ABSTRACT

An essential activity in managing an emergency is planning, preparation, and training for it. The harmful consequences can be diminished if accurate safety metrics are incorporated before. This leads to the simulation of an emergency event which is required to devise a roadmap, evaluate the effectiveness of numerous possible scenarios and thereby mitigate the damages significantly. An agent-based modeling system is implemented to simulate the actions and interactions of independent agents with a motive to assessing their effects and behavior on the emergency situation as a collection. When a region is affected by a disruptive incident, two key interlinked communities usually respond. These two communities are classified as- a. Professionals - this community includes police or firemen. They have higher authority and are well-trained to manage a disruptive event. b. Ad Hoc Community - this includes regular citizens. They are usually equipped with less or no training and must be protected during a disruptive event. The response of the above two communities is not studied well enough. This paper introduces an agent-based modeling method to simulate a fire disaster in a region. The task to handle a disruptive event is based on several rules and constraints. Moreover, it provides different testing scenarios of a disruptive event at no expense. It captures the responses of the community system and professionals system to achieve a clear understanding of the connections and relations between them.

Keywords

Agent-Based Modeling; Emergency Preparation; Dynamic System Behavior; Netlogo

1. INTRODUCTION

In a case of disruption, it is crucial for emergency services professionals and citizens to be prepared. It is recommended to be trained to mitigate the damages and costs. In an incident of a disruptive event, we have two interconnected systems that are affected, as shown in figure 1 -

- Professionals System - they have a higher authority to manage a disruption. Moreover, they are equipped with proper training and disruption management skills.
- Community System - this includes citizens and they are equipped with limited training and disruption management skills. Although, play a significant role when the professional response is inadequate.

Figure 1: Interconnected Systems

Intricate computing model and simulation attempts to solve this issue by providing for testing and evaluating many situations at inexpensive cost. Agent-based modeling is used to simulate interactions between autonomous agents and to examine the relationships and system interaction between interconnected systems. Agents are self-governing in that they have a common interface to the overall simulation but carry within them their own ability to perform tasks without a centralized controller.

This work is critical in judging the interplay between professionals system and community system in a case of disruption. Further, to determine the way to ensure timely, effective, and adequate emergency response to manage disaster.

The reason to use agent-based modeling is because it is one of a class of computing models for simulating the operations and communication of autonomous agents with an aim to estimating the effectiveness of the system as a whole.
Section 2 provides an interesting literature review of the work conducted in agent-based modeling. Section 3 explains in detail the design, environment setup, fire production, tools used to develop this decision support system. Section 4 discusses the results gained after simulating the developed model. Finally, section 5 closes this paper and also discusses the prospective work.

2. BACKGROUND

Two critical steps in emergency management is planning and preparing. The fundamental idea proposed in [4] is a novel prototype for decision system and simulation that is inspired from agent-based simulation and modeling that enables crowd evacuation simulation in the case of a fire disruption and at the same time provides testing of multiple disaster scenarios. The ABM simulation system has been used in an environment setting that consists settings such as emergency exits, seats, and doors. Excellent results were obtained by experimenting the simulation under different conditions and settings of different parameters such as variation in the number of people and level of fire. The experiments conducted to prove that fire evacuation simulation yields better results in the case where a disaster event manager is involved.

In work [3] focuses on the need to make use of agent-based modeling to for Discrete Event modeling. The major advantage the system proposed here is its ability to contain a large amount of active objects that include a large number of people, animals, vehicles, products, and units. Three major paradigms in simulation modeling have been compared: Discrete Event, Systems Dynamics, and Agent-Based Modeling. The focus is also on how these systems interconnect with one another to form a relatively complex system that performs the simulation of event efficiently. An enhanced version of the agent-based model is built using Discrete Event modeling and System Dynamics that handles dependencies and interactions between various elements.

The research conducted in [2] stresses on critical incident management as a responsive way to handle disaster management based on the fusion of various sources obtained through collection technologies into one common platform. It is necessary to account for the variability of data that is gathered through fusion. The authors also take into consideration other major factors that include reliability, uncertainty, and compatibility. The platform that is formed due to such a fusion serves as a baseline for decision making in the system proposed in this paper. Also, model development of the decision support system and its applications to emergency management operations are the major areas of focus of the authors. Also, model designing of the decision support system and its utilization to emergency management operations are the.

3. MODEL DESIGN

The ABM system for fire disaster management was designed and developed in an environment known as Netlogo [1]. The purpose of the system is to simulate the interaction of the two interconnected systems, shown in 1, to handle a fire emergency. The system benefits emergency professionals and citizens to be equipped and stay prepared for fire disruption mitigation. Further, the design has the following key advantages -

1. Simulate multiple fires and various plausible scenarios.
2. Extend the design for a larger region, for example, an 8x8 sized neighborhood region.

The devised system incorporates an agent-based modeling methodology to demonstrate the interplay of autonomous agents in the virtual environment. The outlined system has three autonomous agents - regular citizens, professionals, and fire.

The following subsections define primary elements of the developed system - environment setup, producing fire, and citizens and professionals movement.

3.0.1 Environment Setup

Simulating in a virtual world is conducive to the needs of the emergency services managers and planners. With this in view, the ABM system is designed to be highly flexible and allow customization, a specification and setup of varying components like fire size, community population, grid size to test, and so forth.

The design of the agent-based model(ABM) system comprises of an NxN cellular grid region. Basically, the geographic region is divided into cells distributed on a grid. The 4x4 cells in the figure 2 represents the many areas of the region. A gray patch on the cellular grid represents one area of the entire region.

![Figure 2: Simulation environment without citizens and professionals](Image)
Figure 3 illustrates a 4x4 neighborhood cells in the region with a population of citizens set to 100 and population of professionals, i.e. firemen, set to 30. The input sizes of each agent can decrease or increase depending on the scenario being evaluated. The input sizes of each agent can decrease or increase depending on the scenario being evaluated. The agents in brown represent the community system whereas the agents in black and red uniform represent the professional community.

The algorithm randomly assigns these agents to the neighborhood. Moreover, each set of agents has certain global behavior and characteristics.

3.0.2 Producing Fire

The designed system treats fire disaster as an agent that employs its own properties and behaviors. This agent has the following key properties -

1. Size - indicating the volume of the fire.
2. Health - indicating the intensity of the fire.

The algorithm randomly picks a cell which gets negatively affected by a fire disruption, as shown in figure 4. The cell turns yellow signaling the cell where a fire disaster has occurred. The health of that cell falls below a particular threshold value signifying a "sick cell". Besides, the user can input an additional fire event to test the possibility of two cells catching fire simultaneously. Essentially, a fire disaster is randomly triggered at any of the neighborhood and the health of affected cell drops significantly as shown in figure 4.

3.0.3 Professionals and Citizens Movement

This stage forms the crux of the devised ABM system. The aim of the system is to simulate multiple scenarios where the fire disaster is handled effectively, efficiently, and timely. Additionally, the necessary resources of that affected cell should be unharmed and safe. The simulation attempts to minimize the damage. The emergency services professionals visits the negatively affected cell in the shortest time possible. The tick counter shown in the figure keeps track of time after the disruption occurs until completely handled.

The negatively affected cell becomes a sick cell which means that the health of that cell falls under a threshold value that implies the need of immediate assistance. To gain further insights, a cell is considered healthy if its threshold value is over the value of seven on ten.

Depending on where the fire event occurs firemen nearby move and approach to manage the fire event. The algorithm looks for the firemen within a certain radius distance to handle the disaster. If firemen are outside a certain distance threshold then few citizens within the affected neighborhood try to handle the fire event by themselves until professionals arrive.

Firemen and citizens own a helping probability property. It denotes the authority and training both the agents own. In a fire disaster, the professionals own more helping probability compared to citizens as they are well trained and better equipped compared to citizens. Consequently, let’s assume that if the disaster is managed by three firemen then it may require more than five citizens.

Let’s consider a simulation of a possible scenario of a fire disaster, the figure 5 shows a two-dimensional view of the designed ABM system which randomly chooses a cell where the fire disaster takes place. In the figure 5, the highlighted red part show the following - tick counter, the negatively affected cell, and health monitor of that cell. The professionals face the direction where the event has occurred and
start marching towards the affected cell and handle it. Once they arrive the fire size starts diminishing and the health property of the cell starts rising as seen in the highlighted part of figure 6. The figure 6 displays the same segments but after the simulation stops and with the updated values. The tick component records the overall time taken as seen in the figure 6. Additionally, the system traces the professional’s path for clear understanding. The stopping criteria of the system are achieved once the fire is completely stopped and the health of the cell reaches the required healthy threshold value. Once it is completed the color of the cell is back to gray.

Figure 5: Highlighted part are as follows - tick counter, the negatively affected cell, and health monitor of that cell

In a next scenario consider a plausible case when there’s no professional help within the required distance threshold then the system adapts accordingly and finds firemen from a bigger distance threshold and meanwhile, a handful of citizens reach the disrupted event and attempt to mitigate it. Thus, the designed ABM system dynamically adapts and has the capacity to simulate numerous scenes and safety metrics at zero price. Moreover, this allows emergency managers to experiment various plausible scenarios and perform validation of the safety metrics. Eventually, this drives to making data-oriented and informed support decisions.

4. RESULTS

Figure 7 shows a plot of entire simulation cycle of the health of the negatively affected cell after, captured from one of the many conducted experiments. As it is observed that health of the cell shoots up progressively as the firemen arrive at the affected location. Later, it stabilizes at a value denoting a complete management of the fire and ensuring absolute safety.

Figure 7: Health chart of the affected cell

The second plot, shown in figure 8, is also captured from the same experiment as the one mentioned above, denotes the number of assistance received to manage the fire disaster. It records the number of professionals versus the number of citizens that reached the affected cell to mitigate the disruption. Figure 8 illustrates that four professionals reached the affected cell whereas one of the citizens attempted to provide help and then one more joined them later.

Figure 8: Citizens vs Professionals

Figure 9 displays various experiments conducted on the designed system. The time is tracked using the tick count feature of Netlogo programming language. It is observed that when professionals and citizens merge equally to mitigate the disaster it takes average amount of time, when only professionals are handling the disaster it is the most efficient, and when the professional response is inadequate or delayed
the citizen’s response rises but the time spent to manage the disaster is significantly a lot.

![Figure 9: Conducted multiple simulation and tested in different scenarios](image)

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<tr>
<th></th>
<th>Citizens</th>
<th>Professionals</th>
<th>Time</th>
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<tbody>
<tr>
<td>Exp 1</td>
<td>2</td>
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<tr>
<td>Exp 3</td>
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Figure 10: Table that records various response received during multiple disruption simulation

5. CONCLUSION & FUTURE WORK

This paper introduces a simulation system for fire disruption management. The motive behind the development of such a system is to support experimentation and evaluation of safety metrics that attempt to reduce the effect of a disruption with practically zero cost. The devised system uses an agent-based modeling approach to simulate autonomous agents and show interaction in a virtual environment. Plus, the implemented agent-based model examines the relationships and system interaction of the interconnected systems like professionals and citizens.

The ABM system comes handy in the planning stage of emergency administration and is extremely flexible in adopting varied user specifications and inputs that correctly depict a real fire disaster. Adequate safety metrics is of paramount importance as the regular civilians and additional valuable resources need to be guarded.

Further, the paper successfully described simulation of multiple fire events where the system captured both the community and professionals response during an emergency. The simulation continues until the health of the cell is stabilized. Besides, the health monitor of the negatively affected cell showed slower disaster management when the professional response is delayed.

The designed system could be further expanded by incorporating intricate model through adding individual agents decision-making ability. Additional human habits during an emergency such as panic and random motion could be captured and embedded in the model. A different aspect of system improvement could be applying the fire spread rate with regards to the wind or temperature characteristics of the environment.

Thus, implemented a decision support system which is employed to guarantee timely, economical, and effective emergency management.

6. ACKNOWLEDGMENT

I would like to extend my sincere gratitude to Dr. Carol Romanowski for giving me this opportunity to design such a critical and interesting system. Also, for constantly guiding, mentoring, and motivating me while developing this work.

7. REFERENCES