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# DEVELOPMENT OF EVACUATION SIMULATION SOFTWARE AFTER AN EARTHQUAKE FOR EARTQUAKE PREAREDNESS EDUCATION

**Koichi TAKIMOTO[1] Fusanori MIURA[2] Tomoko IMACHI[3]**

## SUMMARY

Some simulation models have been developed in the field of architecture and civil engineering. However, these models simulate an evacuation behavior in order to consider prevention plan about spaces such as underground shopping centers or department stores. It is impossible for people who are not specialists to simulate evacuation behavior in such places in order to grasp their behavior. Therefore, the author developed simulation software which users such as schoolchildren and teachers can easily used. Therefore, the author developed evacuation simulation software for using earthquake preparedness education by using a personal computer. Furthermore, it was introduced to schoolchildren's and university students , and their evacuation behaviors were simulated after the simulation software developed.

## INTRODUCTION

For years, earthquakes have frequently occurred in Japan and numerous people were either killed or injured in disasters. Many people were also among the casualties caused by earthquake disasters. From these lessons, people who have knowledge about earthquakes and are well prepared for earthquake disasters can avoid damage when they do encounter an unexpected earthquake. So earthquake preparedness is one of the most important and the indispensable factor for disaster prevention measure.

The authors have already developed software for learning knowledge about earthquake prevention by using a personal computer [1]. However, it is very important for earthquake preparedness education not only to learn knowledge about disaster mitigation but also to grasp and understand evacuation behavior after an earthquake. Today, many kinds of computational simulation and simulator for prediction of evacuees' behaviors at a disaster have been developed. However, such simulation or simulator tools are only developed and used for researchers and engineers in the field of architecture and disaster counter measures [2]. From these situation, the authors think it is necessary for people who are not a professional to know their tendency of their evacuation behavior at an a disaster before an earthquake.

[1] Research Associate, Faculty of Engineering, Yamaguchi University
[2] Professor, Faculty of Engineering, Yamaguchi University
[3] Fujitsu Yamauchi Information

Therefore, the authors develop computational simulation software for evacuation behavior that can be performed by the data such as characteristics of evacuees from real-time 3D CG simulator of evacuation by people's operation. People can see their evacuation which is determined by the simulator among other people in a space such as an underground shopping center on screen of a personal computer.

## FEATURE OF SIMULATION SOFTWARE

The software that the author proposed is consists of simulation program, real-time 3D simulator and interface for questionnaires inputs as shown Fiure-1. First, user such as schoolchild answers questionnaires about their characteristics of behavior at a disaster. Secondly, user evacuates two kinds of a simple virtual maze by operating 3D simulator. From these results, the parameters about user's evacuation behavior are automatically determined by the software program. User can see situation of his evacuation among other evacuee models that were determined by the software in a space such as an underground shopping center or a department store on screen of a personal computer. They can learn and grasp tendencies of their evacuation behaviors from the result of the software

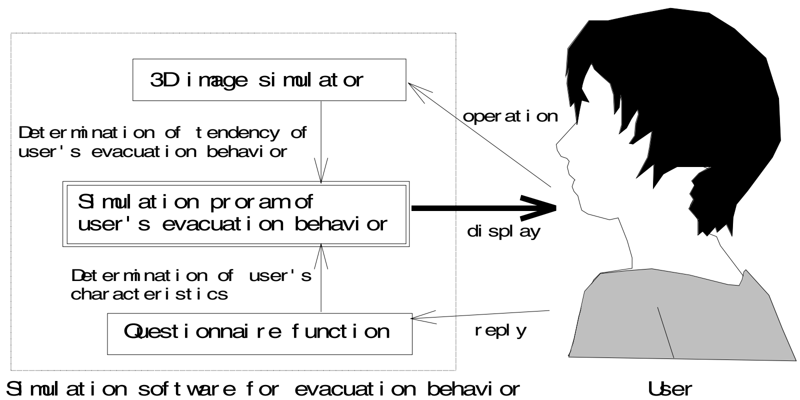


Figure-1 Feature of simulation software

## SUMMARY OF SIMULATION SOFTWARE

### PROCEDURE OF SIMULATION PROGRAMS

The simulation model that the author proposes consists of a floor, fire and human models. Each contents of the modeling are described below.

*Floor Model*

It is difficult and complex to represent space for places such as underground shopping centers, etc., in a computational model. So for the floor modeling, the spaces where people move in, such as, passages and crossings are simply represented with a network of nodes connected by links as shown in Figure-2. An example of the floor model is shown in Figure-2. Nodes and links indicate crossings and passages, respectively. Dots represent the human model that can move on these links.

*Fire Model*

Spreading of fire and smoke is a very complex phenomenon. Therefore, for the fire model after an earthquake, the author assumed that the fire can only break out on a node and smoke simply spreads in coaxial circles as shown in Figure-3. Harmless smoke spreads at first and then poisonous smoke spreads at the velocity of 0.5 m/s after the break out of fire. In this model, the fire does not break out in numerous places simultaneously right after an earthquake but in specific area.

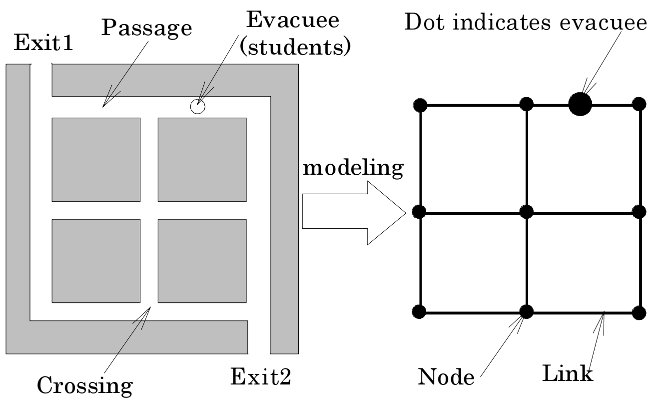


Figure-2 Model of floor

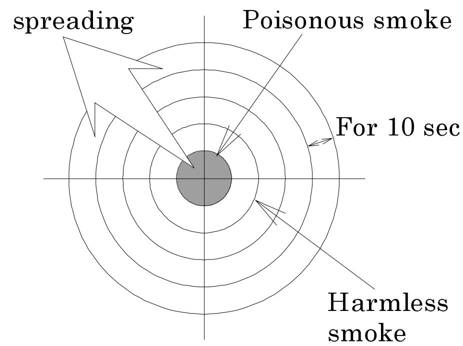


Figure-3 Model of fire after an earthquake

*Evacuees model*

The simulation and character of the evacuation are described in chained codes in the field of image processing. The evacuees have eight codes from A to H. They are summarized in Figure-4. Then evacuee models move and evacuate in accordance with the evacuee's code and the authors' research [3].

| Evacuees code | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|

A: whether the evacuee saw a fire or not. (0:not saw, 1:saw)
B: how long the evacuee stayed in smoke. (0:not stayed, 1:stayed)
C: whether the evacuee has information about the routes to exits or not. (0:no information, 1:the evacuee has information)
D: whether the evacuee arrives at exit or not. (0:not arrive, 1:arrives)
E: whether the evacuee choose the routes where he used previously or not. (0:not choose, 1:chooses)
F: whether the evacuee evacuates with other evacuees or not. (0:evacuate alone, 1:evacuate with other evacuees)
G: whether the evacuee panic or not when he encounter disasters. (0:not panic, 1:panic)
H: whether the evacuee is sensitive to occurence ofdisasters or not. (0:not sensitive, 1:sensitive)

Figure-4 Composition of the codes

## PROCEDURE OF FUNCTION OF QUESTIONNAIRE

In general, evacuees tend to change their evacuation behaviors if they encounter a sudden disaster such as a fire. In this software, user's policy and strategy in an evacuation behavior is determined by the results of 10 questionnaires about character analysis. Function of questionnaires is developed by application software Visual Basic 6.0 (Microsoft Corporation). Results of the questionnaires are automatically saved and evacuees' code G and H in Figure-4 are determined in accordance with the results.

## PROCEDURE OF 3D SIMULATOR

Evacuees tend to choose some kinds of pattern of evacuation behavior when they begin to evacuate at a disaster because past memory influences the choice of evacuation routes. The tendency of user's evacuation routes is determined on the basis of the result of two virtual experiments of evacuation by the 3D simulator. However, it is hard to render real-time 3D CG of virtual mazes by using a personal computer without special software for 3D CG. Therefore, the 3D simulator program is mainly developed by using Direct3D (Microsoft Corporation) in order to draw and move 3D object images such as complex walls or floors of mazes on Microsoft Windows screen without special video devices and software. Screen of simulator is shown in Photo-1.

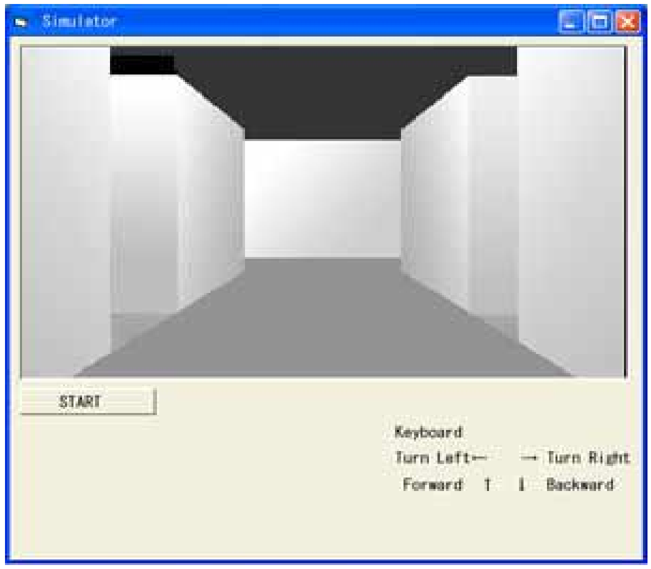


Photo-1 Display of the view-window of the Simulator

3D images of mazes from files in which two kinds of a simple maze were saved displays starting viewpoint of the simulation at initialization. When user pushes buttons on a keyboard in order to move or turn the viewpoint, new locations of floors and walls, etc. are calculated and rendered as new viewpoint by the function of Direct3D. Users can see the motion of viewpoint as if they were walking there by processing input data, calculating and rendering quickly and repeatedly. However, if users collided with a wall, they would stop till they push buttons on the keyboard again.

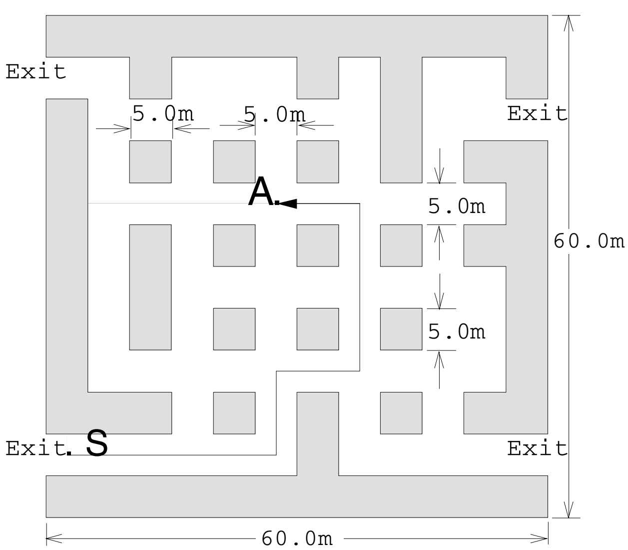


Figure-5 Maze for investigating whether user chooses they used previously.

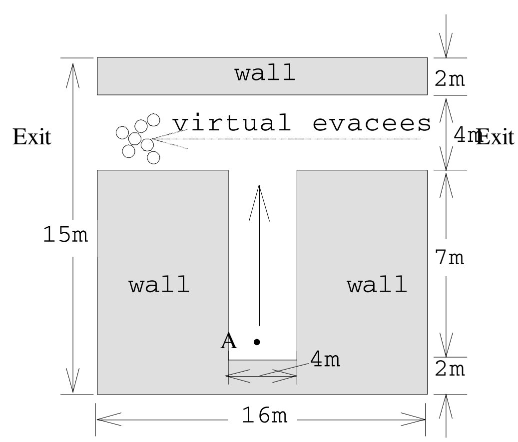


Figure-6 Maze for investigating whether routes where user evacuate with other evacuees.

We have two mazes for a virtual evacuation by using the 3D simulator in order to grasp the differences of user's evacuation behavior. One is to investigate whether users choose the routes where they used previously as shown in Figure-5 and the other is to investigate the influence of other evacuees as shown in Figure-6.

Size of length and width of the maze in Figure-5 is 60m x 60m with 4 exits. Width of passages is 5m and height from floor to ceiling is 2.5m. First, the simulator program guides users to point B along solid line as shown in Figure-5. As soon as user arrives at point B, an earthquake occurs and fire breaks out and a message "Emergency!!" appears. Then users begin to evacuate by operating a keyboard. When user reaches the exit, next view window of the maze appears. From the result of the route, user's evacuee code E in Figure-4 is determined.

When user reaches the exit, the view-window at point A in the next maze as shown in Figure-6 appears. Size of length and width of the maze is 15m x 16m with 2 exits and width of passages is 4m and height from floor to ceiling is 2.5m. As soon as user begins to evacuate in the maze, other virtual evacuees on screen move to the left exit in Figure-6. The view-window is closed and the window of simulation of evacuation appears if user arrives at a left or right exit. We investigate whether users evacuate with other evacuees and user's evacuee code F in Figure-4 is determined from the result of the experiments.

## EVACUATION EXPERIMENT BY USING SIMULATION SOFTWARE

The authors performed evacuation experiments in the simulation software by using underground shopping center model in order to evaluate the simulator that was developed. Testees are 50 students that are consist of four elementary schoolchildren, eight junior high school students and thirty-eight university students. First, testees' characters and patterns of evacuation behavior are gathered by using the simulator and the questionnaire of the software.

The authors also applied the evacuees' codes of 50 testees' behavior to the simulation of evacuation in an actual underground shopping center as shown in Figure-7. Fire breaks out at point A in this figure 30sec after the beginning of simulation. As soon as fire breaks out, evacuees begin to evacuate. Simulation stops when the last evacuee succeeded in evacuating or failed to evacuate resulting in death from fire or smoke inhalation. The time for evacuation is defined as the time when the very last evacuee reaches an exit. The author calculated the number of evacuees who could be killed and the actual time of complete evacuation altered by changes evacuees' code C (0 or 1).

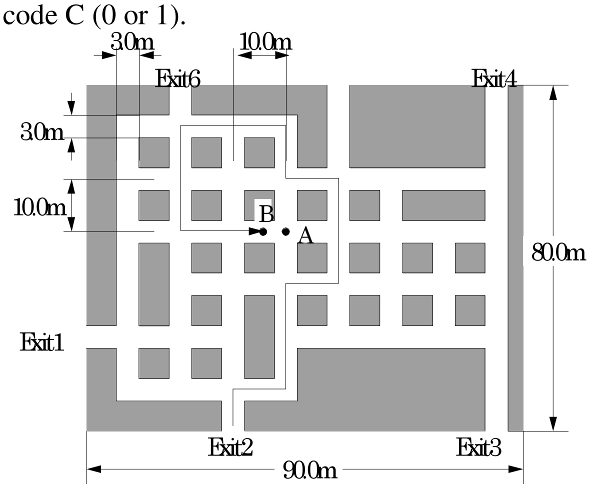


Figure-7 Model of maze with 6 exits

**Result of the experiment**

Classifications of testees' behavior which were gathered from the result of the questionnaire and the simulator are shown in Figure-8. From this figure, we found that most testees tend to evacuate with other evacuees and 60% testees tend to be sensitive to the change of environments.

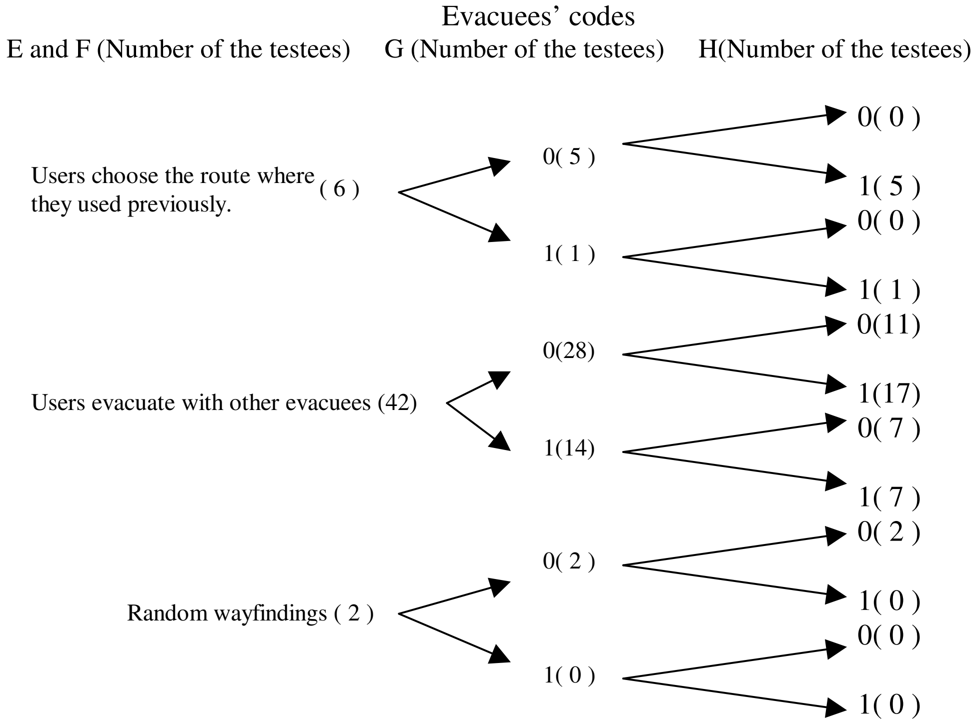


Figure-8 Classification of routes and characteristics of behavior based on the results of the questionnaire and the simulator

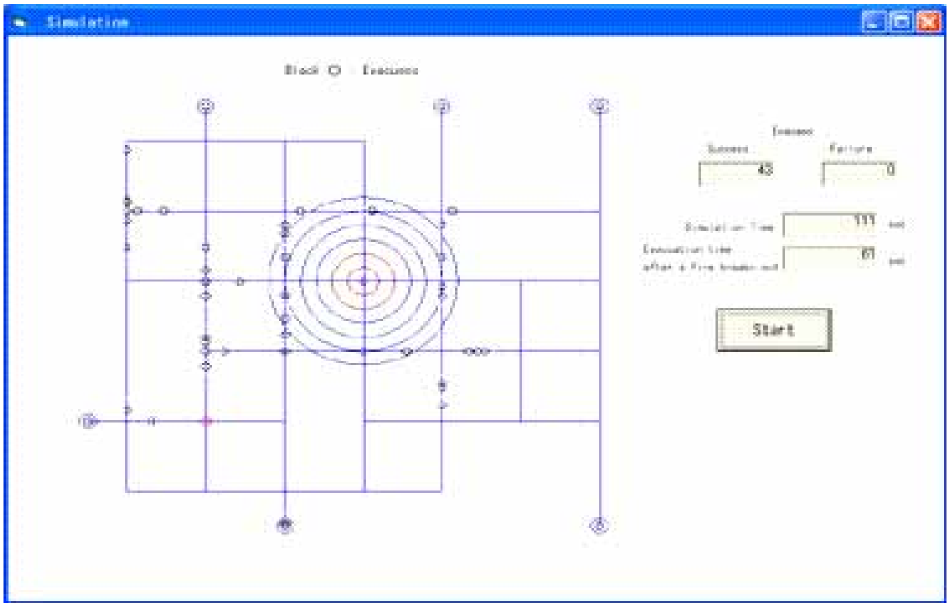


Photo-2 Display of the simulation

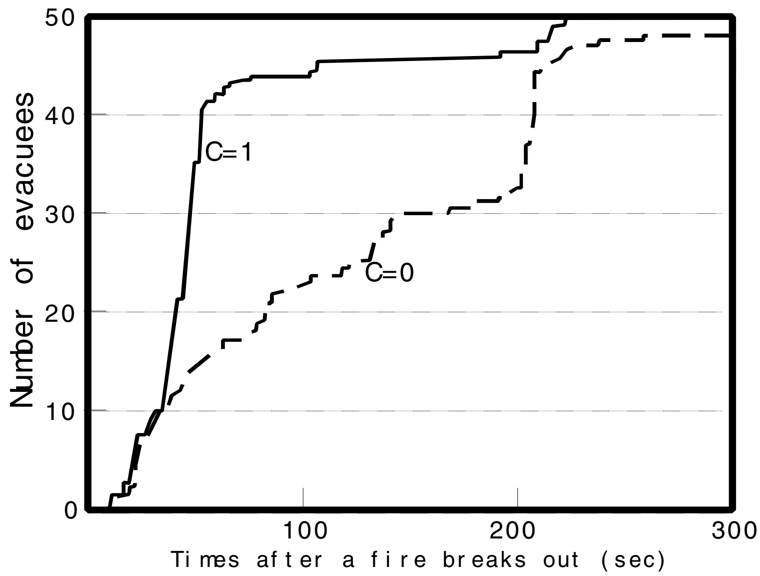


Figure-9 Relation between number of evacuees and time after a fire breaks out

The display of simulation of evacuees after 111 seconds of the beginning of simulation is shown in Photo-2. Symbols › represent evacuees and smoke is shown in coaxial circles in the simulation.

Figure-9 shows us the relation between the number of success in evacuation and the time to complete the evacuation by changing the code C. Full line in figure is the result from the case c=1 and dots line is the result from the case c=0. It is found that virtual evacuees of testees with c=1 are more effective than with c=0. From the result, it was found that information about routes to exits more influenced the effectiveness of evacuation than difference of pattern of wayfindings depended on policy to evacuate.

Finally, the testees were interviewed about the effectiveness of this simulation software after the experiment. As the result, we found that most testees were more interested in evacuation behavior and more wanted to grasp their characteristics of wayfindings by using the software.

## CONCLUSIONS

The author developed evacuation simulation software for using earthquake preparedness education by using a personal computer. The software that the author developed is consists of simulation program, 3D simulator and interface for questionnaires inputs. User can simulate evacuation behavior based on their character and pattern of evacuation behavior among other virtual evacuee models..

Then the authors also tried to apply this simulation model to the actual underground shopping center based on the data of characteristics of behaviors that was gathered from elementary school, junior high school and university students. As the result, we found that the evacuation behavior of other evacuees influenced many testees' choice of evacuation routes even if they were sensitive to the change of environment such that a fire breaks out.

## REFERENCES


1. Kouichi T, Fusanori M. " Development of earthquake preparedness education software for an elementary and junior high school students and its evaluation." Journals of the Japan Society of Civil Engineers, No.619/I-47, 155-167, 1999 (in Japanese).
2. Akira O. "Simulation for Human Behavior at Emergency Evacuation in Underground Structure by using Object Oriented Language." Computer simulation, Vol.2-4, 78-83, 1991 (in Japanese).
3. Kouichi T, Junji K, Fusanori M. "Simulation of evacuation behavior in a disaster and its interaction with guide's instruction." Journals of the Japan Society of Civil Engineers, No.537/I-135, 258-259, 1996 (in Japanese).