Tsunami evacuation modeling and its integration with inundation simulation for planning shelters and evacuation routes

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1. Introduction

The 2011 Great East Japan earthquake and tsunami destroyed several structural tsunami countermeasures. However, approximately 90% of the estimated population living in areas at risk of tsunami survived due to a rapid evacuation to higher ground or inland. Once again evacuation proved to be one of the most effective measures to reduce casualties. Thus, understanding the process of tsunami evacuation could lead to finding better solutions to avoid future casualties and ensure people's prompt reaction. This abstract aims to point to past, current and future research towards effectively integrating tsunami inundation simulation and tsunami evacuation modeling.

2. Integrated model of tsunami inundation and evacuation

We developed an evacuation model that integrates tsunami inundation and evacuee's decision and response to tsunami. The model was developed using the multi-agent approach. Figure 1 shows a summarized scheme of the model framework[1)]. It consists of inputs provided by spatial data in GIS format, human data related to evacuee preferences obtained from questionnaire results, a component of hazard which is provided by the TUNAMI inundation model output, and a set of agent behavior rules. Available outputs from the model are casualty estimation, evacuation times, identification of bottlenecks, analysis of shelter demand, etc.

Within the model, we provided agents with the minimum necessary capabilities to process information and execute evacuation actions through simple behaviors divided into layers:

a) Evacuation decision: We studied the decision and timing for starting evacuation based on questionnaire surveys from past and future hypothetical events. Here we proposed tsunami departure curves as an estimation of the overall behavior of the population in study[1)].
b) Shelter decision: We explored nearest shelter solutions and random selection of shelters. We discuss the demand and capacity of shelters considering spatial allocation[2)]
c) Route decision and path finding: We used A* (A star) algorithm with heuristics in grid space to ensure continuous dynamics.
d) Pedestrian dynamics: Speed variation is estimated from a one-tail normal distribution of evacuee density in the agent field of view.

The model was verified using the 2011 Great East Japan Earthquake and Tsunami data from the evacuation in Arahama, Sendai and Yuriage, Natori in Japan[3)].

3. Tsunami evacuation guidance through reinforcement learning algorithm

To estimate human losses and the survivability of evacuees in the case of an earthquake and tsunami we also developed a model that uses a reinforcement learning algorithm. It considers the road network to calculate the best action-to-take at each node which, with higher chances, will lead to safe haven. A matrix

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of nodes and their corresponding best strategy is used when simulating the movement of the population. Within the reinforcement learning framework, the road network represents the environment in which the agents interact, and a state denotes the information an agent perceives from the environment when it is located at a certain node of the network. In the model, a state may be composed of the node in which the agent is located and the links available to move to a consecutive node. These nodes and links carry information of pedestrian density, damaged condition, and so on. When an agent arrives at a node, he/she has a set of options to continue moving: the links, which are called actions. The effect of every chosen action is quantified by a reward. A reward is assigned to an agent based on whether it arrived or not at an evacuation shelter. In reinforcement learning, the main target is to find the best policy that maximizes the long-term reward (i.e. the accumulated reward from the beginning to the end of the simulation), which is intimately associated with the best evacuation route.

4. Perspectives for Collaboration

After a basic understanding of the tsunami evacuation process and a model built from it, we aim to deepen our knowledge on human behavior in emergencies and improve the agent behaviors that are set in the current model. During the workshop we expect to discuss how tsunami evacuation modeling can be used for planning and tsunami disaster mitigation.

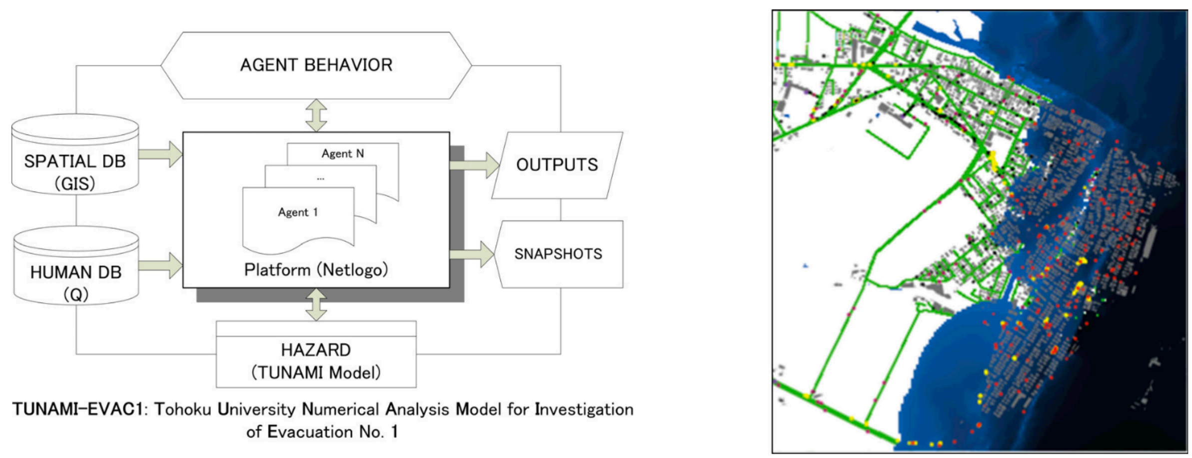

Figure 1 .- (left) Simplified framework of the tsunami evacuation model. (right) A snapshot of the model ran in Yuriage, Natori

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