Towards Modeling Civilian Behavior During a Natural Disaster

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Abstract. This work presents a literature review on civilian evacuation behavior and agent based modeling for disaster planning. The aim is to understand a regional response to a natural disaster. We propose a study to investigate our study area's disaster plan and civilian response at large during such an event. The implications of our proposed work include improved disaster planning and a framework for modeling civilian response to real government disaster plans.

Keywords: Decision Making · Evacuation Behavior · Disaster Planning · Human Factors

1 Introduction

A natural disaster refers to an event caused by the forces of nature which endangers lives. Examples include hurricanes, earthquakes, and forest fires. More people around the world are vulnerable to natural disaster caused devastation due to increases in population, urbanization, and poverty cycles. An analysis by the Centre for Research on the Epidemiology of Disasters (CRED) found that more money is put into disaster relief than disaster planning and reduction efforts. CRED calls for increased evidence-based disaster planning to reduce loss of human life, the priority of disaster mitigation [1]. Governments create disaster plans to set up a course of action in the event of a large scale emergency. The primary goal of such plans is to prevent loss of life.

Our goal is to understand how civilians find their way to safety during a city wide natural disaster. This knowledge will inform evidence-based disaster plans. We aim to understand what characterizes disaster plans, and if these plans will be effective in an actual emergency. We also want to understand civilian behavior during natural disasters and how this relates to a city's disaster plan. This work presents a literature review of research in evacuation behavior and spatial agent based modeling. We then present a proposal for our future work, which involves modeling a disaster plan and civilians' expected behavior.

2 Background

2.1 Evacuation Behavior

In many cases, successful evacuation of an at risk geographic area, will greatly reduce the number of casualties. For example, in 1999 a cyclone made landfall with 155 mph winds and caused 10,000 deaths in Odisha India. In 2013, a similar cyclone made landfall with 140 mph winds and caused 14 deaths in the same Odisha, India. Before the second event, Odisha implemented a zero-casualties policy where almost one million people were evacuated to safer areas, resulting in strikingly fewer casualties. The government provided medical aid, supplies, and over 250 public shelters [2]. Adequate planning and policy for evacuation and resource distribution results in more people making their way to safety.

In order to plan for disasters, decision makers must first understand what to expect during a large scale disaster. Previous research investigates how risk perception affects an individual or household's decision to evacuate in the wake of a natural disaster [3, 4]. Prior evacuation and having an evacuation plan also led to more likely evacuation in a given event. Mandatory evacuation notices, rather than voluntary notices, led to more likely evacuation. Friends or family members telling a person to evacuate also led to more likely evacuation. Many factors affect an individual's perception of risk, and affect the decision to evacuate to safety or remain at risk [3].

Dash et al. [4] calls for spatially related prediction methods for public officials to use during disaster planning and relief. Warnings of any kind instigate individual evacuation decision making. Factors affecting risk perception can be used to predict evacuation rates [4], an important consideration during disaster planning. If decision makers know areas that are more likely to evacuate, they may be able to tailor warning information pre-event and resource distribution post-event. Understanding the civilian response to natural disasters will help decision makers create evidence-based plans.

2.2 Agent Based Modeling

Agent based modeling (ABM) allows for simulation of individual agents in dynamically changing states, and analysis of the characteristics of the system as a whole [5]. ABM has been used for simulating evacuation behaviors during emergencies in the past [4, 6, 7]. Civilians often do not act as evacuation managers expect during emergencies [6]. Modeling behavior based on realistic human behavior can help evacuation managers understand what to expect from civilians during large-scale disasters.

Participatory modeling involves non-technical disaster managers with developers from the beginning of the model design process [8]. This approach allows for models to be created and used for decision making. The use of a graphical modeling tool, such as GAMA, allows for disaster managers and developers to create an entire version of a model using a graphical user interface. This is useful for allowing disaster managers to understand and take part in the initial development [8]. Participatory modeling provides a way to test the impacts of proposed plans and to communicate with data and visualizations where things may go wrong in the plan [9].

ABM has been applied to spatial models of cities to simulate disaster response and policy changes [6, 9, 10]. Adam et al. simulated the Australian bush fires using publicly available data from different sources [6]. Crooks et al. presents an ABM and GIS framework and simulates humanitarian response to an earthquake using different data sources [10]. Spatial ABMs allow for a city to create a personalized simulation for their unique needs.

3 Proposed Research

The proposed study will improve understanding of civilian spatial behavior during a large scale natural disaster. We are interested in how civilians find their way to safety given the disaster plan set up by the government and given their interactions with other civilians. We intend to represent individual civilians as agents in a spatio-temporal model of a region during a flood disaster. CRED states that floods have reportedly affected over 2.6 billion people over the past 30 years [1]. Our work will focus on floods because that is the most common type of natural disaster which threatens the surrounding area of our city on the East Coast of the United States, our region of study.

We will gather data to understand the state of our study area's disaster planning for floods. We intend to use both qualitative and quantitative data for the creation of the model. We are continuing to review the literature for best practices and sources of data. Some sources we will consider based on the literature are volunteered sources of information such as social media and Open Street Map, qualitative interviews with civilians and emergency personnel, and other official documents detailing the city's disaster plan [10, 6]. Furthermore, we will use past studies [3, 4] to define civilian agents disaster related behaviors.

We will use the data we gather from multiple sources to create an agent based model the simulates the city's response plan and civilian behavior. We will analyse the model to understand what geographic areas or demographics of people are most at risk for not making it to safety. We will then make our recommendations for changes to the disaster plan based on our simulations. This model will help the city understand if it is equipped to handle a large scale flood. Different extremes and situations will be tested. We will evaluate the model by comparing the simulation to the events of a real flood event in the region. We will analyse the results of simulation based on expected number of people affected and economic loss. The primary goal will be finding a disaster plan that prevents the most loss of life.

3.1 Limitations

A limitation of the proposed study is that human behavior is difficult to predict, as it is quite complex [5]. Some factors, such as demographics, which affect evacuation behavior have positive or negative correlation depending on other factors [3, 4].

Some limitations of ABM are that ABM can be very time and computationally consuming [5]. ABM is an effective research methodology, yet is not widely used in the public sphere, although there is work towards more stakeholder participation [8].

4 Conclusion

In this work, we presented a literature review of typical civilian evacuation behavior. We also proposed the creation of an agent based model based on various data sources that simulates our study area in the event of a flood. By looking closely at a disaster plan and predicting civilian response patterns, we aim to inform the improvement of the disaster plan. We also aim to demonstrate the applicability of a disaster planning and civilian behavior model to other regions and event types.

References

1. Guha-Sapir, D., Hargitt, D., Hoyois, P.: Thirty years of natural disasters 1974-2003: The numbers. Presses univ. de Louvain (2004).
2. Cyclone Phailin kills 14, leaves trail of destruction in India - CNN, https://www.cnn.com/2013/10/13/world/asia/india-cyclone-phailin-aftermath/index.html, last accessed 2019/09/23.
3. Thompson, R. R., Garfin, D. R., Silver, R. C.: Evacuation from natural disasters: a systematic review of the literature. Risk analysis 37(4), 812-839 (2017).
4. Dash, N., Gladwin, H.: Evacuation decision making and behavioral responses: Individual and household. Natural Hazards Review 8(3), 69-77 (2007).
5. Bonabeau, E.: Agent-based modeling: Methods and techniques for simulating human systems. Proceedings of the national academy of sciences 99(suppl 3), 7280-7287 (2002).
6. Adam, C., Gaudou, B.: Modelling human behaviours in disasters from interviews: application to Melbourne bushfires. Journal of Artificial Societies and Social Simulation (2017).
7. Yang, H., Morgul, E. F., Ozbay, K., Xie, K.: Modeling evacuation behavior under hurricane conditions. Transportation research record 2599(1), 63-69 (2016).
8. Taillandier, P., Grignard, A., Marilleau, N., Philippon, D., Huynh, Q. N., Gaudou, B., Drogoul, A.: Participatory Modeling and Simulation with the GAMA platform. Journal of Artificial Societies and Social Simulation 22(2), 1-3 (2019).
9. Alonso, L., Zhang, Y. R., Grignard, A., Noyman, A., Sakai, Y., ElKatsha, M., Larson, K.: Cityscope: a data-driven interactive simulation tool for urban design. Use case volpe. In: International Conference on Complex Systems, pp. 253-261. Springer, Cham (2018).
10. Crooks, A. T., Wise, S.: GIS and agent-based models for humanitarian assistance. Computers, Environment and Urban Systems 41, 100-111 (2013).