Developing Agent-Based Tsunami Evacuation Model for Pedestrian and Car Evacuees

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INTRODUCTION

Appropriate evacuation strategies play an important role in saving lives during tsunamis. Evacuation by vehicle is generally not recommended, as it would induce severe congestion on roads. Nevertheless, it could be helpful for vulnerable people (e.g. the disabled, elderly, or infants) who live in an area which a tsunami would reach immediately after an earthquake, and cannot walk fast. Despite this, to date there are few simulation tools that can accurately reproduce the evacuation behavior of both pedestrians and vehicles as well as the tsunami inundation process. To help disaster risk managers with this problem, the authors newly developed an agent-based tsunami evacuation model that can consider both tsunami wave hydrodynamics and the behavior of both of these types of agents (i.e. vehicles and people) during evacuation.

METHODOLOGY

The model was developed base on the tsunami evacuation simulation by Takabatake et al. (2017). The moving speed of a pedestrian evacuee was defined to change according to the crowd density on a road. In contrast, the idea of an Intelligent Driver Model (Treiber et al., 2000), which can consider the interaction between itself and the vehicle in front, was incorporated into the model to express the moving speed of each vehicle. While the pedestrian evacuees were assumed go to the closest evacuation place via the shortest route, car evacuees were modelled to choose a main road instead of the shortest route along minor roads. In order to express this tendency, the general Dijkstra algorithm (to calculate the shortest route, see Dijkstra, 1959), was improved to consider the width of a road, and evacuees' preference to take wider roads. In the present study, the effects of the change in the preference to take wider roads were investigated. The change in route choice of pedestrian and car evacuees due to tsunami induced inundation on a road was also considered in the model.

RESULTS

The model was first validated through comparisons with the actual traffic jams observed at Tagajyo City, Japan during the 2011 Tohoku Tsunami. Through this validation, the level of preference to take wider roads were varied and found to be important to reproduce the locations where traffic jams took place (the authors collected several testimonies from survivors regarding the traffic jams that took place). Figure 1 shows an example of the comparisons, in which the traffic jams reported could be accurately reproduced.

The model was then applied to another coastal city in Japan (Shinguu City) to investigate the effectiveness of an evacuation plan that considers vehicle use for evacuation during the future Nankai-Tonankai Earthquake Tsunami. To investigate the effects of the number of people choosing to evacuate by vehicle and the level of preference to take wider roads on mortality rate, the car usage rate and the level of preference was varied. One example of the results is shown in Figure 2, with the number of casualties being found to reach a minimum when the car usage rate was set to be 25%. This shows that the developed simulation model can be a valuable tool for city planners and disaster risk managers to understand the proportion of citizens that should be allowed to use cars for tsunami evacuation.

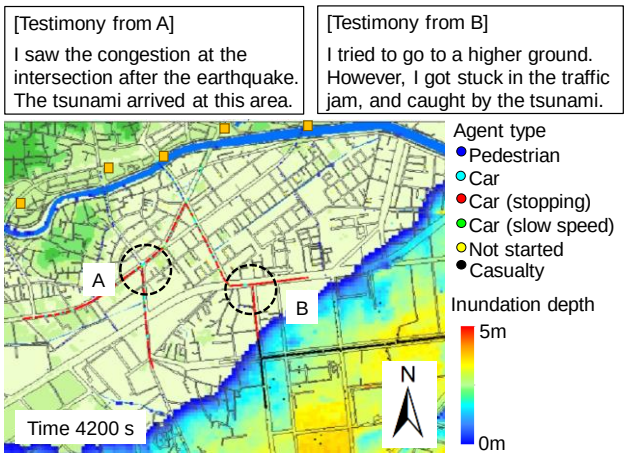

Figure 1. Example of comparisons between simulated traffic jams and those observed by survivors during the 2011 Tohoku Tsunami. Red colored dots indicate the traffic jams.

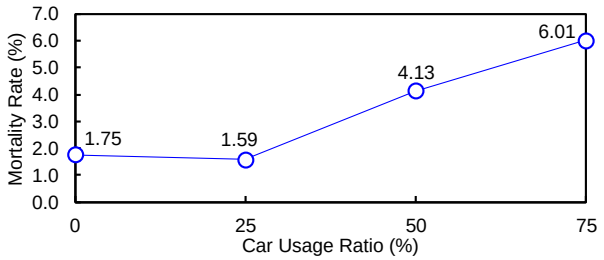

Figure 2. Calculated mortality rate with respect to car usage ratio.

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