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DEVELOPMENT OF AUTOMATIC MODELING SYSTEM FOR SIMULATION OF EMERGENCY EVACUATION BEHAVIOR

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ABSTRACT

In recent years, simulation systems of the emergency evacuation have been proposed. It is required for the development of the simulation systems to verify them by comparing the results of the simulation with the actual human behavior in an emergency evacuation. On the other hand, in the practical use, the modeling of the target area is complex and it takes much labor. This may be the biggest factor which avoids the progress of the simulation of emergency evacuation behavior. In this study, a system is introduced to develop the automatic building system of the analytical model for the evacuation simulation using a numerical map. An example of simulation by Cellular Automata (CA) is demonstrated with the model which is built by the proposed system.

INTRODUCTION

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

In recent years, some simulation systems of emergency evacuation behavior have been developed. These systems enable the simulation of the evacuation under the various conditions. These are based on such methods as Cellular Automata and Multi-Agent System. In the application of the systems, the modeling of the target area is required. It often costs us tremendous labor and time. This is one of the most troublesome problems which delay broad use of the simulation.

The objective of this study is to develop an automatic modeling system using the digital residential map. Almost all the data, which are necessary for the simulation of emergency evacuation behavior, can be created automatically by just only assigning the target area by

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clicking on the map.   The automatic modeling system is introduced in this paper.   Using this system, a simulation of emergency evacuation behavior is also demonstrated.

AUTOMATIC MODELING SYSTEM

Commercially available digital map, which include such information that residents and streets are represented as the polygons or the assembly of the polygons, is used to build the model for the simulation of emergency evacuation behavior.   The automatic modeling system is based on the flowchart which is shown in Fig. 1.   The application programming languages are Microsoft Visual Basic and Microsoft Excel Macro.

On the computer display in which the residential map of the surrounding area is shown as Fig.2, the target area is assigned by clicking on the map as shown in Fig.3.   Then the polygons are highlighted as shown in Fig.4 and the coordinates (latitude and longitude) of the vertices of each polygon are read from the database and stored in the file in Microsoft Excel format as shown in Figs.5 and 6.   The layer numbers and the number of vertices of polygons are written automatically in one of the files (see Fig. 5).   The coordinates of the vertices are written in the other file (see Fig. 6).   The layer numbers of the polygons correspond to the resident, landmark, street, walkway and so on.   The vertices of polygons are automatically numbered serially.   OA-Area 2, produced by Zenrin Co., LTD, and the Active
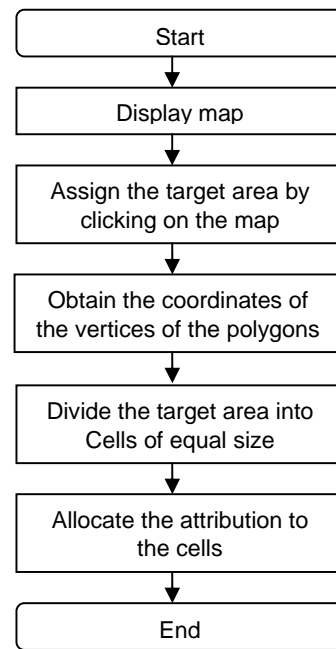

Figure 1.   Flowchart for automatic modeling

Figure 2.   Residential map on the computer display

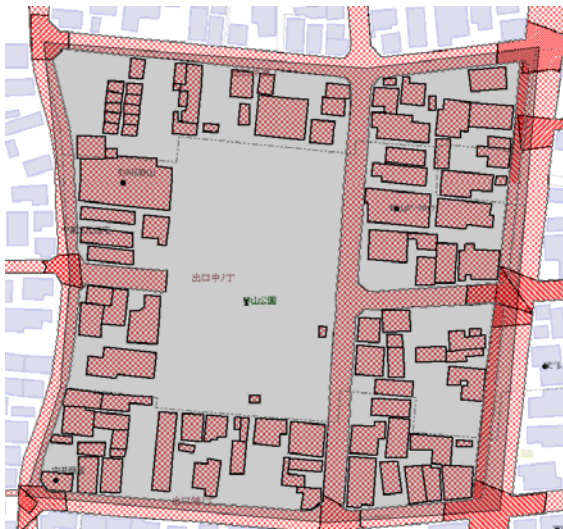Figure 3.   Assignment of the target area by clicking on the map

Figure 4. Polygons in the target area shown by the hatching in red diagonal

	A	B	C	D	E	F	G	H
1	No.	Layer No.	Number of verticies of polygons	Node-1	Node-2	Node-3	Node-4	Node-5
2	1	123	12	1	2	3	4	
3	2	123	21	13	14	15	16	1
4	3	123	14	34	35	36	37	3
5	4	199	5	48	49	50	51	5
6	5	199	4	53	54	55	56	
7	6	199	5	57	58	59	60	6
8	7	209	6	62	63	64	65	6
9	8	209	13	68	69	70	71	7
10	9	216	19	81	82	83	84	8
11	10	216	60	100	101	102	103	10
12	11	216	77	160	161	162	163	16
13	12	216	90	237	238	239	240	24
14	13	216	21	327	328	329	330	33
15	14	216	17	348	349	350	351	35
16	15	216	121	365	366	367	368	36
17	16	217	41	486	487	488	489	49
18	17	217	59	527	508	509	530	53

Figure 5. Excel file in which the layer number and the nodal number of vertices of polygons are written

	A	B	C
1	No.	Longitude	Latitude
2	1	135.1668633	34.21840917
3	2	135.1668775	34.21852222
4	3	135.1668925	34.21863667
5	4	135.166905	34.21875
6	5	135.166905	34.21875
7	6	135.1669472	34.21875
8	7	135.1669286	34.2185925
9	8	135.1669075	34.21843333
10	9	135.166905	34.21842556
11	10	135.1668961	34.21841667
12	11	135.1668883	34.21841167
13	12	135.1668808	34.21840917
14	13	135.1667611	34.21767167
15	14	135.1667772	34.21780667
16	15	135.1667947	34.21794
17	16	135.1668133	34.218075
18	17	135.1668311	34.21820833
19	18	135.1668486	34.21834306
20	19	135.1668572	34.21834083

Figure 6. Excel file in which the nodal coordinates are written

Walking 4.5 km/h
168
Division number 151

Figure 7. Display of target polygons and input of walking speed

Map IS, produced by Kernel Inc are used as the numerical map and GIS engine, respectively.

Then only the target polygons are shown (see Fig. 7) and the area is divided by cells of the same size (see Fig. 8) which is calculated by the average walking speed of evacuees.   The walking speed is required to be input.   Next, in order to assign the attribute such as the street, resident, walkway and landmark to the cells, the search - whether or not each cell is included in the polygons - is carried out.   Fig. 8 shows the cells before the attributes are assigned.   Fig.9 shows the cells to which the attributes are assigned. The attributes are expressed by color. The data of the attributes of the cells are stored in the text format. Thus the modeling of buildings and streets is completed.   Next the evacuees, the goal and the lead signs which show the location of

Figure 8.   Polygons and cells

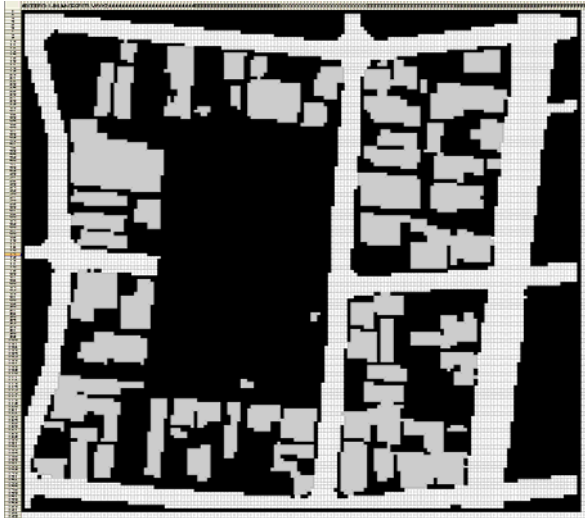Figure 9.   Cells to which the attributes are assigned

Figure 10.   Model in Excel worksheet

attribute – color	
passible way	
building	
impassible area	
sign	
goal	
evacuee	

Figure 11.   Allocation of evacuees, lead
signs and goal

evacuation center are to be allocated.   In order to perform the operation easily, the data of the attributes of the cells are read using Excel Macro, and the model are made on the worksheet of Excel as shown in Fig. 10.   On the worksheet, the evacuees, the goal and the lead signs are allocated by changing the back color of the appropriate cells as shown in Fig. 11.   An integer number from 1 to 8 must be typed manually in the cells of the sign and evacuee.   The number corresponds to the direction to go to.   As for the cell of evacuee, the number means the direction of the first step.   The cells of the streets and walkways are shown in white where the evacuees can walk.   Thus all of the data which are required in the simulation of evacuation behavior are prepared, and again they are stored in the text format.

SIMULATIONS

The simulation of evacuation behavior based on CA (Cellular Automata) is carried out with the model shown in Fig. 12.   Each evacuee has the sight view, in which the direction to go to can be searched.   If the cells of lead sign or goal are inside the sight view, the evacuee walks to the cell.   If the corners of the streets are inside the sight view, the evacuee walks in that direction.   When he reaches the corner, the new target is searched.   In other cases, he keeps the current direction.   Fig.12 shows the example of the directions of the movement of a evacuee. Other various rules such as the prevention of the never ending cycle are introduced in the simulation.   The detail of the rules is described in the reference (Tsujihara 2005, 2008).

In the simulation, 87 evacuees are allocated as shown in Fig.11.   Figs. 13 and 14 show the dynamic states of 78th and 112th step in the calculation, respectively.   1 step corresponds to 1 second.   The evacuees can move up to 2
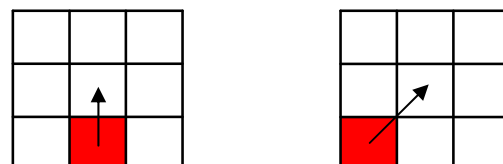

Figure 12.   Travelling direction of evacuee

Figure 13. Dynamic state of 78th step in the evacuation simulation

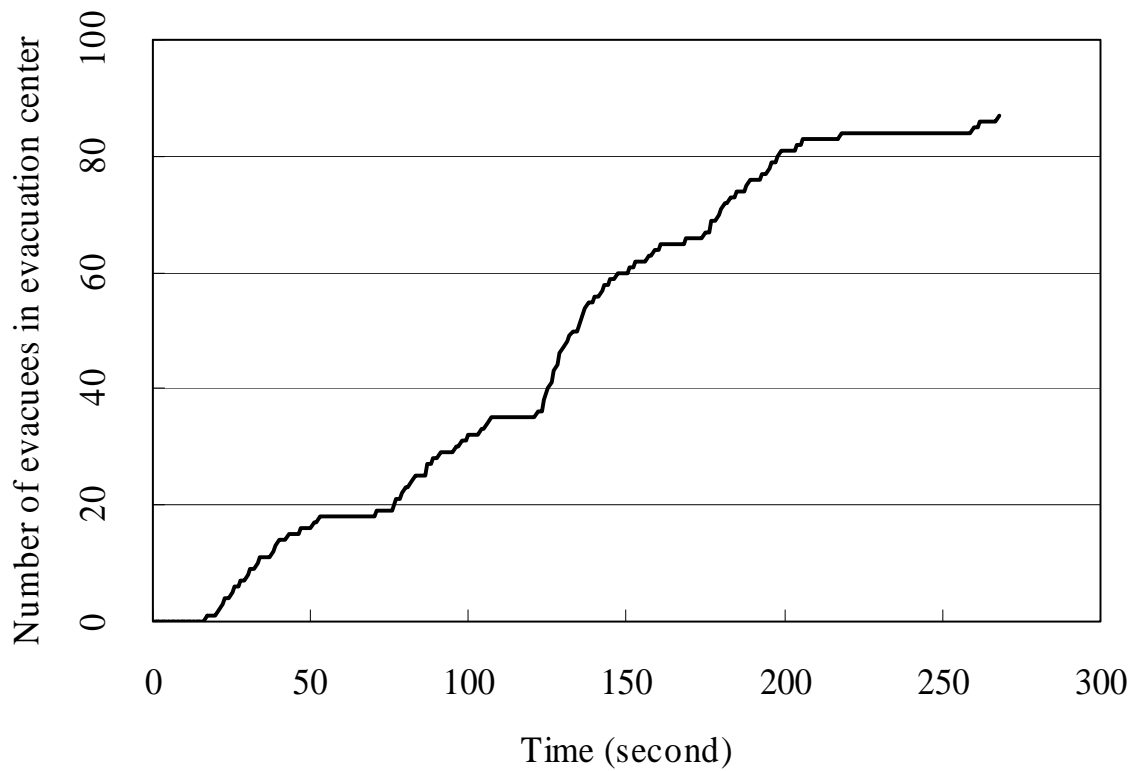Figure 14. Dynamic state of 112th step in the evacuation simulation

Figure 15. Relation between time (step of calculation) and the number of evacuees who complete the evacuation

cells by 1 step.   Fig. 15 shows the relation between the step of calculation and the number of evacuees who complete the evacuation.   It takes 267 steps to complete the evacuation.

CONCLUSIONS

Automatic modeling system for the simulation of emergency evacuation behavior is developed with the programming languages of Microsoft Visual Basic and Excel Macro, and OA-Area 2 as the numerical map and the Active Map IS as the GIS engine.   Although the input of the evacuees, the goal and the lead signs are to be manually carried out, it can be done by the simple operation can be performed on the Excel worksheet.   Using this system, the modeling of most cities and towns in Japan can be carried out in a short time, which may encourage broad use of the simulation of emergency evacuation behavior.

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