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Exhaustive analysis with a pedestrian simulation environment for assistant of evacuation planning

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Abstract

In this paper, we apply an exhaustive analysis to large-scale pedestrian flow in evacuating against tsunami. The exhaustive analysis is a method for understanding the tendency of behavior of a social system based on massive simulation scenarios. With the pedestrian simulation environment, we verify evacuation plan from the point of view of the number of the evacuees and overlapping of evacuation routes. As a result of our exhaustive analysis with 17,496 scenarios, especially in the case with many evacuees, an evacuation plan is required to guide evacuees to prevent from concentration rather than guide to nearby evacuation facilities.

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1. Introduction

Recently, although the clock rate of processors has not increased rapidly, calculation speed has been increasing owing to multiprocessor/multicore technology and GPU acceleration. Furthermore, rapid progress of cloud computing environments has afforded opportunities to deal with problems that require large-scale computational resources. Therefore, we can now treat social phenomena precisely without simplification and parameterization because we have enough computational power.

Conventionally, in modeling social phenomena, only essential parts are modeled, and the social behavior is simplified and parameterized as an environment. However, we have one problem: the number of simulation conditions increases exponentially. For example, in a model that consists of eight parameters, each having ten possible values, the number of combinations is 10^8(i.e., 100,000,000). To understand the response of this model to change in parameters, verifying an enormous simulation scenario, one that is a combination of all parameters, becomes necessary. Although we have sufficient computational resources, there is no established method to treat a massive number of simulation scenarios efficiently with parallel and distributed computing technology on a computer cluster environment.

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Based on this problem, we propose an exhaustive analysis as a method of using computing resources efficiently. This exhaustive analysis aims to understand the tendency of behavior of a social system under various conditions. The emphasis of the exhaustive analysis is not only on identifying optimal solutions but also revealing the stability of such optimal solutions and the difference between the optimal and worst cases.

In this paper, we simulate evacuation against tsunami. After the 2011 Great East Japan Earthquake, evacuation plans against tsunamis were made by local governments because the earthquake triggered powerful tsunami waves, and the tsunami caused extensive and severe damage. However, in the plans, only the locations of tsunami evacuation facilities are described. The plans do not consider congestion of vehicles and persons by overlapping evacuation routes and other realistic factors such as route choice mechanisms, physical ability of evacuees, and the degree of damage caused by the disaster. This is because there exists no reasonable technology to assist in creating and estimating evacuation plans. Therefore, as the first step in our research on exhaustive analysis within the pedestrian simulation environment, we verify the influence of overlapping evacuation routes on evacuation time under severe road conditions. In our simulation, for creating a realistic situation of tsunami evacuation, the position of evacuation facilities against tsunami and the road network pattern and size are based on actual data. Then, the number of the evacuees is calculated based on actual daytime population.

To apply exhaustive analysis to large-scale pedestrian flow, we implement the pedestrian simulator CrowdWalk and the simulation controller PRACTIS. CrowdWalk simulates pedestrian movement based on different granularities and calculation speeds. PRACTIS enables the automatic execution of CrowdWalk for exhaustive analysis.

In Section 2 and 3, we explain the characteristics of CrowdWalk and PRACTIS for exhaustive approach. In Section 4, we apply our exhaustive approach to verify a plan to evacuate 10,000 people against tsunami. Section 5 presents the conclusions.

2. CrowdWalk pedestrian simulator

2.1. Components of CrowdWalk

Our CrowdWalk pedestrian simulator is built around a one-dimensional space model and is composed of three parts: a Network Map Editor, a Simulation Engine, and a 3D Viewer. Using the Network Map Editor, CrowdWalk users can edit network map files to represent evacuation routes, including rooms, corridors, and emergency stairs in buildings and facilities. Network map files thus describe the area around which pedestrians can move. The Simulation Engine updates the position of all pedestrians at every time step according to the pedestrian movement models (Following model, Density model, and Expected Density model). There are three types of input files for the Simulation Engine: network map file, pedestrian data file, and simulation setting file. Network map files describe movable network structures with links and nodes. Pedestrian data files describe the time and link at which pedestrians are generated as well as their destinations. In simulation setting files, various parameters, such as the pedestrian movement model, update interval, simulation termination conditions, and required output data, are described.

Regardless of which pedestrian movement model is selected, the input and output data structure of the CrowdWalk Simulation Engine reamins the same. It is easy for a CrowdWalk user to apply multiple pedestrian movement models because there is no additional model calibration required. Both the network map file and pedestrian data file can be applied to multiple pedestrian movement models without modification. Furthermore, using gas diffusion files, the Simulation Engine can calculate the detriment to individual pedestrians.

2.2. Pedestrian model

2.2.1. Spatial representation

A number of evacuation simulators have been developed recently for various applications (Kuligowski and Peacock (2005)) [1,2,3]. Most pedestrian simulators use a two-dimensional continuous space model and a cellular automata

[1] A&A Co., Ltd. SimTread (online). http://www.aanda.co.jp/products/simtread/index.html.
[2] Legion International Limited. Legion studio (online). http://www.legion.com/.
[3] Savannah Simulations AG. SimTalk (online). http://www.savannah-simulations.com/simwalk/index.html.