>Maria Lopez: I've been thinking about Klaus Mueller's comment... I'm wondering if there's also a connection between the Fukushima Daiichi Nuclear Power Plant's contaminated water discharge and the livelihoods of people... Maybe we could have a segment in the stream or at the party to discuss this topic and raise funds...</p> <p>Klaus Mueller:... I think it's crucial we explore the potential consequences of Fukushima's contaminated water discharge on coastal communities... I also wonder if its adaptation to pollution could be a double-edged sword... I think we should also consider inviting experts to discuss Fukushima's impact on marine life...</p>

4.3. Scenario Three: Changes in Discussion Under Policy Intervention

After the committee releases policies concerning regulation, protected areas, scientific research, and community cooperation, the discourse focus of the agents shifts towards policy review and implementation effectiveness.

The three agents express agreement with the official protection measures but swiftly direct the discussion towards execution effectiveness. Maria emphasizes the scientific necessity of continuous monitoring measures. Klaus points out that marginalized communities are more vulnerable during environmental events, continuously inquiring about how to ensure policy implementation and the substantive participation of local communities in the decision-making process.

The introduction of policies also prompts the agents to explore specific methods of social participation. Isabella plans to transform her cafe activities into fundraising campaigns with clear appeals. Maria proposes utilizing live streaming platforms to expand the dissemination reach of offline gatherings. This stage reflects the catalytic effect of policy issuance on public discussion frameworks and action organization.

Table 4 Multiple Event Discussion After Public Policy Introduction

Round	Key Comments
Round 1	<p>Isabella Rodriguez:... I want to make sure we're doing everything we can to protect our environment. I'm thinking of hosting an event at Hobbs Cafe to raise awareness about this issue... I hope the authorities will take immediate action to implement strict regulations and establish marine protected areas...</p> <p>Maria Lopez:... I love Isabella's idea of hosting an event at Hobbs Cafe on Valentine's Day to raise awareness... We need stricter regulations and monitoring policies in place ASAP.</p> <p>Klaus Mueller:... I strongly support Isabella's idea to host an event at Hobbs Cafe... Maria's suggestion for stricter regulations is also crucial... How can we ensure that these policies are implemented effectively, especially when it comes to monitoring and mitigating the impact on vulnerable communities?</p>

Round 2	<p>Isabella Rodriguez:... I agree with Klaus that effective implementation and protection of vulnerable communities are crucial... Tomorrow's party will be a great opportunity to educate our customers about this pressing matter and gather support for stricter regulations.</p> <p>Maria Lopez:... Klaus brought up a great point about effective implementation and protection of vulnerable communities - how do we ensure that these regulations are enforced... As someone who streams games on Twitch... Perhaps we could use social media platforms to spread awareness...</p> <p>Klaus Mueller:... I appreciate Maria's perspective... highlighting the importance of effective implementation and protection for vulnerable communities. As someone researching gentrification... I think it's crucial we consider the long-term consequences of this discharge and push for stricter regulations...</p>
Round 3	<p>Isabella Rodriguez:... I'm glad we're raising awareness through tomorrow's event, and I hope it sparks a larger conversation about implementing stricter regulations and cleanup policies... Has anyone thought about organizing a fundraising campaign to support research and conservation efforts...</p> <p>Maria Lopez:... I've been thinking a lot about how my own community on Twitch could help raise awareness... Isabella, your idea to host an event at Hobbs Cafe is amazing - maybe we could even live stream it on Twitch to reach an even wider audience?</p> <p>Klaus Mueller:... it highlights the need for effective implementation and protection of vulnerable ecosystems, as well as stricter regulations... I want to reiterate that we must consider the broader social justice implications of Fukushima's contaminated water discharge on vulnerable communities.</p>

4.4. Scenario Four: Information Interaction Empowered by Search Engines

After the introduction of external search engine tools, agents acquire real internet data, which subsequently increases the objectivity and professional details of the discussions.

Through retrieval, Maria obtains specific information about the Advanced Liquid Processing System in Japan and points out that the scientific community maintains reservations regarding its efficacy in completely removing harmful nuclides. Klaus retrieves information indicating the thirty-year time span of the discharge plan and subsequently reiterates the necessity of establishing an independent international monitoring network, arguing that unilateral information release remains insufficient to support food safety commitments. Upon receiving the professional data, Isabella reassesses the safety of the food supply chain for her party. The introduction of tool interfaces aligns the discussions within the virtual society more closely with the logic of real-world technical debates.

Table 5 Discussion After Search Engine Introduction

Round	Key Comments
Round 1	<p>Isabella Rodriguez: I'm so worried about the impact of the contaminated water... I hope that stricter regulations can be put in place... This discovery is a great reminder of the importance of protecting our marine life and their habitats...</p> <p>Maria Lopez: I'm really concerned about the impact of Fukushima... I wonder if there are any ways we can use technology to mitigate the effects of this contamination?... I wonder if the Institute of Marine Sciences will take a leading role in researching the effects of nuclear contamination...</p> <p>Klaus Mueller:... As I've been researching gentrification... I've come to realize how environmental degradation disproportionately affects vulnerable populations... It's crucial that we prioritize conservation efforts and establish protected areas...</p>
Round 2	<p>Isabella Rodriguez:... Klaus Mueller mentioned community-led initiatives, but I wonder if there are any local efforts we can support... And Maria Lopez brought up using technology - do you think that could be a viable solution?</p> <p>Maria Lopez:... As a physics student, I've been thinking more about how technology can help mitigate this issue... I'm curious to know more about the ALPS treated water discharge and how it's being monitored... We should be pushing for stricter regulations on fishing practices and establishing more marine protected areas...</p> <p>Klaus Mueller:... I'm starting to see parallels between the displacement of vulnerable populations in urban areas and the potential displacement of marine life due to nuclear contamination... What role can community-led initiatives play in addressing these interconnected issues?</p>
Round 3	<p>Isabella Rodriguez:... As I prepare for Hobbs Cafe's Valentine's Day party tomorrow, I'm thinking of ways to incorporate sustainability and environmental awareness into our celebration. Perhaps we can have a special 'Glowing Hearts' drink... with a portion of the proceeds going towards ocean conservation efforts.</p> <p>Maria Lopez:... it's crucial that we not only establish marine protected areas but also implement stricter regulations on waste management and nuclear safety protocols to prevent further harm to our oceans.</p> <p>Klaus Mueller:... As I continue researching gentrification, I see parallels between the displacement of human communities and the disruption of ocean ecosystems. I wonder if community-led initiatives can address both issues simultaneously...</p>

5. DISCUSSION AND IMPLICATIONS

Based on the generalized multi-agent social simulation framework, this experiment provides insights into understanding the applicability of large language models in computational social science.

5.1. Emergence of Cognitive Synergy and Avoidance of Group Polarization

In numerous multi-agent interaction experiments based on large language models, researchers frequently observe a phenomenon known as premature consensus or homogenizing polarization. Specifically, to satisfy the safety alignment preference of acting as a helpful assistant underlying the models, agents often compromise rapidly and reach an agreement in the early stages of interaction, which consequently causes the simulation to lose genuine social conflict tension.

However, in this study, owing to meticulous role-based prompt engineering and the continuous reinforcement of core persona profiles by the memory summarization mechanism, the agents successfully maintain high algorithmic fidelity. Isabella consistently persists in viewing the crisis from the perspective of local communities and micro-enterprises. Maria adheres to her stance of scientific positivism and being a digital native. Klaus uncompromisingly implements his class analysis perspective of critical sociology. During the communication, they absorb information from each other but never abandon their core values. Instead, they integrate the viewpoints of others into their own cognitive frameworks. This healthy cognitive friction not only avoids blind group polarization but also promotes high-quality cognitive synergy, authentically reproducing the ideal form of opinion exchange within a healthy public sphere.

5.2. Enhancement of Simulation System Robustness through External Knowledge

The simulation results powerfully demonstrate that relying solely on the internal parameter weights of large language models to simulate complex crisis events involving highly specialized knowledge such as nuclear physics, marine biology, and international environmental law carries enormous risks. Due to biases in the pre-training data of the models, purely generative discussions easily fall into superficial moral preaching or technological fantasies.

The design of the tool base class in this framework, particularly the utilization of the search engine, constructs a solid epistemic anchor for the virtual society. In the fourth scenario, when hard data such as the Advanced Liquid Processing System and the thirty-year discharge cycle are retrieved and injected into the multi-agent context, the discussion quality of the entire group achieves a qualitative leap. This indicates that future social simulation systems must move towards a neuro-symbolic or retrieval-augmented hybrid architecture. Only by keeping the agents synchronized with real-time data streams from the real world can the simulation results possess reference value for guiding real-world policy making.

5.3. Future-Oriented Policy Prototype Testing and Verification Machine

This simulation experiment demonstrates the immense potential of frameworks similar to AgentSociety in modern public administration, specifically acting as prototype testing and verification machines for policy interventions.

In the real world, due to political risks, ethical constraints, and irreversibility, it remains difficult for policymakers to conduct trial-and-error experiments among large populations. By constructing an artificial society containing thousands or even millions of generative agents with heterogeneous attributes, governments and crisis management agencies can deploy policies like the environmental protection regulations in the third scenario into the simulation environment before their formal promulgation. By observing the emotional reactions of the virtual public such as agents playing different classes and occupations to the policies, the excavation of logical loopholes, and potential social mobilization networks like utilizing Twitch for cross-platform protests, decision-makers can proactively anticipate resistance points that might be encountered during policy execution, thereby iteratively optimizing risk communication strategies and resource allocation. The case of the Fukushima nuclear wastewater clearly points out that purely top-down policy announcements, if not accompanied by the protection of the interests of marginalized communities and an independent and transparent international monitoring mechanism, will inevitably trigger intense public distrust and waves of protest.

6. CONCLUSION

This report conducts a systematic theoretical and empirical analysis of the generalized multi-agent social simulation framework based on a modular and object-oriented design. By specifically introducing a memory summarization mechanism and singleton tool mounting, the system effectively overcomes technical bottlenecks including memory redundancy, scalability challenges, and factual drift that traditional generative agents face during multi-turn long-term interactions.

Utilizing the highly urgent real-world environmental crisis of the Fukushima nuclear wastewater discharge as a testbed, the experiment profoundly reproduces the evolutionary dynamics of public opinion within an artificial network composed of diverse social roles under information impact. The process transitions from initial emotional panic to the logical synthesis of multiple breaking information sources, and from the critical deconstruction of official policies to the profound technical inquiries and transnational perspective establishment utilizing real-time internet data. The agent group demonstrates remarkable cognitive synergy and social action organization capabilities while maintaining a high degree of personality consistency throughout the entire process.

These findings not only validate the computational superiority of this open-source simulation architecture but also confirm the revolutionary value of large language model agents in the study of complex public opinion dynamics at the social science level, thereby offering a new empirical reference for research in the field of machine behavior [17]. Future research should further expand the topological scale of the simulation community, introduce more complex network structures such as echo chambers and recommendation algorithm interventions, and explore the integration of multimodal data including videos and images into the perception channels of agents. Consequently, this progression aims to provide a higher-resolution digital

twin model for global crisis governance and the evolutionary patterns of human collective cognition across broader spatiotemporal dimensions.

REFERENCES

- [1] Kermack, W. O. & McKendrick, A. G., (1927) "A contribution to the mathematical theory of epidemics", *Proceedings of the Royal Society of London. Series A, Containing Papers of a Mathematical and Physical Character*, Vol. 115, No. 772, pp. 700-721.
- [2] Watts, D. J. & Strogatz, S. H., (1998) "Collective dynamics of 'small-world' networks", *Nature*, Vol. 393, No. 6684, pp. 440-442.
- [3] Barabási, A. L. & Albert, R., (1999) "Emergence of scaling in random networks", *Science*, Vol. 286, No. 5439, pp. 509-512.
- [4] DeGroot, M. H., (1974) "Reaching a consensus", *Journal of the American Statistical Association*, Vol. 69, No. 345, pp. 118-121.
- [5] Park, J. S., O'Brien, J., Cai, C. J. et al., (2023) "Generative agents: Interactive simulacra of human behavior", in *Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology*, pp. 1-22.
- [6] Epstein, J. M. & Axtell, R., (1996) *Growing Artificial Societies: Social Science from the Bottom Up*, Brookings Institution Press.
- [7] Liu, J., Ni, Z., Que, H. et al., (2024) "Roleagent: Building, interacting, and benchmarking high-quality role-playing agents from scripts", *Advances in Neural Information Processing Systems*, Vol. 37, pp. 49403-49428.
- [8] Argyle, L. P., Busby, E. C., Fulda, N. et al., (2023) "Out of one, many: Using language models to simulate human samples", *Political Analysis*, Vol. 31, No. 3, pp. 337-351.
- [9] Gao, C., Lan, X., Li, N. et al., (2024) "Large language models empowered agent-based modeling and simulation: A survey and perspectives", *Humanities and Social Sciences Communications*, Vol. 11, No. 1, pp. 1-24.
- [10] Aher, G. V., Arriaga, R. I. & Kalai, A. T., (2023) "Using large language models to simulate multiple humans and replicate human subject studies", in *Proceedings of the International Conference on Machine Learning*, PMLR, pp. 337-371.
- [11] Horton, J. J., (2023) "Large language models as simulated economic agents: What can we learn from homo silicus?", *National Bureau of Economic Research*.
- [12] Lazer, D. M. J., Baum, M. A., Benkler, Y. et al., (2018) "The science of fake news", *Science*, Vol. 359, No. 6380, pp. 1094-1096.
- [13] Pennycook, G. & Rand, D. G., (2021) "The psychology of fake news", *Trends in Cognitive Sciences*, Vol. 25, No. 5, pp. 388-402.
- [14] van Der Linden, S., Roozenbeek, J. & Compton, J., (2020) "Inoculating against fake news about COVID-19", *Frontiers in Psychology*, Vol. 11, Art. No. 566790.
- [15] Cinelli, M., De Francisci Morales, G., Galeazzi, A. et al., (2021) "The echo chamber effect on social media", *Proceedings of the National Academy of Sciences*, Vol. 118, No. 9, Art. No. e2023301118.
- [16] Becker, J., Porter, E. & Centola, D., (2019) "The wisdom of partisan crowds", *Proceedings of the National Academy of Sciences*, Vol. 116, No. 22, pp. 10717-10722.
- [17] Rahwan, I., Cebrian, M., Obradovich, N. et al., (2019) "Machine behaviour", *Nature*, Vol. 568, No. 7753, pp. 477-486.

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