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MODELING AND SIMULATION OF RESCUE ACTIVITY BY THE LOCAL RESIDENTS IN THE SEISMIC DISASTER

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SUMMARY

A significant amount of data concerning the rescue activities of local residents following the 1995 Hanshin-Awaji Great Earthquake in Kobe, Japan has been collected during several independent investigations, yet has so far been processed and analyzed separately. Integrating the different factors affecting disaster relief is necessary in order to effectively incorporate the data into agent-based models simulating dynamic human activity. Of particular concern are mortality rates during and after earthquakes, which can vary significantly according to agent activity and location. The purpose of this study is to integrate GIS with multi-agent seismic disaster simulations to investigate factors significantly affecting rescue efforts, and to clarify countermeasures for saving lives.

INTRODUCTION

As most casualties were those who trapped in the collapsed buildings and being suffocated or crushed to death, quick rescue is critical when a big earthquake occurs. The possibility of survival drops dramatically with the progress of time, especially for those individuals who cannot help themselves because they are either trapped in the collapsed buildings or injured. In the time of chaos immediately following the earthquake, it is clear that rescue activities by local are indispensable.

This study aims to 1) clarify the regional characteristics from the standpoint of the typical earthquake related casualties 2) to propose the technique of performing the rescue activity simulation using the multi-agent system in order to work on the counter measure, and finally 3) to demonstrate the usefulness of it by the case study.

BACKGROUND AND PURPOSE

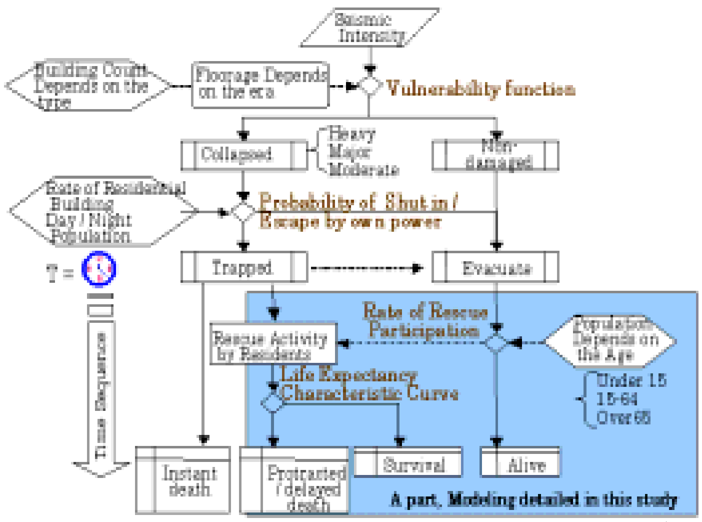
Various highly specialized studies concerning Hanshin-Awaji Great Earthquake have been presented in the past, e.g. the rate of ejectment from collapsed building by them, the rate of life expectancy, and time to dig up buried people. So far each case is treated individually. These factors must be combined and be considered as a system, because a series of various phenomena influence each other in rescue activities. In this study on rescue activities from collapsed buildings, the mechanism of outbreak of casualty was ordered, and then static damage assumption was performed in consideration of the element in connection with each scene, in the effort to examine the effect of shortening the time it takes for rescue activities.

First of all, the variables that influence the probability of survival were determined based on the published reports written by various authors. Then the available GIS data related to them was arranged.

Secondary, seismic intensity assumption was set, and distribution of individuals being buried alive was calculated for every area.

Thirdly, the relationship between the survival and death after rescue activity was quantitatively grasped based on the characteristics of rescue activity participants, which in turn was determined from the residents attribute.
The occurrence probability of each phenomenon is calculated in consideration of the following elements.

- Seismic intensity distribution prediction [2)]
- Building damage function (vulnerability function) [2)]
- The probability of being trapped in buildings [3)]
- The rate of rescue participation[3)]
- Amount of rescue activities[4)]
- Life-expectancy characteristic curvilinear [5)]



Figre1. Summary Flow Chart of outbreak of casualty[1)]

However, this analysis did not take into account the spatiotemporal elements, such as distribution of damaged buildings and individuals, i.e. each value, such as population or total floorage were dealt with zonal statistics. Several matters are listed below.

- Cannot perform the spatial grasp when seeing micro view, since calculation processing with the group.
- In this model, rescuer uniformly go into rescue spot as one, so travel time nor default spatial relationship are not considered.
- Hands may surplus at a rescue spot, and individuals who can help other casualty are not considered.

(The above technique is called "static analysis")

To solve these problems, it is useful to incorporate a multi-agent's concept. Thereupon, this study simulates rescue activity from collapsed building by local in the pilot area, which assumed the time immediately following the big earthquake.
Especially, an action pointed in Fig.1 was modeled in detail.
The purpose of this study is to clarify the regional characteristics by comparing the result of static analysis using GIS with dynamic analysis using MAS. Then it aims to what should we do as a counter measure to reduce the number of casualties.

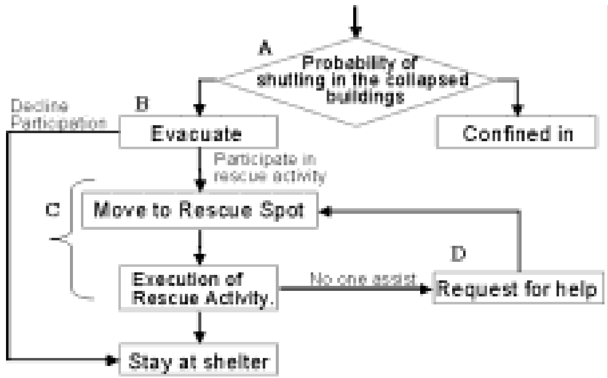
MODELING THE EVACUATION AND RESCUE ACTIVITY

In the model space, building agent exist above road agent. Human agent are allocated to building depends on floorage. Some of them are assumed as being trapped in the collapsed buildings. The individuals who can escape by themselves rescue other casualties during evacuation.

As well as that, they request supporter around them or who is in shelter.

Finally, MAS simulate the term until rescuers terminate digging out all discovered individuals who were buried, and finish refuge activity.

Moreover, to simplify models, the transportation of injured individuals was not regarded.



figre2. Activity flow chart

The actions considerate in that process are shown at figre2. Although the process that comes to shut up as initial conditions has branched by the same probability as static analysis, a different point is that the place to generate agents is set at random.

In each scene, a parameter and probability were similarly determined based on what referred to static analysis. [1)]

(A) Trapped in the collapsed buildings

At first, human agent is divided into two statuses, whether shutting up or not. It is determined from "the probability of being trapped in buildings" based on the structure of building and prediction of seismic intensity

Hereupon, agents who avoid being trapped in buildings keep refuge activity. Agent closed in collapsed buildings maintains that condition. Then agents respectively suppose to undertake an injury and determined the time to death. If rescued within a time count, it considered as survive. Otherwise fail to save lives.

(B) Evacuation activities

In this status, agents move to schoolyard as a refuge space. On the way, choose whether part in rescue activity or not in case get recognition of request of manpower.

This judgment gives priority to the participates in the spot that people buried alive was discovered

In that case, agent considers the situation within a view (particular distance from agent's position). At this time, it keeps evacuation when it does not participate in that spot or there is no request of aid into a view. If there are any requests of aid in sight, also choose whether respond that or not, otherwise keep moving to shelter.

In either case, once it will take part in rescue, they will move to rescue spot. Finally, it will stay at schoolyard until there is not any request or all of agent complete evacuation.

(C) Rescue activities

This situation, agent confirm how many agents are perform rescue. If the member of agents exceeds specific number per buried person, then the agent who came later abandons participation. The reason of this modeling is that so many people cannot work at a narrow space. In other words, Rescue activities are performed when the fixed number is not reached. After certain time passed, still aiding alone, then leave the spot to call another available agent. Then if certain time after start aiding. Alternatively when two or more agents exist, rescue activity shall be accomplished.

(D) Request for help

The agent who request support shall look for refusing agent. If find that, go around to call them. Otherwise visit shelter and try to request.

The agent who looks for refusing agent moves quickly than usual. Because it is assumed that the action that goes to call aid has required emergency.

When request was undertaken, they go to the rescue spot immediately.

Finally, when nobody replied to aid, or when nobody exists also in a shelter, the agent shall return to the rescue spot for the time being, and rescue activities shall be resumed.

IMPORT GIS DATA TO MAS

Along with the above flow yet written, the simulation was carried out in the pilot study expressed in the real world. GIS data was used to create this space. The vector data was expressed three kinds of features: line, point, polygon that represents such a centerline of road, buildings, and schoolyard. However, only square or hexagonal cell represent all the space in MAS. So it became possible to exchange the GIS data (vector data) to MAS data (raster data) via ASCII format

① Prepare the building data

It is impossible to read in the building footprint as it is on a cell, because they have various shape and size. Moreover, since one agent has to be stationed at one cell, building data needs to express itself as well.

Then create center point of building and convert to grid data. Besides that, coordinate data and attribute data like floorage and structure cannot import to MAS at once. Therefore, primarily import coordinate data, after that, export it to GIS and unite with attribute table. Finally import combined table to MAS again.

② Prepare the road data

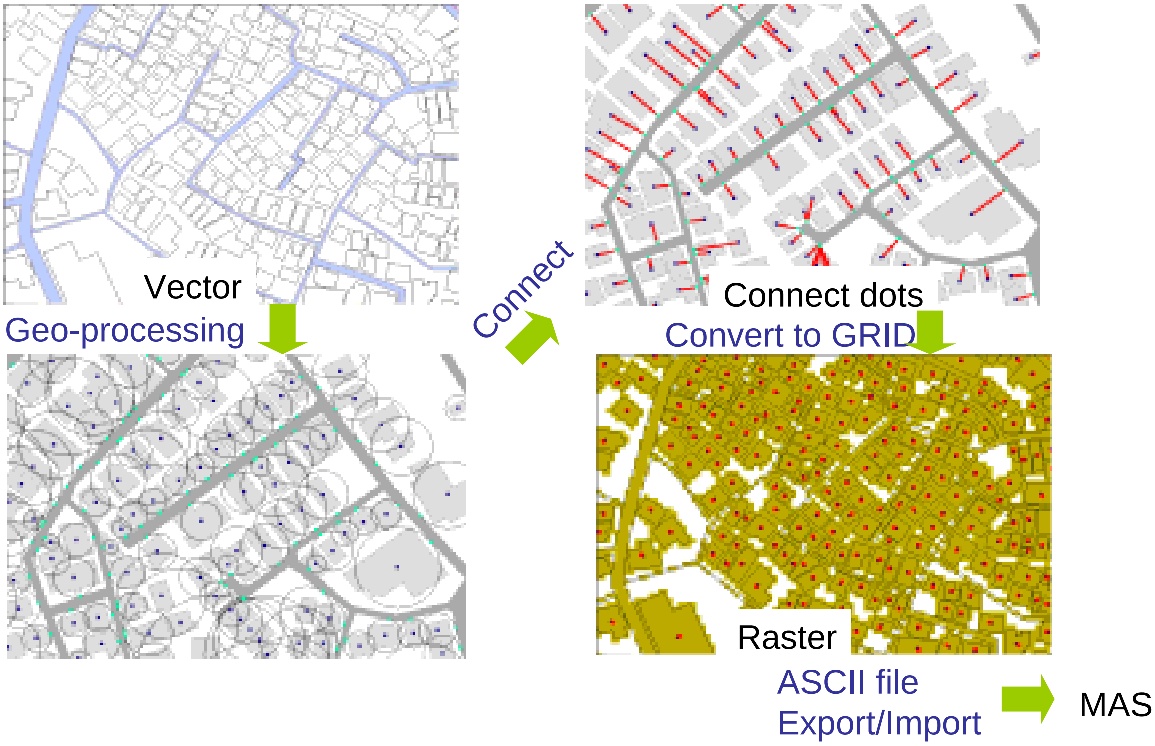
The human-agent move only on the road-agent. So every building must have juncture to road agent.
However, almost all of agents don't meet this condition since GIS data is described particularly.
Then create buffer with the closest distance from centroid (which was created in step4-1) to road polygon. And connect the point of contact to centroid as additional road so that all building agent correspond requirement.

Through this step, road agent was set up in pilot study area.

③ Prepare the human data

In the virtual model space mentioned at previous section, the coordinate of human agent was manually inputted. But this time, the whole agent was allocated to the building automatically via programming since there is too much number in this model.

In this study, floor area per person was calculated to decide how many residents might be there, because it is difficult to get to know the habitation number in each building correctly.



CASE STUDY

It was selected as a case study area that 1 Mineoka city, Hodogaya ward, Yokohama City considering the performance of personal computer and power of MAS. A population of that are about 2400 and wooden building occupy many part, and about 540 building exist there in total. At a present stage, it is difficult to simulate in bigger area more than this size.

In study area, assume that Minami-Kanto great earthquake (the seismic intensity 6.0) have occurred, then other initial conditions was determined based on building damage function, the life-expectancy characteristic curve, and so on.

The rate of shut up was set to 30%, and participating probability was set to 30% depends on the bibliography.

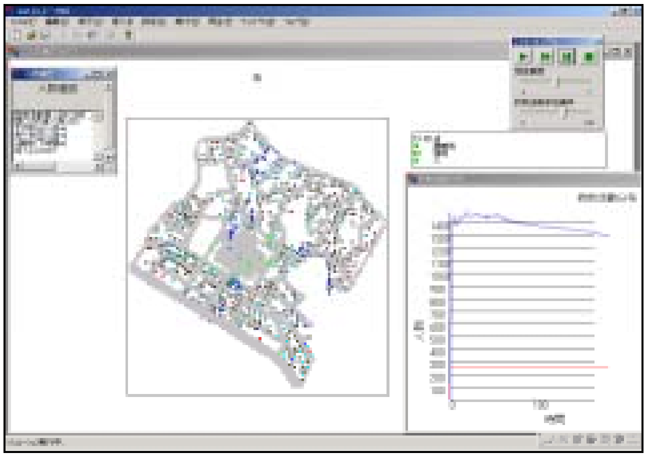
In furthermore, the man who can work simultaneously was carried out to five persons at a spot.

And one person shall carry out an aid request after continuing rescue activity for 30minites.

The shelter was made into the Mine elementary school located at the center of the case study area.

And walk speed was set 50 meter per minute (per one simulation turn), the view of the agent who is searching for buried person was set up to 10 meter (2 cells).

When going in request of an aid, agent shall move with twice as fast as usual.



Figre3. Interface of KK-MAS

Table1. Comparing the result of Static with Dynamic Analysis

	GIS	MAS
Time taken to rescue (minutes)	120.0	281.7
Number of Survivor (person)	308.0	304.8
Number of Casualty (person)	11.0	22.0

¦Total Population is 320

Table1 shows us that MAS reflecting more phenomenon what we should consider, that is why following reasons.

- The time of movement is taken into consideration in this simulation.
- The timing in charge of rescue is not simultaneous, in other words, the rescue activity start after discover the devastated spot.
- The number of rescuer for each spot is different; it means there are the spots that cannot secure sufficient number exists.

INTRODUCTION OF PARAMETER TO MAS

In previous chapter, the result of static analysis with GIS and dynamic analysis with MAS was compared.

In this chapter, it is clarified that how the probability of participation in rescue activity affect to the number of survivor.

Besides 30% yet mentioned, 60% and 100% was applied. 100% means that agent always take part in salvage when discovered the rescue spot. These three cases are examined and result is shown below.

People persisted under the collapsed buildings described in table2 is the agent who was not discovered since the spot that they were buried alive was not on the way to shelter. It means that they shall die if nobody find nor aid them.

Then, when all agent refuge to schoolyard except who was shut in building, this simulation shall end.

Table2. Alternate the Probability of Participation to Rescue Activity (10 times)

Probabirity of participation to rescue adtivity (%)	30		60		100	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
Time taken to rescue (minutes)	281.7	71.9	268.1	51.7	242	53.8
Number of Survivor (person)	304.8	46.4	311.8	48.9	315	51.3
Number of Casualty (person)	6.4	1.6	6.9	2.4	6.9	2.3
Number of residents persisted under the Collapsed	15.6	12.4	8.3	6.1	5.2	4.7

Table3. Comparing result of static Analysis to Dynamic Analysis (average of 10 times)

Static

Probabirity of participation to rescue adtivity (%)	30	60	100
Time taken to rescue (minutes)	119.0	76.0	57.0
Number of Survivor (person)	308.0	308.0	308.0
Number of Casualty (person)	11.0	11.0	11.0

Dynamic

Probabirity of participation to rescue adtivity (%)	30	60	100
Time taken to rescue (minutes)	281.7	268.1	242.4
Number of Survivor (person)	305	311.8	315
Number of Casualty (person)	22.0(15.6)	15.2(8.3)	12.1(5.2)

( ) : Number of local persisted under the collapsed building

Table2 and Table3 show that the relation between the rate of participation to rescue and the number of death toll (eliminate the remaining people) was not inverse proportion.

It is presumed that this model restricts the number of rescuer at a spot and some agent unable to join for rescue activity when discovered needs of help.

Moreover, even if the rate of rescue activity was 100%, some people cannot be found.

It is because that rescue activities of this model is thought as process from habitation building to shelter along road agent. These settings brought about the oversight.

Although the result was shown above, generally time for finishing rescue activity and the number of remained agent buried alive show a marked declining tendency and the number of survivor shows a marked rising tendency according to the rate of participation in rescue.

On the basis of those results, another case was assumed. It considers the property of community, so agents confirm the neighborhood (who exists within 25 meter) before rush into shelter.

Table4. The Case that Care about Neighborhood (average of 10 times)

Probabirity of participation to rescue adtivity (%)	Care about Neighborhood
Time taken to rescue (minutes)	220
Number of Survivor (person)	317
Number of Casualty (person)	9.9(3.2)

As shown in table3 and table4, it is more effective to confirm neighborhood with 30% engage in rescue activity, rather than to raise the probability of participation for that from 30% to 100%. Since it compresses the time of operation and it decreases the number of casualty. In this case, more agents have possibility of discovering swerve people.

Thus, it became to be possible by using MAS to express the factors that difficult to regard in Static Analysis.

CONCLUSION

In this study, the following result were obtained about rescue activity from collapsed building after great earthquake occurred

- Multi-Agent Simulator could represent the human action with which interferes complicated each other.
- The usefulness of dynamic analysis using agent-based model has demonstrated.
- As an element in connection with improvement in the rate of lifesaving, introduction a parameter of rescue participation and association with neighborhood. Then analyze the influence of these factors by changing values.
- Since a neighboring confirmation gathers the rate of survival rescue rather than raising the rate of rescue participation, it should carry out such enlightenment also in usual disaster prevention education.

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