Large Language Model–Enhanced Agent-Based Modeling for Intelligent Crowd Evacuation under Disaster Scenarios

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Introduction

Crowd evacuation modeling is critical for disaster resilience, yet traditional agent-based modeling (ABM) rely on predefined rules that fail to capture adaptive decision-making and social interactions. This study integrates large language models (LLMs) into ABM to enable context-aware reasoning and more human-like behaviors. By incorporating dynamic interactions and environmental awareness, the framework improves the realism and adaptability of simulations, supporting large-scale evacuation analysis and decision-making.

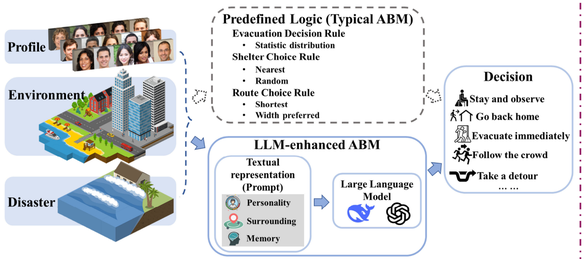

Fig. 1. Schematic illustration of the core concept: replacing the predefined logic of conventional ABMs with the autonomous decision-making capabilities of LLMs.

Results of Case Study

In this study, Arahama Village in Japan is selected as the case study area. As a coastal community, Arahama experienced severe devastation during the 2011 Great East Japan Earthquake and Tsunami. The tsunami struck approximately one hour after the earthquake, reaching a maximum wave height of 10 m.

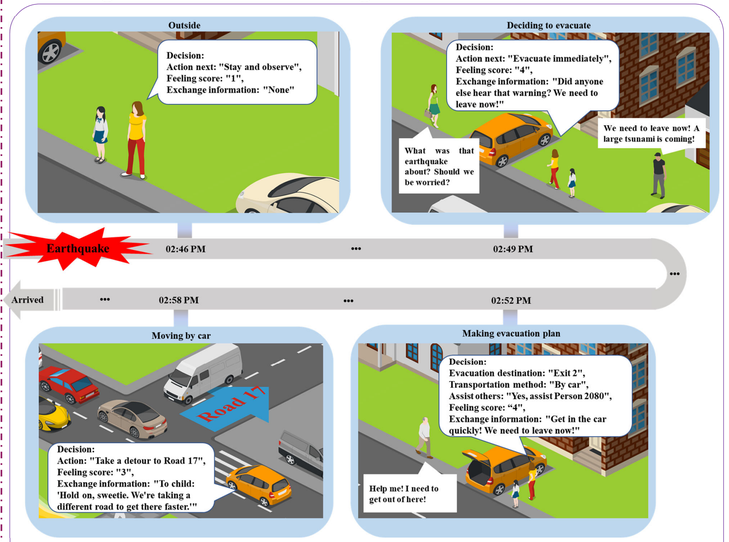

Fig. 3. Illustration of a typical agent's evacuation process. Agents enhanced with LLMs demonstrate adaptive and rational decision-making.

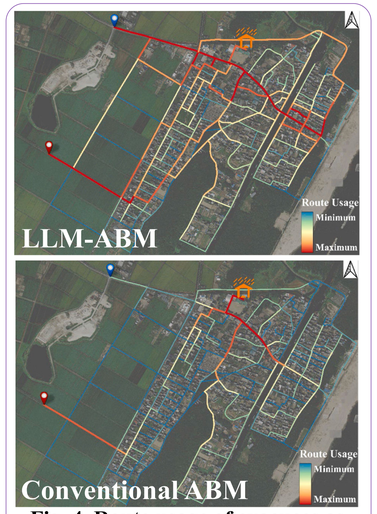

Fig. 4. Route usage of evacuees as determined by different methods. LLM-enhanced ABM aligns more closely with observed behavior

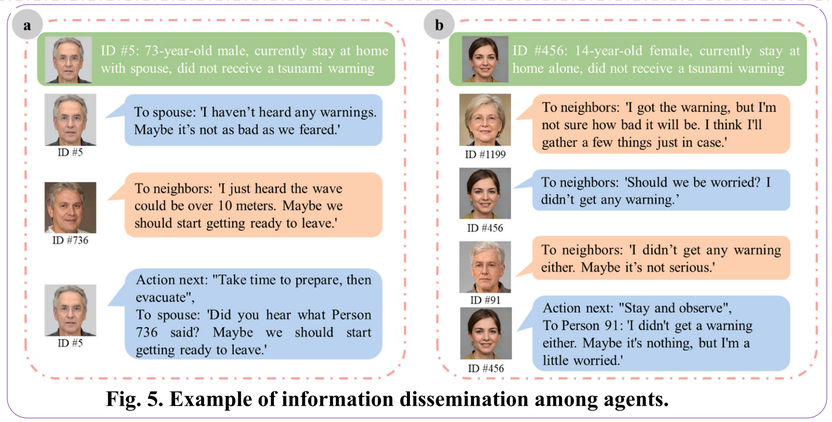

Fig. 5. Example of information dissemination among agents.

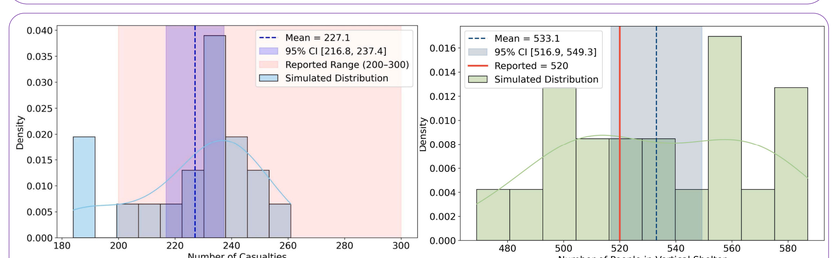

Fig. 6. Distribution of simulated casualties (the reported casualty range 200–300) and simulated number of people in vertical shelters (the reported value of 520).

Methodology

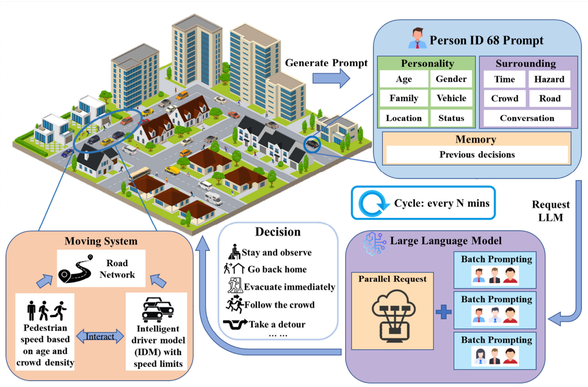

Fig. 2. The proposed framework for LLM-enhanced ABM.

1 Generate Prompt

Imagine you are the person described and act as if you are experiencing the scenario. Keep your response concise and grounded in the situation.
Based on your personal characteristics and surrounding environment, decide your next action by selecting the most realistic option from the given choices.
Rate your current emotional intensity on a scale from 1 to 5 to indicate your level of panic. Emotional intensity should evolve logically. As the situation worsens or improves, emotions should shift in realistic ways, influenced by personal experiences, external events, and direct sensory input.
If you would like to engage with others by asking questions, answering others, or sharing information about the situation, provide what you would say. Avoid repeating what was last said in Memories. Consider what you've heard, what you've previously said, your emotions, and the surrounding environment to respond authentically.
You are simulating multiple individuals. For each individual, provide a separate response.

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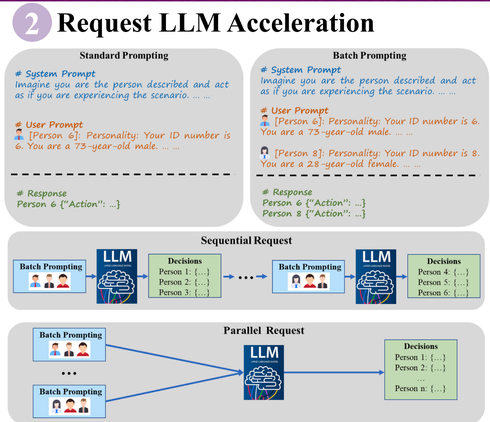
Personality: Your ID number is 2163. You are a 74-year-old male. You live in a flat coastal plain village. You are currently at home, 710 meters from the coastline. You have a car. You have a spouse, and they are with you currently.

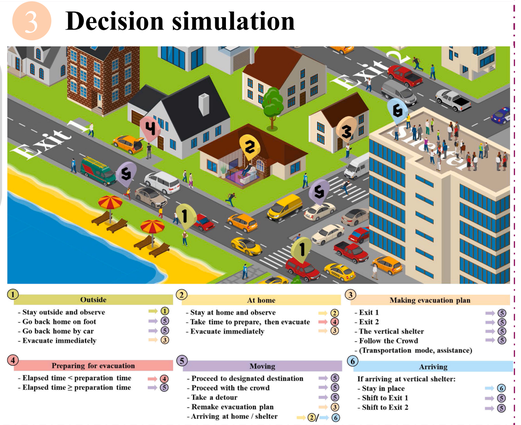
Surroundings: It is 02:52:00 PM. An earthquake occurred 6 minute(s) ago. You received a tsunami warning with an estimated wave height of 6 meters, 3 minute(s) ago. Only a small portion of people around you are moving. Most remain in place. Most people around you appear calm, though a few show mild concern in their expressions. You hear people around you communicating. Their messages are as follows:
Person 740: "Is Exit 1 still accessible, or is it blocked?"

Relevant memories: You thought tsunami would come with little damage. Most recently, you decided to return to your residence from outside by car to check on family members, collect important belongings, or address specific concerns, despite potential risks.

2 Request LLM Acceleration



3 Decision simulation



Conclusion

The proposed LLM-enhanced ABM significantly improves the realism and adaptability of evacuation simulations by enabling human-like decision-making and interactions, offering valuable insights for disaster preparedness and resilience planning.

Reference: Yang S, Ceferino L, Zhang Y, et al. When Agents Learn to Think: Large Language Model-Enhanced Agent-Based Modeling for Crowd Evacuation in Disaster Scenarios[J]. **Reliability Engineering & System Safety**, 2026, 269: 112056.