# A PHYSICAL-BEHAVIORAL FRAMEWORK FOR CAPTURING THE COMPLEXITY OF FLOOD EVACUATION BEHAVIORS IN AGENT-BASED MODELS

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## 1 INTRODUCTION

Areas prone to flood inundation affect 255-290 million people worldwide [1]. Thus, models that simulate evacuations from at-risk areas can aid decision-makers to better prepare for flooding disasters in the future. However, traditional models typically do not capture important complexities inherent to city-level evacuation dynamics.

First, existing cellular automata (CA)-based flood models lack the validation with real data that would be necessary for their integration with agent-based models (ABMs) to appropriately model the evacuation process and allow for representation of agent-environment interactions. When CA models are combined with ABMs for evacuation, validation is often focused on only the agent-based simulation part of the modeling framework. Using real data for case studies and validating the evacuation model can enhance the trustworthiness of the proposed framework in decision-making.

Second, most existing flood evacuation models do not include dynamic agent-environment interactions, although some simplistic attempts have been made. Flood disruptions on the road typically do not change as the flood progresses; hence, the representation of dynamic agent-flood interactions is missing. Thus, modeling adaptive mobility behavior, including agent-environment interactions, is important for simulating flood evacuations.

Third, the ad-hoc representation of decision-making is common in evacuation models, but it cannot capture the heterogeneity in evacuation responses of individuals. For example, representing evacuation using a 100% evacuation participation rate might not be able to capture the complexity of the evacuation decision-making process. The individual's perception of risk, socio-demographic factors, prior hazard experience, and hazard warning are significant factors when making the decision to evacuate or not [2].

Therefore, the study proposes a data-driven coupled CA and ABM framework that can capture the complexity of evacuation dynamics. The flood inundation will be modeled using a validated flood CA which will be coupled to an ABM that simulates individuals' evacuation behavior and agent-environment interactions. Machine learning approaches will be used to inform individuals' evacuation decisions.

This proposed CA-ABM framework will address the questions: 1) To what extent can validating the flood inundation model with real data in an urban setting improve evacuation simulations and the potential to use such models for evacuation decision-making and response?, 2) How can simulating mobility behavior for route choice and agent-environment feedback be integrated within framework?, 3) To what extent can a data-driven machine learning approach improve the representation of human evacuation behavior in ABMs? The model will be applied to the case study of flooding due to Hurricane Ian in Lee County, Florida, 2022.

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## 2 PROPOSED METHODS

In order to answer the first question, a CA model will be developed to represent the flooding in the environment. Each cell will be characterized by the state "flooded" or "not flooded". Specifically, the CA flood model will be updated at each time step, leading to the evacuation of agents. To calibrate and validate the CA model, 30m resolution flood inundation data of past hurricane flooding will be used in the study region.

In order to answer the second question, the ABM will include agents' dynamic response to their environment based on the results of the CA model. To represent adaptive agent-environment interactions, evacuating agents will re-route if they were to encounter floodwater depth of at least 0.25m within their immediate evacuation path. An evacuating agent will get negatively impacted by the flood if it cannot find a path to its shelter. Agents that decide to stay will get negatively impacted by the flood if critical water depths ($\geq$ 0.25m) reach the cell they are on.

In order to answer the third question, machine learning approaches will be used to predict individuals' evacuation decision. Machine learning models trained on multiple factors from survey data will be developed and results of the different approaches will be compared. The findings from the models will provide important insights into determinants of evacuation, e.g. demographics, social influence, perception of storm. Then, the demographics and ability to observe and perceive their environment will be encoded into each agent, and based on these, the agent will apply the trained model to themselves to decide whether to evacuate or not.

## 3 PRELIMINARY WORK AND EXPECTED RESULTS

Progress has been made in initializing the agent population. First, agents with age characteristics were loaded into the ABM. The spatial distribution of the population in the study region was retained using population counts for the census block groups (CBGs) obtained from census data. Based on the home CBG attribute of the agents, each agent selects a residential building within their home CBG to assign it as their home building. Furthermore, agents were assigned work locations using a Monte Carlo sampling approach [3].

In conclusion, the proposed dissertation will make contributions to enhance the representation of flood hazards and evacuation behavior in simulation studies. Proposed results should help evacuation decision-makers better understand how people would respond to emergency situations.

## REFERENCES

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