TENDENKO: Agent-Based Evacuation Drill and Emergency Planning System

(Demonstration)

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ABSTRACT

Evacuation drills are conducted periodically with the intent of practicing smooth evacuations from buildings, and for practicing rescue operations at emergency sites. An agent-based evacuation simulation with information diffusion provides a platform for simulating human evacuation behavior during emergencies that can be affected by various social and human factors. TENDENKO aims to conduct evacuation drills at buildings where real drills cannot be conducted, and to improve the buildings' evacuation planning in order to save more lives during future emergencies.

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1. INTRODUCTION

During emergencies, it is extremely important to egress safely from buildings, as well as to perform rescue operations quickly. Evacuation drills are conducted periodically at schools and shopping malls with the intent of practicing smooth evacuations, and to practice conducting rescue operations properly. The drills are used to estimate egress time and to improve prevention plans for predictable emergencies. However, it is difficult to conduct drills involving many people in real environments under various scenarios.

Disaster reports have provided crucial lessons on reducing human casualties. One key lesson is that people tend to respond individually during emergencies. Emergency information is usually announced through speakers or circulated as people communicate with each other. The rapidity with which people respond to announcements and the behavior people demonstrate can influence their own lives and those of the people around them. Evacuation announcements significantly influence human behavior during emergencies.

Drabek's study on a 1965 Denver flood found that most behavioral responses could be classified into four categories, namely, appeals to authority, appeals to peers, observational confirmation, and latent confirmation [2]. The National Institute of Standards and Technology documents related to the World Trade Center attacks on September 11, 2001, and reports from the cabinet office of Japan on the manner in which people evacuated during the Great East Japan Earthquake and the resulting tsunami on March 11, 2011, revealed similar evacuation behavior patterns and individual responses over the past 50 years, despite changes in the manner in which people communicate [1][3].

In order to evaluate the effectiveness of evacuation drills, it is necessary to analyze human evacuation behaviors from two perspectives: the evacuee's and the rescue responder's. From the evacuees' perspective, the main concern is how quickly and safely they can evacuate buildings. Conversely, the rescuers' main concern is how smoothly and efficiently they can reach the target points and begin rescue operations. TENDEKO [1] provides the following features in a simulation of the evacuation of a crowd of heterogeneous agents (i.e., evacuees and rescuers) in realistic situations. First, emergency information is announced to agents; agents then communicate information about evacuation via various methods. Second, the agents have social and personal relationships among them and behave according to their roles within the relationships. Third, some rescue agents move against the flow of evacuee agents, thus introducing perception-driven behaviors at the reactive level.

2. SIMULATION FOR EVACUATION DRILLS

2.1 Simulation Platform

In emergencies, humans behave much differently than usual. People's mental state affects their behavior. For example, when people are scared about their physical safety, they tend to think only about themselves, and therefore, they will flee from a building without consideration for anything or anyone else. However, when no anxiety is experienced, people tend to consider others and will evacuate together. Social relationships among people, their emotions, and other factors are also different from individual to individual. Perry et al. used their study's empirical findings to summarize these human relationship factors in decision-making processes [5].

TENDENKO consists of an authority setting mode and an evacuation simulation mode. The evacuation simulation

[1]Named after a Japanese tradition of saving lives from tsunamis.

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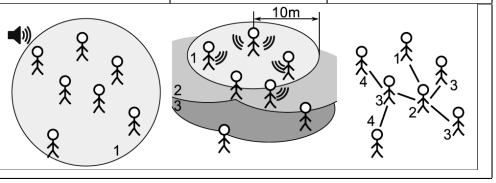
Table 1: Communication methods used to communicate emergencies to others.

types	broadcast	face-to-face	SNS
range	entire building	surrounding	no range
number	large	small	middle
trust	low	middle	high
			

mode can simulate the behavior of people during emergencies, taking people's social and psychological factors into consideration [4]. Following are two main components of the simulation system:

Agents: The number, location, role, and type of agents are set in the authority mode according to the drill scenarios. The agent roles are rescuers, security officers, and evacuees. The different agent types specify their actions upon hearing alarm bells: some people evacuate immediately; others do not, despite hearing announcements made by authorities. The agents' behaviors are represented in the BDI models.

Environments: The environments are 3D CAD models of buildings with different communication model parameters. Three different types of communication models are implemented in the present version. Table 1 lists three types of parameters: broadcast (announcements), face-to-face (word of mouth), and social network (e-mails).

2.2 Examples of Evacuation Scenarios

The following are two examples of evacuation drills that were simulated using TENDENKO.

Evacuation from a subterranean shopping malls.

Many people visit malls. Fig. 1 (a) illustrates one of the subterranean malls in our city. The mall has approximately 90 shops distributed into three rows; there are two main walkways between the rows. Exits to the ground level are located every 50 meters. A total of 4,039 people were randomly placed throughout the mall. After reviewing TENDENKO's simulation, the management company from this particular subterranean mall prepared emergency manuals, and periodically conducts drills based on these manuals.

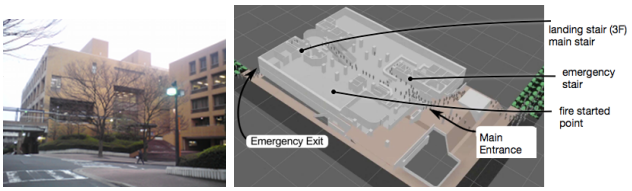
Evacuation from a building and rescue operations.

Many people work in buildings. During emergencies, rescue teams enter the building to conduct rescue operations as the building occupants evacuate the building. Fig. 1 (b) shows a facade of a five-floor library building and an image of the agents' behavior on the second floor. The scenario depicted is of 1,000 occupants (200 occupants on each floor) evacuating the building at the same time at which a rescue team enters the building for rescue operations.

3. DISCUSSIONS AND SUMMARY

During emergencies, emergency information is crucial to evacuate people safely from buildings and to conduct rescue operations quickly. Today, nearly everyone has a mobile phone, and people communicate with each other using SNS. This type of communication has increased the number of

(a) Mall interiors and the initial position of 4,039 agents. (Middle arrow points to an agent who say the first emergency via face-to-face or social networking communication).)



(b) Library facade (left) and snapshot of agents' behavior on the second floor (right).

Figure 1: Simulations of evacuation scenarios.

people who can be alerted of ongoing emergencies, has the potential of assisting in the instant evacuation of many more people than was previously possible, and they can help improve emergency prevention plans.

TENDENKO supports communication among agents by providing evacuation guidance to agents via face-to-face and SNS communication models in addition to the traditional broadcast announcements using PA systems. The differences in the communication methods, the content of such communication, and the source of announcements can cause different simulation results. The simulation results that we obtained indicate that TENDENKO can evaluate existing emergency planning systems and improve the effect of such planning in buildings and areas where evacuation drills cannot be conducted to plan for real situations.

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