

Annual Research Report for Shida Scholarship

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1. Self-Introduction and Past Research

In August 2023, I enrolled in the PhD program in Civil and Environmental Engineering at the University of Southern California (USC). Initially, my research focused on wind-wave dynamics, specifically developing a numerical model to simulate the generation and growth mechanisms of wind-driven waves. I presented this work at the 38th International Conference on Coastal Engineering (ICCE) in Rome, Italy, in 2024 (Photos 1,2). Furthermore, in late 2025, I published a first-author paper with Professor Mori's research group at Kyoto University, where I worked before [1]. Subsequently, I attempted to incorporate the Lattice Boltzmann Method (LBM) into my wave modeling. However, this approach encountered significant technical challenges and did not yield the expected results, which led me to make the pivotal decision to transition to a new research topic in my third year.

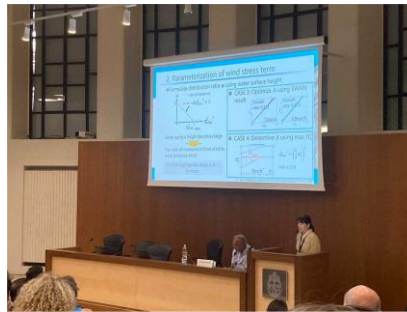


Photo 1: Presentation at ICCE



Photo 2: Colosseum in Rome

2. Current Research Topic: Multi-Agent Tsunami Evacuation Model

My current research focuses on developing a multi-agent tsunami evacuation model. I was inspired by Japan's national digital twin initiative, "PLATEAU" [2], particularly its sub-project, "Finding optimal evacuation shelters using machine learning" [3]. I aimed to construct a novel tsunami evacuation model by integrating Celeris, a wave model developed by my advisor, Professor Patrick Lynett [4]. However, having taken only a few introductory computer science courses out of personal interest, I had no prior formal background in machine learning. As a result, developing this multi-agent model has been a tough learning experience for me. Currently, I am advancing this research with valuable guidance from colleagues in computer science and faculty members introduced through their network.

3. Research Details and Current Progress

[Background and Purpose] During a tsunami emergency, evacuees typically head toward the nearest shelter via the shortest route. However, this behavior can expose people to the incoming tsunami, worsen traffic congestion, and overcrowd evacuation shelters [5]. Tsunami evacuation must be accomplished within a strict temporal window before initial wave arrival. However, evacuation can be delayed by congestion and infrastructure availability. Seismic activity and tsunami waves amplify this vulnerability by damaging road networks, obstructing intended evacuation routes, and forcing evacuees onto unfamiliar or sub-optimal paths [6]. These

cumulative delays lengthen exposure to hazard, substantially increasing casualty rates and preventing timely access to safety.

Furthermore, in reality, each evacuee has their own characteristics such as age, physical capabilities, and family structure, which affect how they experience these delays and what routes are optimal for them. Capturing this individual-level diversity is therefore important as well. Agent-based models are well suited to this problem because they can represent evacuees as autonomous agents with these distinct individual attributes, rather than assuming a homogeneous population that moves at a uniform speed and follows identical decision rules [7]. This makes evacuation simulation more realistic and better suited to informing individualized evacuation guidance. My objective is to build an adaptive routing model that identifies optimal evacuation paths by accounting for individual attributes, real-time traffic conditions, road availability, and shelter capacities. Ultimately, I aim to develop a system capable of delivering personalized evacuation guidance directly to individuals' mobile devices.

[Approach and Previous Attempts] My methodology integrates Professor Lynett's wave model, "Celeris," with advanced machine learning frameworks, specifically Multi-Agent Proximal Policy Optimization (MAPPO) (Figure 1) and, in future work, Graph Neural Networks (GNN). In this framework, the road network is represented as a graph, and each evacuee is modeled as an independent agent that selects a route based on its own local observations, such as nearby congestion levels and shelter accessibility, rather than a centrally computed optimal solution. The goal is to facilitate decentralized decision-making that alleviates congestion, minimizes evacuation time, and maximizes survival rates without requiring global information across the entire urban network, as gaining a complete overview during an emergency is often impractical, and reliance on a central controller introduces a further point of failure if communication is disrupted during a disaster.

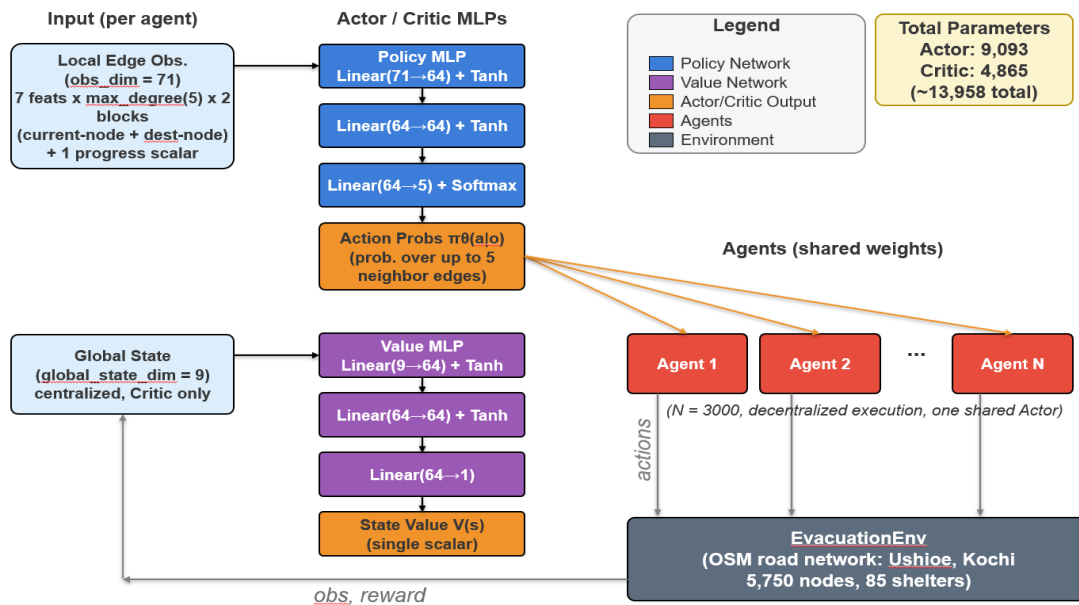


Figure 1: MAPPO architecture overview. All agents share one Actor MLP (71-dim local observation → softmax over candidate edges), a centralized Critic MLP (9-dim global state → scalar value) is used only during training (CTDE). Environment: OSM road network of Ushioe, Kochi (5,750 nodes, 85 shelters).

Initial simulations were conducted using OpenStreetMap (OSM) data and actual shelter information from the Ushioe district in Kochi Prefecture, Japan, a coastal area with tsunami risk, consisting of approximately 5,750 road nodes and 3,000 evacuees (Figure 2), using the MAPPO component alone. GNN integration is planned as a subsequent step to better capture the network structure of the road graph and adapt to topology changes.

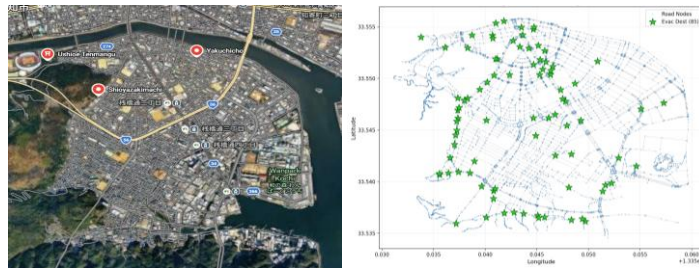


Figure 2: Kochi Ushioe district OSM road topology and evacuation destinations (★: evacuation destinations)

[Current Challenges] When training the model using MAPPO, the policy repeatedly converged toward the baseline "shortest-path" heuristic, with nearly all agents defaulting to their nearest shelter regardless of how congested that route became. The algorithm struggled to manage dynamic pedestrian flows and failed to re-route individuals toward secondary shelters when primary facilities reached capacity, even though doing so would have reduced overall evacuation time. Given the high dimensionality and complexity of real-world urban maps, with thousands of road segments and many possible interactions among agents, pinpointing the root cause of this issue was challenging. It was difficult to tell whether the problem lay in the reward design, the network architecture, or the training procedure itself. Therefore, I decided to temporarily step back and evaluate the model using a simplified, synthetic grid environment, and eventually an even simpler two-shelter line topology, where the dynamics could be inspected and debugged directly. Currently, I am testing whether the core algorithm can effectively encourage pedestrian dispersion and balanced shelter utilization under these controlled conditions, systematically refining the framework step by step before reintroducing the full complexity of the real road network.

4. University Life and Surviving Abroad

Giving up a research project after two and a half years of dedication was mentally demanding. As I watched my fellow PhD students advance in their research, it was not easy to take time to pause and reconsider my true interests again. Likewise, learning computer science from scratch has been exceptionally challenging. Based on my limited prior coursework in this field, I struggled to feel confident and even questioned whether the new topic I proposed was the right path. However, my perspective gradually shifted through self-study, connecting with CS PhD students and professors, and countless rounds of trial and error. I began to realize that computer



Photo 3: Civil ceremony at the registration window



Photo 4: Visited Kumasi, Ghana to celebrate my friend's wedding

science offers powerful new tools to address complex real-world problems, even though this differs significantly from my background in civil engineering. This journey taught me the importance of stepping outside my comfort zone rather than relying solely on past experiences. Moving forward, I am excited to pursue this new research topic with dedication and am eager to embrace every challenge through graduation.

Beyond academia, I have navigated typical cross-cultural adaptation challenges and experienced growing uncertainty about the future in the face of rapid political/immigration policy shifts. Managing these everyday life disruptions alongside my research has required continuous resilience. Yet, during this dynamic period, I celebrated a major personal milestone: I got married this year! :) I am happy to have someone special to stand strong with in this eventful and intense season of my life.

Having navigated several health challenges earlier this year, I am focusing on maintaining balance by prioritizing rest, staying connected with people, and relying on my support network. I see these combined pressures as a valuable opportunity for personal and professional growth, and I remain committed to making steady progress day by day.

5. Acknowledgments

Finally, I would like to express my appreciation to everyone who has supported me throughout this journey. First and foremost, I would like to thank the Shida family for supporting my PhD studies in the US. The Shida Scholarship has given me not only financial support, but also meaningful connections with wonderful people. I am also grateful to Ms. Rika Okayama for her dedicated assistance since my initial application for this scholarship, as well as to both members of the selection committee, Mr. Masatsugu Takamatsu and Ms. Michiko Namazu. I also sincerely appreciate Ms. Nanako Tojo for her continuous support. I also would like to thank Ms. Ryoko Araki, who connected me with this scholarship and offered valuable advice prior to my arrival at USC. I am deeply grateful to everyone who supported me through the Shida Scholarship and the Kyodai collaborative. Beyond crucial financial assistance, this scholarship has allowed me to connect with the distinguished Kyoto University community, offering tremendous encouragement. Inspired by their support, I am dedicated to pursuing excellence in my research and look forward to supporting future Kyoto University scholars studying abroad.

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