Quantum-Inspired Modeling of Collective Behavior in Social Networks

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***Abstract*—Understanding collective behavior in social networks is a central challenge in social science, data science, and computational modeling. Classical network and agent-based models often assume linear interactions and independent decision-making, yet real-world social systems exhibit nonlinear dynamics, rapid opinion shifts, polarization, and context-dependent responses that are difficult to predict. This study explores how quantum-inspired modeling frameworks can enhance the analysis of collective behavior by incorporating principles such as superposition, interference, and probabilistic state transitions. Rather than treating individual opinions as fixed, quantum-inspired approaches model social agents as existing in multiple potential cognitive or behavioral states that evolve through interaction and contextual influence. Through qualitative synthesis of literature in network science, behavioral modeling, and quantum-inspired computation, this paper examines how these frameworks capture emergent phenomena such as opinion cascades, synchronization, and abrupt phase transitions in social dynamics. The analysis highlights applications in misinformation diffusion, social polarization, collective decision-making, and adaptive coordination. The findings suggest that quantum-inspired models offer a flexible and scalable approach for representing uncertainty, ambiguity, and contextual dependence in social systems. Ultimately, this study positions quantum-inspired modeling as a promising tool for advancing the predictive understanding of collective behavior in complex social networks.**

Social networks play a fundamental role in shaping collective behavior, influencing how opinions form, information spreads, and coordinated actions emerge within societies [3]. From political polarization and viral misinformation to collective movements and market sentiment, social dynamics often arise from complex interactions among individuals embedded in networked structures. Traditional models of collective behavior—such as threshold models, diffusion processes, and classical agent-based simulations—have provided valuable insights into these phenomena [1]. However, they frequently rely on assumptions of independent decision-making, stable preferences, and linear interaction effects that fail to capture the full complexity of real-world social systems.

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Empirical evidence suggests that human behavior in social networks is context-dependent, uncertain, and nonlinear. Individuals may simultaneously hold conflicting opinions, change their stance depending on framing or social cues, and respond differently to identical information depending on timing or network position [7]. These characteristics produce emergent behaviors such as sudden opinion reversals, polarization, echo chambers, and cascading effects that are difficult to model using classical probabilistic frameworks [4]. As digital platforms amplify the speed and scale of interactions, the limitations of traditional models become increasingly apparent.

Quantum-inspired modeling offers an alternative conceptual framework for representing these complexities. Drawing on mathematical structures from quantum theory—without implying physical quantum processes in the brain—quantum-inspired models treat cognitive or behavioral states as probabilistic superpositions rather than fixed values [8]. In this perspective, social agents exist in multiple potential opinion states simultaneously, and interactions with other agents or information sources act as contextual "measurements" that influence state transitions. Interference effects allow models to capture how overlapping influences can amplify or suppress certain behaviors, while non-commutative dynamics account for order-dependent effects in information exposure.

Applying quantum-inspired frameworks to social networks enables a richer representation of collective dynamics [2]. These models can naturally explain abrupt shifts in public opinion, synchronization across communities, and the persistence of ambiguity in belief systems. They also provide tools for modeling how misinformation spreads, how polarization intensifies, and how collective decisions emerge under uncertainty. Importantly, quantum-inspired approaches complement rather than replace classical models, offering additional layers of flexibility for handling uncertainty and contextual dependence [6].

The relevance of such models extends beyond theory. Improved understanding of collective behavior has practical implications for public policy, digital platform governance, crisis communication, and the design of interventions to counter misinformation or promote cooperative behavior [5]. As societies increasingly rely on networked digital environments, the need for models that accurately reflect human complexity becomes more urgent.

This paper investigates the theoretical foundations and application potential of quantum-inspired modeling of collective behavior in social networks. Through an interdisciplinary review of social science, network theory, and quantum-inspired computation, the study demonstrates how these frameworks can enhance predictive accuracy and conceptual understanding. Ultimately, it argues that quantum-inspired approaches represent a promising direction for capturing the emergent and context-sensitive nature of collective social behavior.

REFERENCES

1. Adornetto, C., Mora, A., Hu, K., Garcia, L. I., Atchade-Adelomou, P., Greco, G., ... & Larson, K. (2025). Generative Agents in Agent-Based Modeling: Overview, Validation, and Emerging Challenges. IEEE Transactions on Artificial Intelligence.
2. Alodjants, A. P., Tsarev, D. V., Zakharenko, P. V., Khrennikov, A. Y., & Boukhanovsky, A. V. (2025). Quantum-inspired modeling of social impact in complex networks with artificial intelligent agents. Scientific Reports, 15(1), 35052.
3. Baqir, A., Chen, Y., Diaz-Diaz, F., Kiyak, S., Louf, T., Morini, V., ... & Galeazzi, A. (2025). Unveiling the drivers of active participation in social media discourse. Scientific Reports, 15(1), 4906.
4. Caldarelli, G., Artime, O., Fischetti, G., Guarino, S., Nowak, A., Saracco, F., ... & de Domenico, M. (2025). The physics of news, rumors, and opinions. arXiv preprint arXiv:2510.15053.
5. Colasanti, N., Fantauzzi, C., Frondizi, R., & Rossi, N. (2025). Digital Technologies and Participatory Governance in Local Settings: Comparing Digital Civic Engagement Initiatives During the COVID-19 Outbreak. In Managing Networks in the Digital Economy: Alliances, Cooperatives, Franchise Chains, Platforms and Digitalization (pp. 347-362). Cham: Springer Nature Switzerland.
6. Kyriazos, T., & Poga, M. (2025). Quantum-Inspired Statistical Frameworks: Enhancing Traditional Methods with Quantum Principles. Encyclopedia, 5(2), 48.
7. Mehdizadeh, A., & Hilbert, M. (2025). When Your AI Agent Succumbs to Peer-Pressure: Studying Opinion-Change Dynamics of LLMs. arXiv preprint arXiv:2510.19107.
8. Youvan, D. C. (2025). Quantum-Inspired Cognition: A Unified Model of Learning, Thinking, and Memory in Biological and Artificial Intelligence.