AGENT-BASED RUMOR SPREADING MODELS FOR HUMAN GEOGRAPHY APPLICATIONS

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1. INTRODUCTION

Communication has a large impact on the outcome of a population's response during disaster scenarios [1]. The ability of a population to access news and disaster relief information as well as the population's perception of the information they receive effects behavior during a disaster scenario [2]. In this paper, two agent-based rumor (information) spreading models are developed to study the spread of information during disaster scenarios. The disaster scenario studied in this paper is the evacuation of an island population to shelters.

Many rumor-spreading models have been developed in the literature. A large number of these methods focus on spreading information across a network with minimum communication overhead, robustness to failures and time efficiency [5][6][7][8]. Models have also been developed specifically for social network analysis, wireless networks, and others. However, few models have been developed to mimic human information spread, particularly, in disaster situations [3][4]. An important feature of the two models proposed here is that the agents are moving and the agents in their neighborhood (those that they share information with) are continually changing. Thus, the rumors are not being spread on a fixed grid or network. Furthermore, the agents in this model are viewed as single individuals or a small group of individuals.

2. RUMOR SPREADING MODEL I

The initial rumor-spreading model focuses on the spreading of information rather than the perception of the information by an individual agent once it has been received. This model is based on a randomized pull model. During each iteration, an agent will move one step towards their desired evacuation center. After taking a step, the agent will select at random one of any available neighboring agents and, then, question the neighboring agent for any new information. In this implementation, the information that is being spread is on the availability of additional evacuation shelters. If the agent learns of a closer shelter or learns that their desired shelter has reached capacity, the agent will re-evaluate and change direction towards another shelter on the island.

Psuedo-code: Rumor Spreading Model I

```
while(agents are still evacuating)
    randomize agent order
    for i = 1 to Number of Agents
        move agent_i one-step closer to desired evacuation shelter
        search agent_i neighborhood for other agents
        if(neighboring agents are found)
            select 1 neighboring agent (nagent_i) at random
            poll nagent_i for new rumors
            if (new rumors are heard)
                evaluate and update desired evacuation shelter for agent_i
            endif
        endif
    endfor
endwhile
```

3. RUMOR SPREADING MODEL II

Studies in the communication literature illustrate that individuals are often more skeptical of information received from individuals outside of their community. For example, Spence, et al. discuss that minority communities are less likely to accept disaster warning information without confirming the information through personal networks and, also, minority groups were less likely to be tuned into local news that often broadcasts local disaster information [2]. This was also discussed in Falkheimer, et al. where, in their case studies, it was found that minority groups were less likely to read mainstream newspapers for an area, which limited their knowledge of local risk information [9]. In order to incorporate this behavior, each agent was assigned a community/ethnicity and given a threshold of the number of times they must hear a rumor before giving credence to that rumor. Agents placed more weight on rumors heard through agents from their own community and were more skeptical (smaller weight) of rumors heard through agents from outside of their community. Therefore, each agent would believe a rumor more quickly if it were heard from agents with a similar background.

Psuedo-code: Rumor Spreading Model II

```
while(agents are still evacuating)
    randomize agent order
    for i = 1 to Number of Agents
        move agent_i one-step closer to desired evacuation shelter
        search agent_i neighborhood for other agents
        if(neighboring agents are found)
            select 1 neighboring agent (nagent_i) at random
            poll nagent_i for new rumors
            for k = 1:number of rumors heard
                if(ethnic(nagent_i) == ethnic(agent_i) )
                    set belief(rumor_k) = belief(rumor_k) + w_sameethnicity
                else
                    set belief(rumor_k) = belief(rumor_k) + w_diffethnicity
                endif
                if(belief(rumor_k) > threshold)
                    evaluate and update desired evacuation shelter for agent_i
                endif
            endfor
        endif
    endfor
endwhile
```

4. EXPERIMENTAL RESULTS

The disaster scenario considered here is the evacuation on an island to evacuation shelters. A map of the island and an example of the shelter placement is shown in Figure 1. The agent based rumor spreading models were implemented in both the Repast agent-based framework [10] and MATLAB. In all experiments, 1000 agents were initialized with locations uniformly distributed across the island.

The first experiment considered Rumor Spreading Model I with varying capacities of the three evacuation centers. In this experiment, agents were initialized with uniformly random information about which evacuation shelters are available and agents are restricted to moving on the road network. Table 1 summarizes the results of varying evacuation center capacities. For each configuration, the model was run 10 times. Table 1 lists the mean and standard deviation of the percentage of agents to reach a shelter within a set number of iterations.

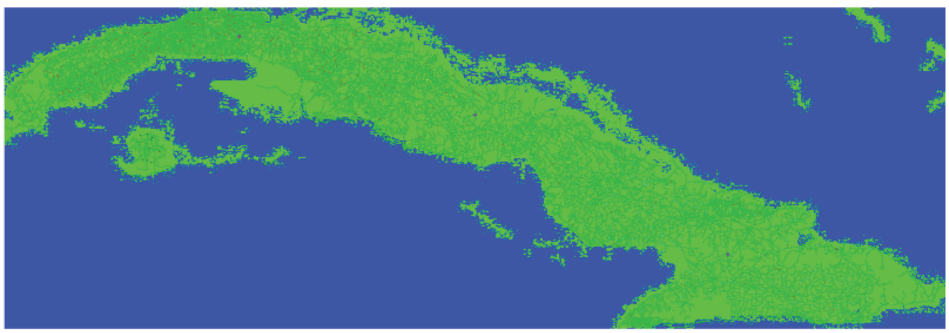

Figure 1: Map of island (green), road network (dark green), and three evacuation shelters (purple)

Table 1: Results of Experiment 1 where a large shelter capacity is cycled between Shelters 1, 2, and 3. This experiment examines the impact of shelter location given random uniform initialization of agent locations.

Iteration	Percentage of Agents to Reach a Shelter Shelter Capacities: 150, 800, 281	Percentage of Agents to Reach a Shelter Shelter Capacities: 800, 150, 281	Percentage of Agents to Reach a Shelter Shelter Capacities: 150, 281, 800	Percentage of Agents to Change Shelters Shelter Capacities: 150, 800, 281	Percentage of Agents to Change Shelters Shelter Capacities: 150, 281, 800	Percentage of Agents to Change Shelters Shelter Capacities: 150, 281, 800
250	63% ± 0.4%	68% ± 1.7%	66% ± 1.1%	20% ± 1.3%	22% ± 1.5%	22% ± 1.4%
500	71% ± 1.9%	76% ± 1.8%	79% ± 1.1%	23% ± 1.1%	25% ± 1.3%	26% ± 1.5%
750	82% ± 2.2%	87% ± 1.7%	79% ± 1.0%	38% ± 1.5%	40% ± 2.3%	26% ± 1.3%
1000	98% ± 0.9%	88% ± 1.5%	80% ± 0.9%	58% ± 2.3%	41% ± 2.4%	28% ± 1.4%

As shown in Table 1, the placement of the largest shelter on the island impacts the amount of time agents need to reach a shelter. Factors that influences this is the road infrastructure surrounding each shelter and the average distance of largest shelter to the rest of the island (i.e. as one might expect, a centrally located large shelter provides the quickest evacuation). The last three columns of Table 1 summarize the percentage of agents that changed their desired shelter while evacuating. As seen, the configuration with the largest percentage of sheltered agents also had the largest percentage of agents that changed direction. This indicates the agents are quickly hearing the important rumors needed to guide their behavior.

The second experiment employed Rumor Spreading Model II. In this experiment, agents were initialized with information to evacuate to the nearest shelter and agents were not restricted to moving on the road network. Table 2 summarizes the results of varying weights for rumors heard from within and outside of an agent's community/ethnicity. For each configuration, the model was run 10 times. Table 2 lists the mean and standard deviation of the percentage of agents to reach a shelter within a set number of iterations.

4. SUMMARY AND FUTURE WORK

In this paper, two rumor spreading models to investigate information spread in disaster scenarios are described. In the experiments shown, the impact of various scenario parameters were examined in terms of percentage of agents able to reach a shelter within a prescribed amount of time. Future work will include adding rumors for information other than the availability of evacuation shelters. For example, additional rumors on traffic or road closings and conditions will be included. The inclusion of traffic and road information will cause agents to consider and update paths to evacuation shelters based on each agent's individual knowledge of the road structure and the information that gets passed to them. Furthermore, in the second rumor-spreading model, agents have some level of skepticism about the rumors. They must hear a rumor several times before trusting the information. The level of an agent's skepticism or how an agent perceives information may be related to personality. Future work will incorporate personality traits into each agent and these traits will be used to modulate how agents perceive and make use of the rumors they hear.

11. REFERENCES

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Table 2: Results after varying the skepticism level for rumors heard from inside and outside of an agent's community

Iteration	**Percentage of Agents to Reach a Shelter** $\mathbf{W_{sameethnicity} = 0.5}$ $\mathbf{W_{diffethnicity} = 0.01}$ **Threshold = 2**	**Percentage of Agents to Reach a Shelter** $\mathbf{W_{sameethnicity} = 1}$ $\mathbf{W_{diffethnicity} = 0.01}$ **Threshold = 2**
500	38% ± 1.4%	39% ± 0.9%
1000	71% ± 1.8%	70% ± 0.5%