16th World Conference on Earthquake, 16WCEE 2017

Santiago Chile, January 9th to 13th 2017

Paper N° 1172

Registration Code: S- J1464531915

SIMULATION OF EVACUATION BEHAVIOR FROM EARTHQUAQUE IN SNOW SEASON UTILIZING MULTIAGENT SYSTEM

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Abstract

In this study, disastrous earthquake that occurred in the snowy region in the winter is organized, and the investigation result shows the present situation of disaster prevention and future assignment during the wintertime. And the simulation model of evacuation behavior at the earthquake in snow season is proposed by using Multi-agent system. The snowy district as Hokkaido and Tohoku in Japan should pay extra attention to the complex disaster of snow and earthquake, and need to promote the measure for disaster prevention. We are holding many problems due to enlarged seismic disaster caused by collapse of piled snow on streets and roofs, moreover, securing escape route and space for the rescue activities are the big difficulties. However, current disaster prevention measures are mostly considered for the time of the summer, and study of earthquake risk assessment in snow season is a few. The author has developed the earthquake risk assessment system for Akita in consideration of the effect for snow (Mizuta [1]). This assessment system is consisted of three risk factors that are “house collapse”, “street blockage” and “residential isolation”. Based on those data (system), Multi-agent system is applied to Yokote city in Akita. Therefore, the system that simulates the influence of piled snow and roof snow can be showed.

Keywords: Snowy season, Earthquake damage, Multi-agent simulation model, Evacuation, Yokote city

1. Introduction

The snowy district as Hokkaido and Tohoku in Japan should pay extra attention to the complex disaster of snow and earthquake, and need to promote the measure for disaster prevention. We are holding many problems due to enlarged seismic disaster caused by collapse of piled snow on streets and roofs, moreover, securing escape route and space for the rescue activities are the big difficulties. However, current disaster prevention measures are mostly considered for the time of the summer, and study of earthquake risk assessment in snow season is a few. The author has developed the earthquake risk assessment system for Akita in consideration of the effect for snow (Mizuta [1]). This assessment system is consisted of three risk factors that are "house collapse", "street blockage" and "residential isolation".
In this study, the system that simulates evacuation behavior in snow season is developed by utilizing multiagent system. The outline and examples of its application are reported to Yokote city.

2. Example of damage from the winter earthquake and issues for disaster prevention

2.1 Earthquake disaster in snow season in Japan

First of all, we sorted out the history of earthquake disasters that occurred in snow region in the winter. The research paper written by Dr. Kagami [2] has more detail about damage from the winter earthquake. Table 1 is referred from Dr. Usami's catalogue [3] and it shows the disaster that happened between December to March in Hokkaido, Tohoku (side of Japan Sea), Hokuriku and Sanin. The numbers are as showed in "Materials for Comprehensive List of Destructive Earthquakes in Japan". Also, the Fig.1 was made based on the distribution map with epicenter of winter earthquake. The designated area as heavy-snow region and extremely heavy-snow region are showed in color. Half of Japan is occupied with heavy-snow region that is designated by "the Special measures for heavy-snow belt", it possibly snows for four months through December to March that is the 1/3 of a year. There is 1/6 probability of encountering earthquake disaster in the snow, but there have been only few earthquake occurred in the heavy snow as shown in chapter 2. West Niigata earthquake in 1666 had 4.5m of snow and that was the worst. Nagaoka earthquake in 1961 follows to it with 2m of snow. There was Kita-Tango earthquake in 1927 that occurred with 50cm to 1m of snow. The excess weight of roof snow was the direct influence caused by snow. At West Niigata earthquake in 1666, large number of buildings was corrupted, and at Nagaoka earthquake in 1961, discussion had made for the problems about the building damage and excess weight of roof snow. The massive fire disaster from earthquake happened at West Niigata earthquake in 1666, at 1766 Aomori earthquake in 1766, and at Kita-Tango earthquake in 1927, and they ask difficult questions about how hard to stay in the shelter in the snow. Photo 1 shows the damage situation with much more snow after Kita-Tango earthquake in 1927. The interference with snow against rescue action was exposed at Nagaoka earthquake in 1961.

Photo 1 – Kita-Tango earthquake in 1927 occurred in the snow
(Collection of Tango earthquake memorial hall: photographed by Mizuta)

Table 1 – List of damaging winter earthquakes occurred in snowy region

Day/Mo/Yr	M_{JMA}	Name/Region	Damage		
			Human casualties	Building damage	Others
03/02/0830	7.0-7.5	Akita		Collapsed Akita fortress	Land break
28/01/1502	6.5-7.0	Southwest Niigata	Many died in Naoetsu		
01/02/1666	6 3/4	West Niigata	Dead 1400-1500		
08/03/1766	7 1/4	Aomori	Dead 989		Big fire
08/02/1793	6.9-7.1	West Aomori	Dead 12	Collapsed 154	
18/12/1828	6.9	Sanjoh, Niigata	Dead 143	Collapsed 13,149	
07/12/1833	7 1/2	Akita, Niigata			Sand blow
09/02/1834	6.4	Isikari, Hokkaido		Collapsed 23	Sand blow
14/01/1848	6.0	Hirosaki, Aomori		Minor damage	
14/03/1872	7.1	Hamada, Shimane	Dead 804	Collapsed 4,527	
15/03/1914	7.1	Senboku, Akita	Dead 94	Collapsed 640	
07/03/1927	7.3	Kita-Tango, Kyoto	Dead 2912	Collapsed 5,024	Burned 7,527
04/03/1952	8.2	Tokachi-oki, Hokkaido	Dead 28	Collapsed 815	
07/03/1952	6.5	Off Daisyouji, Ishikawa	Dead 7, Damaged 8		
02/02/1961	5.2	Nagaoka, Niigata	Dead 5	Collapsed 220	
26/02/1971	5.5	South Niigata	Injured 13, Damaged 1		
21/03/1982	7.1	Off Urakawa, Hokkaido	Injured 167	Collapsed 9	
15/01/1993	7.5	Off Kushiro, Hokkaido	Dead 2	Collapsed 12	
07/02/1993	6.6	Off Noto, Ishikawa	Injured 1	Collapsed 1	
14/12/2004	6.1	Rumoisityou, Hokkaido	Injured 8	Minor damage165	
25/03/2007	6.9	Off Noto, Ishikawa	Dead1	Collapsed 686	
12/03/2011	6.7	North Nagano, Nagano	Dead 3	Collapsed 73	

M_{JMA}: Magnitude in JMA (Japan Meteorological Agency) Scale

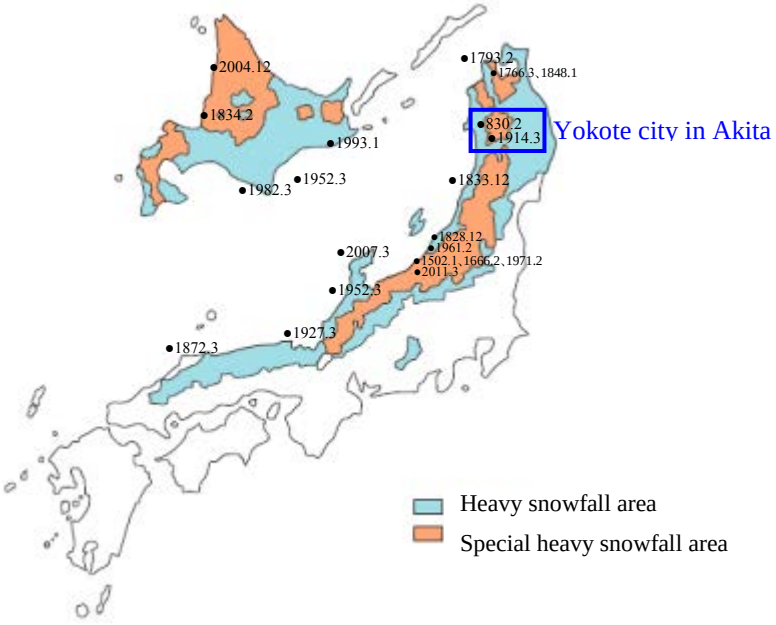

Fig. 1 – Location of winter earthquakes in heavy-snow region in Japan

(The locations of earthquake are added on the figure referred from White Paper Disaster Management in Japan 2013)

2.2 Present situation and future assignment about disaster prevention in the winter

To promote disaster prevention measure, disaster control in the winter is important. Especially when winter earthquake occurs, direct damage from piled snow and roof snow is considered to be increased. Moreover, direct action for the evacuation, the rescue and the emergency medical action in the snow may have many difficulties. On the other hand, present disaster prevention measure is made mostly with consideration for the summer issues (without snow) but not for the winter. Therefore, hearing investigation about the present situation and future issues for the winter disaster prevention has made on the crisis management section and the fire headquarter of Yokote city. (Investigation has made on April, 2013 and on December, 2015) As a result, following concerns are mainly given.

1) Supposition of damage situations with roof snow along seismic intensity has not been taken by Yokote city. Possibilities of damage for buildings, streets, public facilities and residents aren't considered, so that the consideration doesn't come up to the rescue action. Removing snow may be impossible when the large size of earthquake happens.
2) If snow isn't removed from streets, the most of the rescue action will have a big problem.
3) The weight of snow on the roof may close hose doors (especially sliding doors) and block evacuation action of the residents. The back doors are often closed by snow, so there will be few escaping exit because of snow barricade around the houses.
4) To extinguish fire immediately in the snow, the local volunteer fire company usually cooperates for removing snow around the fire cisterns. However, there are difficulties to do so since there are too many of them. There are also many gas leak and kerosene leak because the roof snow breaks plumbing and oil tank when it falls from the roof. When fire breaks out at the buildings, extra caution with roof snow should be paid to extinguish fire, because the collapse is highly expected.
5) The emergency evacuation space for earthquake is likely become a place for snow dumbing during the snowy season. Regular disaster prevention measure cannot react when earthquake occurs in the snow. The emergency evacuation space may be cleared with snow, but not around the exits.
6) It's difficult to secure parking space for the rescue party in emergency situation, because there are the public facilities that don't remove snow from the parking space.
7) It's difficult to prepare with snow slide, so that taking rescue action will not be easy.

3. Simulation outline of earthquake disaster in the snow season

3.1 Outline and present situation in disaster prevention measure with snow season of Yokote city

Yokote city locates South-east of Akita prefecture. In 2005, it became the second biggest city in Akita of over 100 thousand population by municipal merger. It's the one of the districts with heavy snow as it's popular with Kamakura. Photo 2 shows Yokote city in the winter. For the snow control measure, "the Yokote standard snow control measure" was established in 2013. The earthquake disaster measure is placed as the priority issue in the case of emergency. The transmission of information, the evacuation plan considering piled snow, the protection measures from the cold weather, are listed up to be considered to prepare for the earthquake in snowy season. According to the research result that was revised in 2013, the regional earthquake disaster prevention plan is now in the process of build by considering earthquake in the snow.

Photo 2 – Yokote city in the winter

3.2 Scenario

After earthquake, piled snow on the roofs and debris of wrecked buildings may block off the exits and streets. In such situations, residents have to find the way to escape. In the middle of evacuation, each residents has to make a decision if they should help out others, or if they should keep running until they reach the safe place. They also should keep them off from blocked streets and dangerous spots, and finally, need to find the safe way to the shelter. Snow ploughs and other heavy machineries remove snow and debris to clear the way to the shelter. The simulation model is developed based on those scenario.

4. Building simulation model

4.1 How to make database

Artisoc of Kozo Keikaku Engineering Inc. is the developing tool. For the necessary database for the simulation, certain contents are selected from The Digital Maps (Basic Geospatial Information) issued by Geospatial Information Authority of Japan, and those coordinate information is suitably changed for the use on artisoc.

4.2 Outline of the model

"Residents", "vehicles (snow ploughs and heavy machineries)", "buildings", "streets", and "shelters" are defined to design the agent. And the agents of "debris", "snow fallen from roofs", and "rescuee", that are created are modeled according to the disaster situation. Example of buildings and dropped snow from roofs in Fig.2. Because the buildings are coded polygonally (vector data), they are translated by selecting mesh that includes center of the cell in the polygon. Snow that dropped from roof also can be set in 50cm.

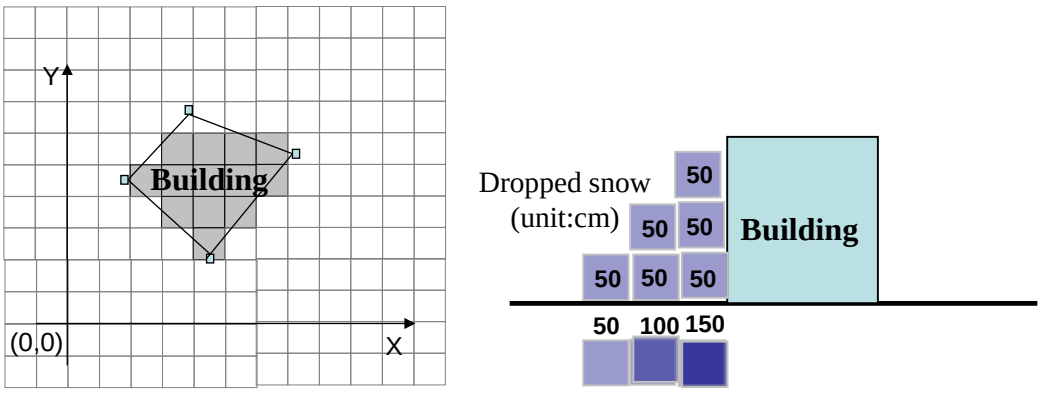

Fig. 2 – Model example (right: building left: snow that droped from roof)

For the evacuation movement, the result that is earned from the shortest calculation with Dijkstra method is used. Also snow ploughs can remove snow from blocked streets, and heavy machineries can clear streets and help residents by removing debris of collapsed houses. By focusing center of Yoko city and its neighbor area, the modelization of space is created with two dimensions grid model of mesh structure of 1m side of a cell, and with the size of North-south 5000 x East-west 4445. Fig. 3 shows the example of simulation model for the winter earthquake disaster in Yokote city.

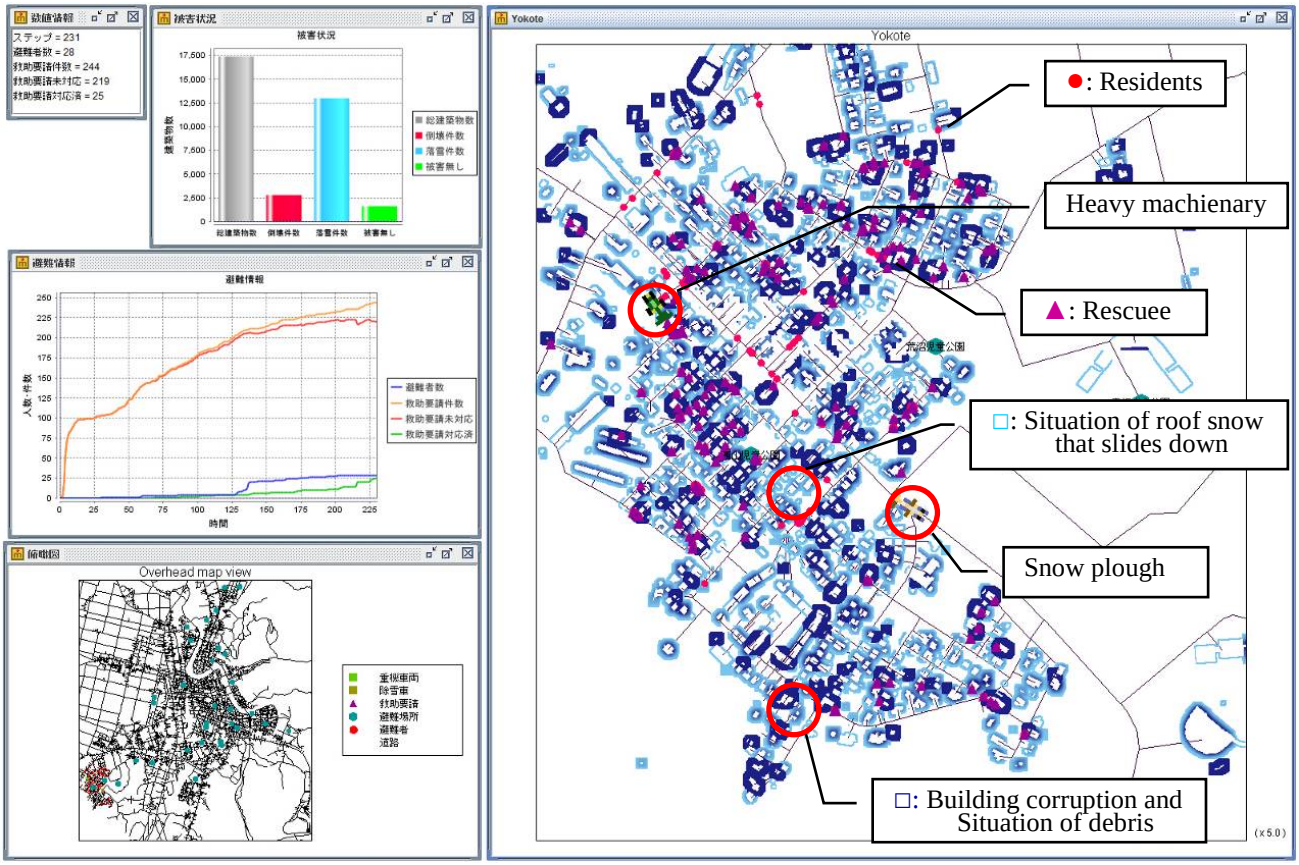

Fig. 3 – Example of winter earthquake disaster simulation model utilized for Yokote city

4.3 Interface

The conditions for the number of residents, heavy machineries, and their speed and performance are freely settable from control panel. Fig. 4 shows the setting screen.

1) The number of agents for residents.

2) Amount of snow.

3) The number of vehicles. (snow ploughs and heavy machineries)

4) Corrupt ratio of buildings

5) Speed of movement. (residents, snow ploughs, and heavy machineries)

6) Performance to remove snow. (taken by residents, and by snow ploughs)

7) Street width after clearance of snow.

8) Display size is resizable.

Fig. 4 – Condition setting screen

5. Concluding remarks

In this study, multi agent model, that can consider condition under influence of piled snow and roof snow, was built. Improvement of the disaster measure will be made by studying its validity and effectiveness within people in charge with disaster management and fire headquarter of Yokote city. There are possibilities for us to have extremely high-risks on the whole process over expansion of disaster, evacuation, rescue action and restoration, when earthquake occurs in snow season. This system is considered to be able to make specific investigation as prioritizing the operation of snowplow and renovation for earthquake resistance by considering the further rescue activity and earthquake disaster prevention measure for snowy district. Also, by developing the literature research with past winter earthquake disasters, disaster situations and points of issue will be organized to consider earthquake disaster prevention in the snow.

6. Acknowledgements

This work was supported by JSPS KAKENHI Grant Number JP12345678. Special thanks to Mr. Shigehiro Ogasawara from Five Tech Link, Ltd. to cooperate with building the model.

7. References

[1] Mizuta, T. (2012): Development of earthquake risk assessment system using GIS for snow country. *Proceedings of 15th World Conference on Earthquake Engineering*, CD-ROM.

[2] Kagami, H. (2004): Specified Problems on Winter Earthquake Disasters at Snowy Cold Region in Japan. *Proceedings of 13th World Conference on Earthquake Engineering*, CD-ROM.

[3] Usami, T. (2013): Comprehensive Bibliography of Japanese Damaging Earthquakes, Tokyo Univ. Press, 605pp (in Japanese).