EMERGENCY EVACUATION SIMULATION VISUALIZED BY MOBILE MAPPING SYSTEM

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Recently, studies on evacuation simulations have drawn up scenarios of evacuation under various situations. In this study, a system is proposed to show the results of evacuation simulations for disasters such as tsunamis and fires, with maps and serial images taken by MMS (Mobile Mapping System). The all-around view camera, angle meter, and GPS (Global Positioning System) antenna are mounted on a moving object, such as a car, in MMS. The serially-taken images can be related to GIS (Geographic Information System). Users can not only virtually experience the evacuation but also find the dangerous places by observing the 360-degree surrounding image.

Keywords: Cellular automata, Global positioning system, All-round view camera, Virtual reality, Geographic information system.

1   INTRODUCTION

Emergency evacuation plans should be made to prepare for disasters such as earthquakes and tsunamis.   In practice, the route, space, and lead signs for the evacuation are required to be assigned in the area.   The estimation of the damage and required time to complete the evacuation is also important to discuss evacuation scenarios.   A grand-scale emergency escape drill under the cooperation of the community is one of the methods for making such an emergency evacuation plan. However, it is not necessarily effective since various cases of disaster are assumed, and it is not possible to hold drills several times under different conditions in the same area.

Some simulation systems of emergency evacuation behavior have been developed to enable the simulation of the evacuation under various conditions.   These are based on methods like CA (Cellular Automata) and Multi-Agent System. Modeling of the target area is required, which often costs labor and time, delaying the broad use of the simulation.   Tsujihara (2010) developed a user-friendly evacuation simulation system in which the analytical model of the target area was built automatically using the digital residential map. A comprehensible expression of the analytical results is also required for the promotion and implementation of the emergency evacuation simulation system. The objective of this study is to develop the system in which the results of the evacuation simulation can be shown by the location on the map as well as images recorded by MMS (Mobile Mapping System).

2   OUTLINE OF EMERGENCY EVACUTION SIMULATION

2.1   Simulation of Evacuation Behavior by CA

The simulation is carried out by CA (Cellular Automata). In CA, the area is expressed by a grid of cells. Each cell has a state, and it is defined by synchronizing the state of its neighboring cells. CA is generally applied to such the problems that cannot be formulated by dominant equations like differential equations. It enables to solve complex phenomena such as computational theory, biology, heredity, diffusion, and traffic stream, by modelling the problem as the local interaction of cells.

The target area is expressed by the regular grid of square cells in the simulation of the emergency evacuation. The horizontal and vertical size of a cell is equivalent to the average length of a one-second walk. Each cell is categorized into "obstacle", "walk way" and "goal". Evacuees who are allocated on the cell of "walk way" can move to the neighboring cells categorized as a "walk way" per second.

An evacuee travels toward the object cells in the eyesight zone as shown in Figure 1. The object cell, toward to which an evacuee travels, is selected in the following priority order:

1) The cell of goal

2) The cell of sign

3) The neighboring cell to the blind corner

Integral number up to 8, which denotes the direction to travel as shown in Figure 2, is embedded in the cells of sign allocated at some corners. The following additional rules are given beside the above basic rule:

In case that two or more cells of 3) are found in the eyesight zone, the cell for which the angle from the forefront direction is smallest is selected.

If the object cell can not be found in the eyesight zone, it is searched for in the new eyesight zone in the direction of 45 degrees to the present traveling direction. If it fails, it is searched in the new eyesight zone in the direction of 90 degrees to the present traveling direction. If all else fails, the evacuee travels in the present traveling direction. However, if the forefront cell in the eyesight zone is invisible, the road ahead is regarded to be blocked and the traveling direction is changed by 180 degrees.

To avoid back and forth, if one cell is selected by an evacuee, priority order is lowered for the same evacuee. If the cell an evacuee is supposed to move to is occupied, the evacuee moves to a neighboring cell. If all those cells are occupied, evacuee remains.
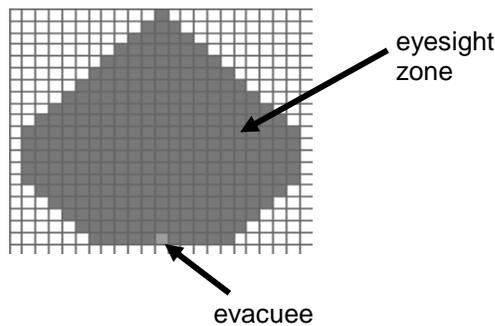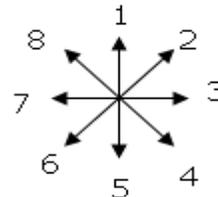

Figure 1. Eyesight zone.

Figure 2. Integral number of traveling direction.

2.2   Analytical Model

A commercially-available digital map is used to build the model for the simulation of emergency evacuation behavior.   It includes information such as residents and streets represented as polygons or an assembly of polygons.   In the computer display in which the residential map of the surrounding area is shown, the target area is assigned by clicking on the map as shown in Figure 3.   Then the coordinates of the vertices of each polygon are read from the database automatically, and the data are streamed to the disk in Microsoft Excel format.

Figure 3. Assignment of the target area on the map.

The data file is read by Excel Macro, and the target area is shown in the sheet of Excel as shown in Figure 4. The cells which correspond to houses and closed area is filled in gray and black, respectively. The cells which are not filled in any color correspond to the walk way.   Then, the cells of evacuees, goal and signs are allocated by filling them in the corresponding colors as shown in Figure 5.
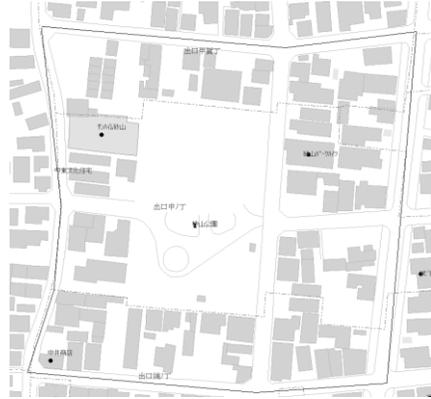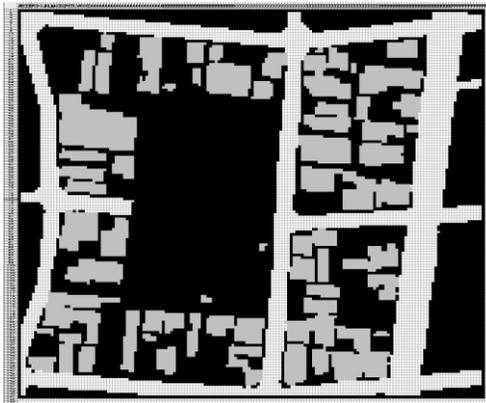

Figure 4.   Model in Excel worksheet.

Figure 5.   Allocation of evacuees, lead signs and goal.

3   MOBILE MAPPING SYSTEM

MMS is the modular measurement system consisting of an all-around view camera, clinometer, GPS antenna, and their base units as shown in Figure 6. The multi-camera system Ladybug3 made by Point Grey Research Inc. is used. The Ladybug3 has six 2 megapixel cameras which allow JPEG-compressed 12 megapixel resolution images to be streamed to disk at 15 frames per second.   Figure 7 shows a sample of the frames in sequence. It contains all pictures recorded by six cameras.

Figure 8 shows it in Mercator projection. Only part of the image in Figure 7 is visualized in Figure 8. However, the 360-degree surrounding image can be visualized by rotating the mouse cursor on the movie window in Figure 8 by right-drag as shown in Figure 9. The location of camera can be indicated on the map by the locator (the arrow on the map in Figure 10).
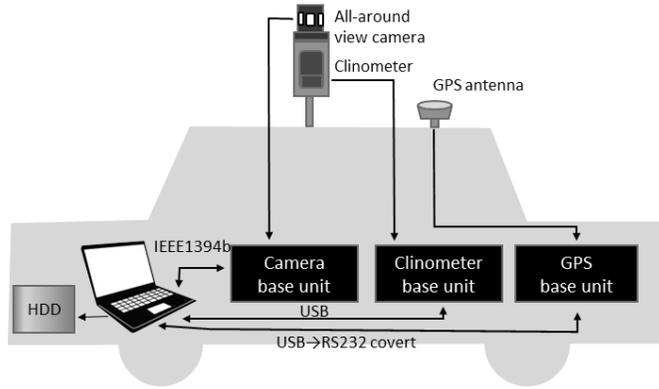

Figure 6. Mobile Mapping System.

Figure 7. Sample frame recorded by six cameras.

Figure 8. Sample frame in Mercator projection.

4   VISUALIZATION OF RESULTS OF SIMULATION USING MMS

Figure 11 shows the map of the target area and the allocation of evacuees in the simulation. Safe entrance is regarded as the goal. Eighty-seven evacuees are supposed to move simultaneously with the speed of 4.5km/h. The expression of the evacuation behavior of all the evacuees in time series is possible with the over image, as shown in Figure 11 (Tsujihara et al. 2014).

The system proposed in this study enabled the expression of a walk-through image of an arbitrarily-chosen evacuee as well as the current location on the map. To choose location of the evacuee were checked. Figure 13 shows the location and the image in the evacuation route of the selected evacuee shown in Figure 12. The location of the traveling evacuee is illustrated by the locator on the map and the view image can be shown. The view image is updated in connection with the location of the evacuee at 10 frames per second. Thus the evacuation can be experienced as if you are the evacuee.
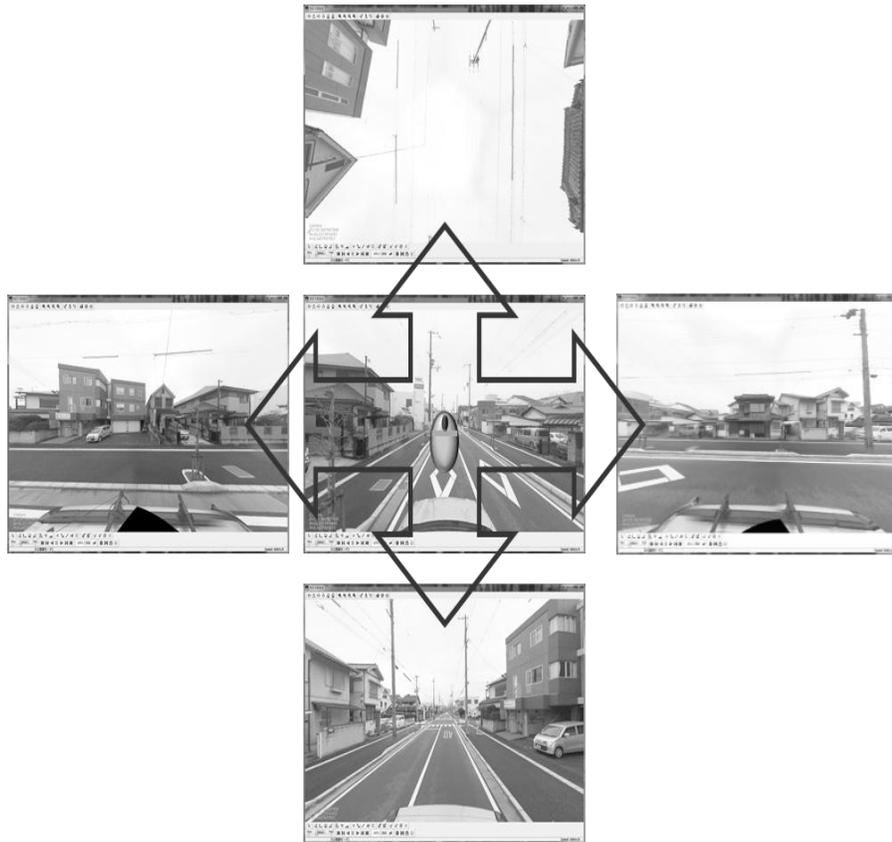
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Figure 9. View point control.

Moreover, you may find something dangerous by observing the all-around image along the route.

5 CONCLUSIONS

A virtual evacuation simulator was developed by the combination of an evacuation simulation and MMS. Users can not only virtually experience an evacuation but also find dangerous places by observing the 360-degree surrounding image.

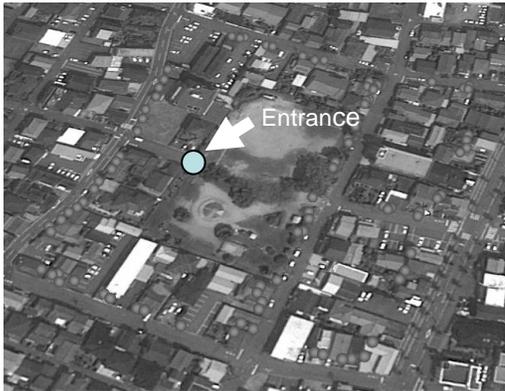Figure 10. Current location on the map.

Figure 11. Map of the target area and the allocation of evacuees (©2012 Geo Eye, © 2008 ZENRIN, © 2012 ZENRIN, Google Earth)

Figure 12. Track of the evacuee used in walk through view (©2012 Geo Eye, © 2008 ZENRIN, © 2012 ZENRIN, Google Earth)

Figure 13. Location of evacuee and the view image.

Acknowledgments

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