



DEVELOPMENT OF TSUNAMI EVACUATION SIMULATION AND ITS USING AS DISASTER EDUCATIONAL PROGRAM

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ABSTRACT: Japan Science and Technology Agency (JST) and Japan International Cooperation Agency (JICA) have been developing the science and technology research partnership for sustainable development targeting global issues. With Indonesia government, the joint research of the earthquake volcano from various standpoints was implemented from 2009 to 2011. Authors took charge of development of the tsunami evacuation simulation system in the above project. The system was considered and developed as using of disaster prevention educational program.

Key Words: tsunami evacuation, simulation, disaster education, international cooperation

INTRODUCTION

The Great East Japan Earthquake caused the death or disappearance of nearly 20,000 people, but the 2004 Indonesia-Sumatra Earthquake and Indian Ocean Tsunami caused over 170,000 casualties in Indonesia alone. While the level of knowledge about tsunamis differed greatly between the two countries, proper evacuation behavior could have reduced the number of casualties in both disasters, highlighting the need for disaster management education.

In that vein, independent administrative agencies Japan Science and Technology Agency (JST) and Japan International Cooperation Agency (JICA) have been developing the Science and Technology Research Partnership for Sustainable Development (SATREPS) since 2009. In Indonesia from 2009 to 2011, they implemented comprehensive disaster management plans for earthquakes and volcanic eruptions during which they performed multifaceted, joint research on earthquakes and volcanoes and broadly examined ways to reduce the damage caused by such disasters.

We, the authors, were responsible for developing the tsunami evacuation simulations performed by

the research group within this project charged with promoting disaster management education and increasing awareness. To be specific, we developed a networked multi-agent system for simulating tsunami evacuation built on a combination of tsunami inundation simulations and evacuation simulations and added an on-demand function to the simulator. In so doing, we developed and introduced a system that serves as a resource for disaster management education and urban planning and can be widely used by local educators, children and all citizens. We describe the results in this paper.

DEVELOPING TSUNAMI EVACUATION SIMULATIONS

The target area of this simulation was 10 kilometers in all directions from the city limits of Banda Aceh, Indonesia, and the simulation included around 47,000 agents within the area in family units evacuating on foot, by motor bike or by car and represented the evacuation of the equivalent of 100,000 agents on the computer's road network. Behavioral rules for each agent were set based on the results of field studies conducted on the extremely tumultuous evacuation triggered by earthquakes that struck the city of Meulaboh in April and May of 2010. We will cover more detailed settings in the next section.

To develop the simulation, we first constructed a model with a restricted target area and then simulated disaster management education with students and faculty involved in disaster management at seven elementary, intermediate and high schools in Banda Aceh. We expanded the area to include the entire city upon examining the results of education from amongst all results and interviewing the Banda Aceh Municipal Education Bureau, the Urban Planning Bureau and the Aceh Province Culture and Tourism Department's Tsunami Museum to determine their needs(Goto 2012a).

We also developed an additional simulation system capable of determining on an on-demand basis whether agents whose escape methods are set by individual users evacuate successfully or not compared to other agents. We loaded this system onto DVDs to enable operation by personal computer, and we provided 220 of these DVDs to elementary, intermediate and high schools and related departments in the city of Banda Aceh. We also provided a system easily operable by touch screen to the Tsunami Museum(Affan 2012b).

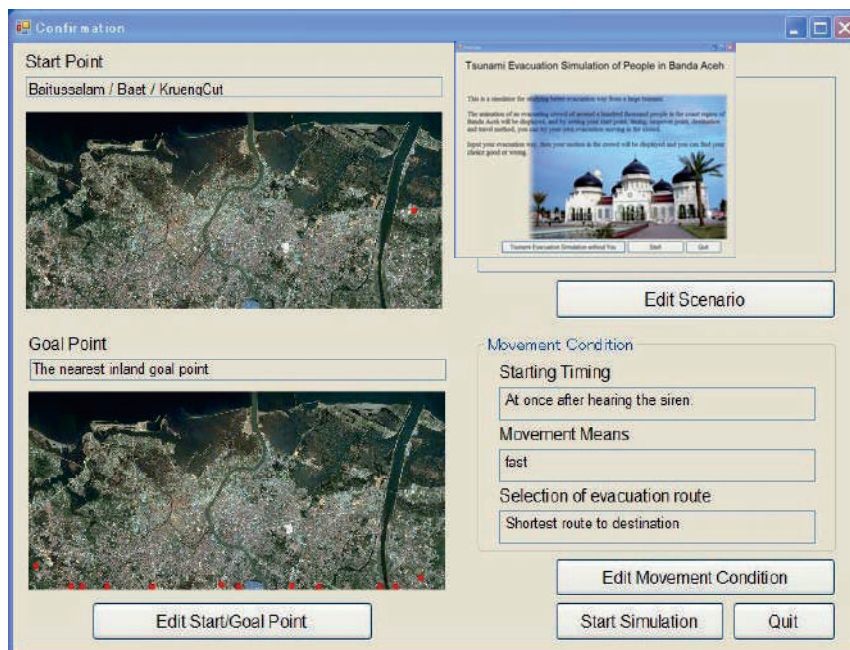


Fig. 1 The main page of tsunami evacuation simulations for educational purposes

DEVELOPED FUNCTION 1: EVACUATION BEHAVIOR CONTROL FUNCTION

The multi-agent simulation we developed simulates individual citizens' escapes based on evacuation scenarios, road network data (Fig. 2), population distribution data and time-series data on tsunami inundation, and it plays back an animated representation of the results automatically.

Below are examples of control rules used:

- Target time period: from the earthquake strike until citizens have evacuated completely
- All citizens are in their homes when the tsunami waves strike
- A tsunami warning goes out about 10 minutes after the earthquake strikes, citizens begin evacuating two minutes after that (some people begin evacuating prior to the warning)
- Evacuation on foot, by motor bike or by car
- Choosing to move toward multiple evacuation buildings or tall buildings that can be used for evacuation or to move inland via main roads on the shortest possible route (Fig. 3)
- Setting by which it is difficult to evacuate toward the ocean
- Changing the destination when evacuation areas reach maximum capacity
- Differing evacuation speed due to degree of congestion, method of escape (on foot, by motor bike or by car), depth of water in cases where tsunami waves have inundated roads, presence of family members requiring special care, width of roads
- The number of casualties corresponds to the depth of the water (one meter)

Below are the results from simulations performed for standard scenarios by the system:

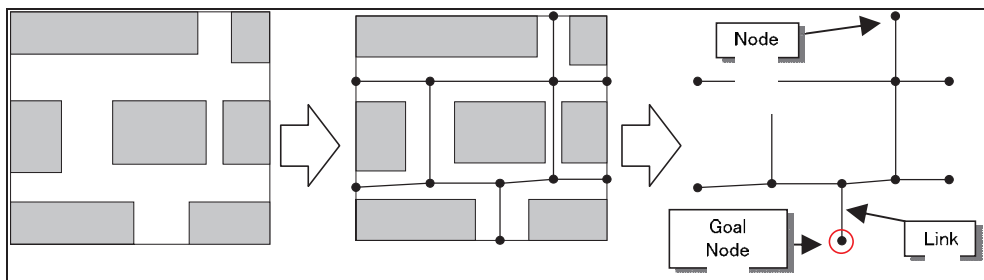


Fig. 2 Network data image

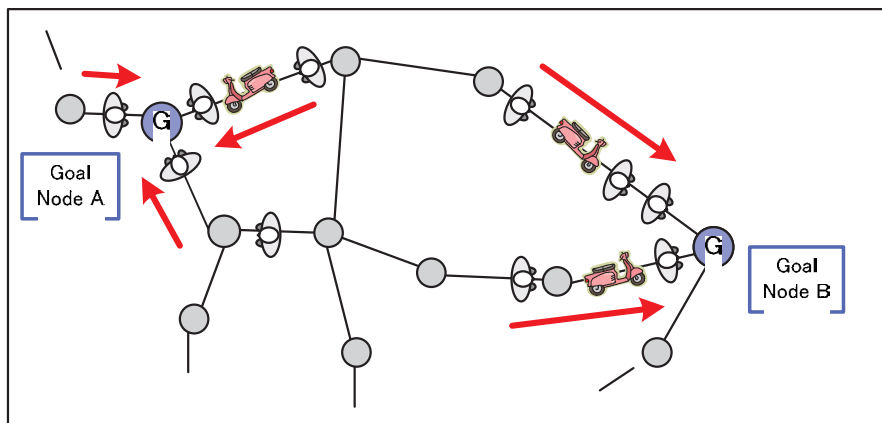


Fig. 3 Evacuation route selection image

- Simulation Settings
 - Escape Method: Car (17%), Motor bike (66%), Walking (17%)
 - Evacuation Timing: As soon as the tsunami siren sounds
- Simulation Results



Fig. 4 Simulation results

Discussion on Verifying Accuracy and Divergence

As mentioned above, we considered settings based on the results of field studies conducted on the extremely tumultuous evacuation triggered by earthquakes that struck the city of Meulaboh in April and May of 2010 to perform these simulations of citizen evacuation within the city limits of Banda Aceh. Extremely tumultuous in the same way was the evacuation from the city of Banda Aceh, capital of Aceh Province on the island of Sumatra, about 400 kilometers removed from the magnitude-8.6 earthquake that struck off the west coast of Northern Sumatra on April 11, 2012. Fortunately, tsunami waves greater than one meter in height did not strike the coast, but over 100,000 people from coastal areas evacuated inland for fear of a tsunami, causing heavy traffic all around.

Figure 5 shows congested areas according to the simulation (places where the speed fell below $1/10$) 30 minutes after the earthquake struck.

The dotted yellow circles in Figure 5 represent places where the simulation captured actual congestion well. The image in the top right of Figure 5 shows an example of a traffic-inducing bottleneck: a road growing narrow just past an intersection.

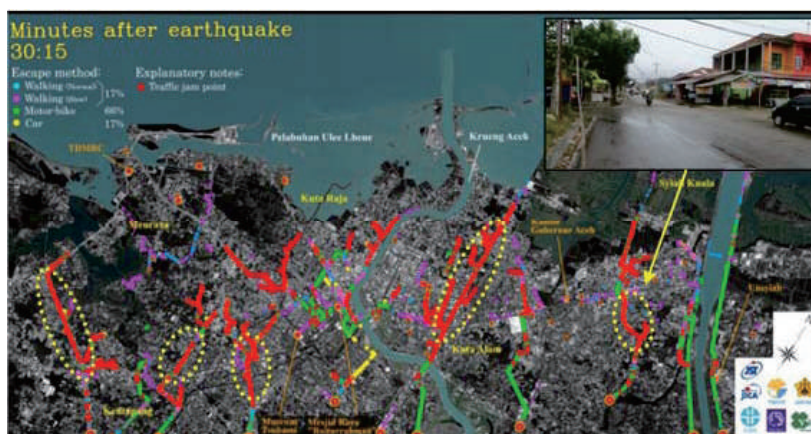


Fig. 5 Congested areas according to the simulation 30 minutes after earthquake strike

DEVELOPED FUNCTION 2: ON-DEMAND FUNCTION FOR EDUCATIONAL PURPOSES

The purpose of this project was to increase awareness of preparation and disaster management before disasters strike by constructing a system that can be widely used by local educators, children and all citizens. We put our heads together toward that end to make the following example items simple enough for children and others to operate themselves and provide realistic results.

- ① Evacuation start time (difference between acting quickly and slowly)
- ② Evacuation start location (home, school)
- ③ Points along evacuation routes (avoiding places that always become congested, etc.)
- ④ Destination (safest high ground, etc.)
- ⑤ Escape methods (walking slowly, walking quickly, motor bike)



Photo 1 Children using the system at the System Delivery Ceremony

CONCLUSION AND THOUGHTS ON THE FUTURE

In this paper, we described the development of an evacuation system for educational purposes based on how evacuation occurs when tsunami waves strike Indonesia as well as examples of how to use that system. We also confirmed the reproducibility of the results of simulations by the system we developed.

However, our system has not yet incorporated settings to account for people returning home from work and then evacuating as we saw during the Great East Japan Earthquake, or for traffic rules at intersections, road closures and other scenarios.

We will continue to fine-tune this system by equipping it with the aforementioned settings. It still needs a tool that enables local authorities to identify areas from which it is difficult to evacuate, consider the distribution of evacuation buildings and make other basic considerations in a quick and cost-effective manner. Thus, we will work to spread disaster management awareness with the simple version of the system in which basic functions of these results are set as defaults (Figure 6) so that it can be used as a tool for the initial examination of evacuation plans as part of the revision of tsunami prediction in Indonesia.

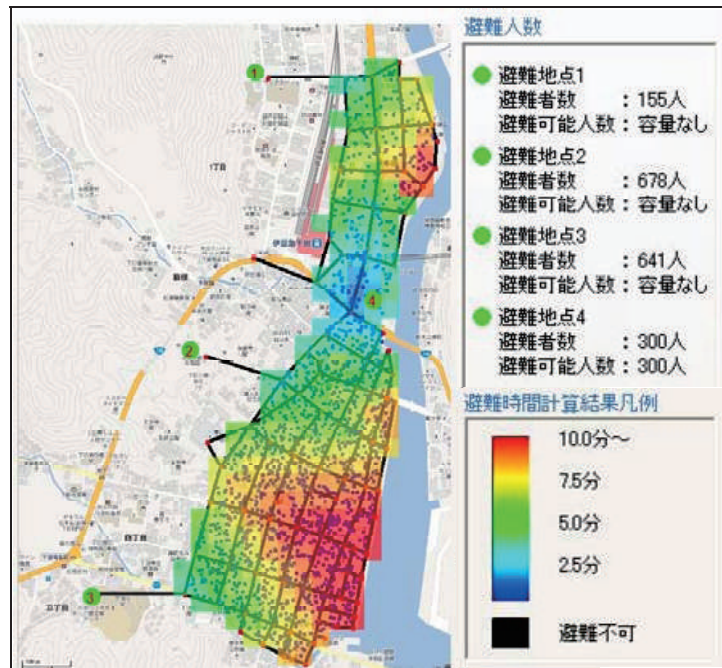


Fig. 6 Output screen from tsunami evacuation simulation, simple version
(development complete : Japanese only)

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