

Multi-agent Based Collaborative Modeling for Flood Evacuation Planning -Case Study of Nagata, Kobe

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Synopsis

In order to describe and simulate an aggregate evacuation behavior in a community-wide area based on a micro level of evacuation behaviors at individual and household levels, we present an approach that addresses the knowledge acquisition process through a collaborative modeling which builds in a multi-agent based evacuation simulation system (EvaSim). In this paper, we show the process of using the collaborative model to build and improve the EvaSim system. The EvaSim is a multi agent simulation tool to analyze and improve the local evacuation planning through simulating people's evacuation behaviors.

Keywords: collaborative modeling, Multi-agent simulation, mutual aid, "Crossroad" game

1. Introduction

In recent years, along with the revision of disaster prevention related law, it has also been noted that self-help and mutual aid play very important role in response to a disaster. The regional evacuation planning reflecting local people's intention and fitting for the geography condition and the regional characteristic is requested. Therefore, community knowledge should be combined when making regional evacuation planning. Community members, the source of expert knowledge about communities' strengths, problems, needs, and preferences, have the irreplaceable role of sharing their experiential expertise (Linda S. Thompson, 2002). So collaborations among academic institutions, government, and local communities have the potential for enormous benefits for all parties, but implementation remains a challenge (Thompson, 1999). Collaborative research involves a working relationship between at least one academic institution's research unit and one community-based organization. The community-based organizations of interest are those from and representing underserved communities.

Now, many countries have already moved into an

aging society and as we know the aged takes a large part among all victims by a flood disaster because of their physical handicaps in daily life. So how to provide social support to the aged in disaster is a problem the local government has to face up with when they make evacuation planning for a flood disaster. Some case studies of social support to the aged have been done by academic researchers. For example, Katada T. et.al made an on-the-spot investigation in Koriyama, Japan on the evacuation behaviors of frail elderly and the aged in a river flood disaster [Katada T. et.al, 1999; Katada T. et.al 2002]. This research detailed the actual situation and problems of the evacuation activities of the aged and examined what evacuation plan for the weak should be. In this paper, we will focus on the social support from neighborhood to the aged based on a case study in Nagata ward, Kobe, Japan through a collaborative modeling which builds in a multi-agent based evacuation simulation system (EvaSim). Evasim is developed as a tool of communication to carry out the collaboration among each party by incorporating more specifically residents' evacuation behaviors and concerns. We presented the communication process with a case study in Nagata ward, Kobe, Japan.

2. Methodologies

Collaborative approaches have been based on various techniques such as, the individual interviews for the individual knowledge acquisition, or questionnaires or brainstorming and role playing games for collective knowledge acquisition. In this research, three methods including a questionnaire, a game named “CrossRoad” and a multi-agent based simulation are implemented. Following figure shows the architecture of collaborative parties and technologies. It is a mutual process between local community and researchers as shown in Fig.1. On the one hand, questionnaire, “Crossroad” game and multi-agent simulation will be conducted among participants to get residents’ concerns and decisions regarding evacuation issues; on the other hand, researchers will evaluate residents’ opinions and disseminate the outcomes to local community through workshops and further improve the communication tool like multi-agent simulation.

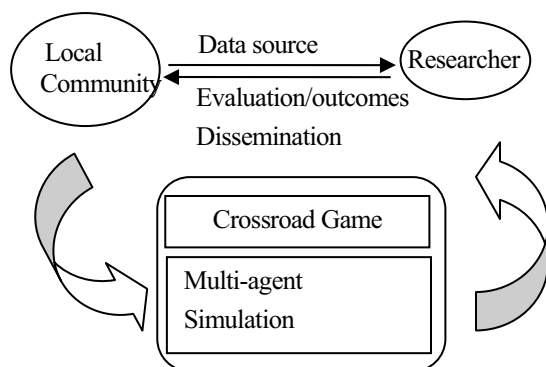


Fig.1 Architecture of collaborative parties and technologies

2.1 “Crossroad” game

Gaming is a participatory approach to problem solving that engages a real-life situation compressed in time so that the essential characteristics of the problem are open to dynamic environment requiring periodic decision. The use of games by groups to explore values, ideas, and behaviors as communication function gives participants a better understanding of themselves and others (Henry Sanoff, 2000, pp76). “Crossroad”, is designed for the general public and for disaster response personnel in national and local government or non-governmental organizations, for the purpose of increasing their awareness of the problems faced in disaster situations [Toshiko Kikkawa et.al.]. There are five to seven players to a game, with an odd number of

players preferable for each group. At the beginning of a game, each player has exactly the same deck of ten episode cards at hand. She or he also has one “YES” card and one “NO” card. Every episode card has the same format, consisting of three parts. The first part consists of a description of a certain role that is to be played when faced with a dilemma in a disaster situation. A short description of the situation follows. The third part consists of a description of both the “YES” and “NO” decisions [Toshiko Kikkawa et.al.]. In this research, totally 10 cards are made and one of them are related to mutual aid among neighbors as shown in Fig.3.

We list three cases representing different family structure such as family with old people, family with young children and others. The result of “Crossroad” game can be used to identify the possibility of each type of household to help an old people who live in their neighborhood. Actually in this game, the reason for choosing Yes or No means a lot because it shows how people evaluate the difficulties during their evacuation that will help us to understand the people’ s concern.

The “Crossroad” game was conducted with Nagata elementary school community on Apr.1st, 2007. There are total 29 participants, 15 male and 14 female among them with the average age as 63.8 years old. The participants are divided into five groups. Fig.3 shows the pictures by three groups.

Table 1 shows the results for each group.

No.	With answer “Yes”	With answer “No”
G1	6	1
G2	5	2
G3	4	3
G4	5	0
G5	3	4

We use the following equation to calculate the possibility of mutual aid.

$$p = N_y / (N_y + N_n) * 100\%$$

Where,

P is probability to provide help to a neighbor

N_y is the total amount of people who answer “Yes”

N_n is the total amount of people who answer “No”

Family with old people	Family with young child	Family with elder child
<p>A family with mother (70 years old) and two children in elementary school. Rush rain continues. You know a flood may happen and evacuation order has been issued. A single old person lives in your neighborhood and needs help. Are you going to help her/him?</p>	<p>A family with two children in one and three years old. Rush rain continues. You know a flood may happen and evacuation order has been issued. A single old person lives in your neighborhood and needs help. Are you going to help her/him?</p>	<p>A family with three children in middle school. Rush rain continues. You know a flood may happen and evacuation order has been issued. A single old person lives in your neighborhood and needs help. Are you going to help her/him?</p>
<p>Yes (go to help him/her) OR No (do not go to help him/her)</p>	<p>Yes (go to help him/her) OR No (do not go to help him/her)</p>	<p>Yes (go to help him/her) OR No (do not go to help him/her)</p>

Fig. 2 “Crossroad” game card

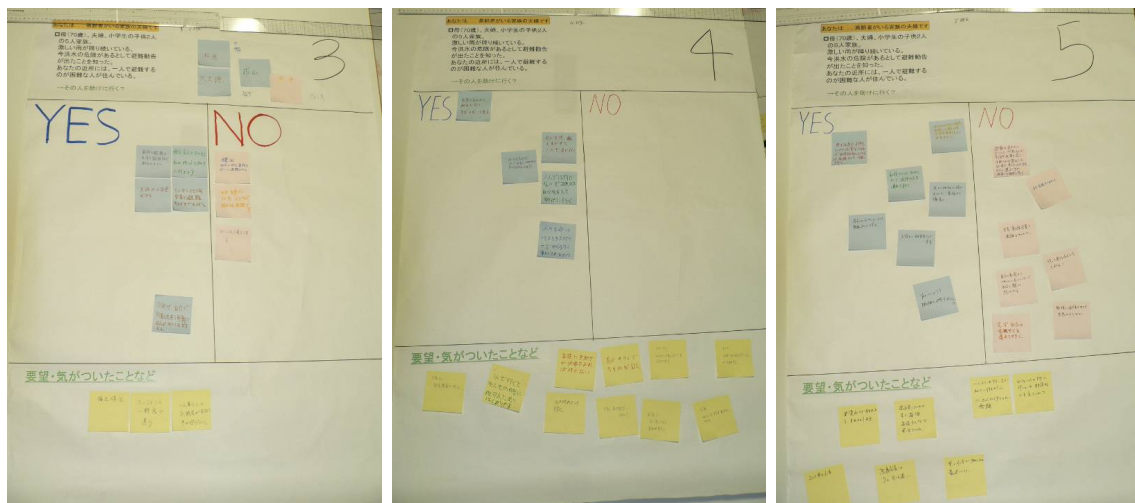


Fig.3 Crossroad game conducted in Nagata Elementary School community

The results show 69.7% people choose “yes” which means “will provide help”. We summarize the reason for choosing “Yes” and “No” as follows. The reason for choosing “Yes” can be classified into two types, conditionally rescue and non-conditionally rescue. Conditions of aid implementation focus on two areas: the first is to ensure the safety of the family; the second is the ability to provide help. Other conditions include that they will help if they received request from those vulnerable. The reasons for choosing “No” mainly

include family priority and potential problems of unwilling evacuation. So from the reasons, we can find that the safety of family is the main factor to influence their decisions to provide help.

2.2 Multi-agent simulation

Multi-agent technology is very interesting for the development of applications which solve very complex, real-time problems in an uncertain and changing environment. MAS realize a balance between an

application's long-term goal-directed behaviors and its short-term reactive one [Norbert Glaser, 2002]. In this research, the EvaSim simulation system is developed based on KKMAS, the platform of multi agent development [KKMAS homepage]. The EvaSim has been used as a medium in the communication activity with people from "Zonta club" in Kyoto who had their regular meeting on Oct.11, 2006 regarding evacuation issues. Most of the members show great interests in the evacuation simulation and the simulation process stimulate them to think about evacuation problems that they may face up with. Moreover, as said above, EvaSim is expected to be further improved and extended to incorporate more specifically residents' evacuation behaviors and concerns.

3. Case study

The case area is located in south of Nagata ward in Kobe, Japan where has suffered severe damages from the Great Hanshin-Awaji (Kobe) Earthquake in 1995. After earthquake, activities of disaster prevention started to increase the regional anti-disaster power by co-coordinating the efforts from citizens, business and government in local area. According to statistic data in Kobe by June 2006, totally there are 2371 households and 4487 people in this area as shown in Table 2. And Shinyo elementary school serves as the only formal shelter in this area. In this research, we think of hazard

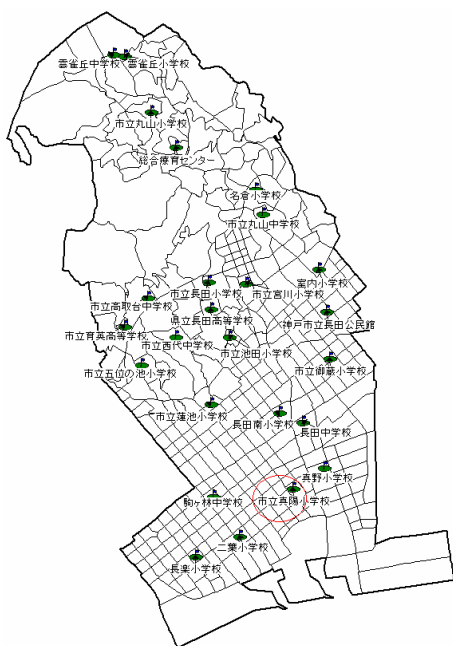


Fig. 4 Map of case area in Nagata ward, Kobe

as a flood inside a levee by a flash storm and we assume that a hazard remains the same level with time.

In this research, the organization structure is composed of researcher and Nagata elementary school community as shown in Fig.5.

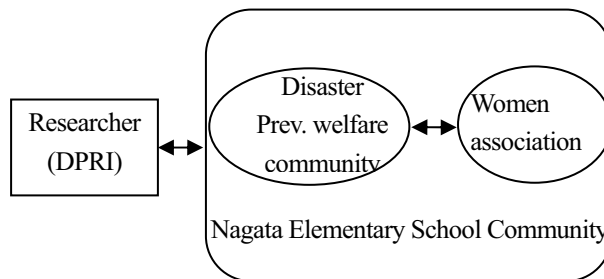


Fig.5 organization structure in case study

3.1 Definition of agents

In the case study, from family composition by age point of view, the agent is classified into "old", "young" and "child" type as shown in Table 3. Moreover, from evacuation capacity point of view, "Young" type and "child" type and family with a member who is more than 65 years old in "Old" type are considered as potential rescuer which means that they can not only carry out an independent evacuation but also they are capable of helping those who are unable to move to a refuge by themselves. But it is easy to find that although they are capable to help others, they are facing difficulties in different level during evacuation. So the probability of mutual aid in neighborhood could be different from each other that are much related to social characteristics in local area and disaster situations. For single old people and old couple, if their living status meet one of the following cases as shown in Table 4 then they will be viewed as people who can receive rescue from their children or relatives when a disaster happens. But for those old people who live far from their children and even have no children; they will be viewed as a group who need help when a disaster happens as shown in Table 5.

So using above statistical data, we get the total people who need help during evacuation in the case area take 25.7% and correspondingly the people who potentially can receive rescue from their family take 28.5%.

A household is viewed as the simulation unit and the simulation step is defined as one second. In the simulation, we suppose that all agents will evacuate to

Table 2 Spatial region scope of the case area

Cho Name	Chome No	Formal Shelter	Household	<i>Population</i>
Udezukacho	1-4	Shinyo elementary school	465	899
Kubocho	1-4	Shinyo elementary school	482	919
Shiodacho	1-4	Shinyo elementary school	557	1059
Futabacho	1-4	Shinyo elementary school	587	1157
Komaecho	1-4	Shinyo elementary school	78	139
Nishishiriikecho	3-5	Shinyo elementary school	202	314
Total			2371	4487

data from Kobe city website

Table 3 Agent type regarding population structure

<i>Type</i>	<i>Item</i>	<i>Percentage*</i>	<i>Type Description</i>
“Old”	Old couple	54.2	“Old” type means that at least one family member is more than 65 years old.
	Single old person		
	Family with a member who is more than 65 years old		
“Young”	With child who are more than 6 years old	42.2	“Young” means that every family member is between 6 and 65 years old
	Single		
	Couple		
“Child”	Family with younger child who are less than 6 years old	3.6	“Child” means that the family has children who are less than 6 years old.

Percentage is calculated by statistic data in Nagata ward from Kobe website.

Table 4 Definition of people who potentially can receive rescue from their family

<i>Item</i>	Live together	Same building	different building in the same sub-district	Within 5 minutes walking distance	one way distance is less than one hour	Total	Percentage
Old couple	60	170	480	750	1620	3080	52.5%
Single old person	40	180	450	580	1860	3110	

Table 5 Definition of people who need help from neighbors or public rescue teams

<i>Item</i>	Has child, separate living	No child	Total	Percentage
	one way distance is more than one hour			
Single old people	1170	2440	3610	47.5%
Old couple	960	1030	1990	

Data source: statistical household data in Nagata Ward for single or couple people who are more than 65 years old. [Kobe city homepage]

the nearest shelter by walking and walking speed depends on the type of a household. For “old” type, the walking speed is set as 0.8m/s; for “young” type, it is set as 1.4m/s and it is set as 1.0m/s for the “child” type. When the evacuation ratio changes, total evacuees for each household type will be automatically calculated and put in the two-dimension simulation space.

3.2 Definition of shelter

In this research, besides the designated shelter for the case community area, some schools and welfare facilities located nearby the case area are taken into account as potential destinations of evacuation.

3.3 Simulation model

Many researchers viewed the evacuation problem from the standpoint of whether there is evacuation activity. However, regarding evacuation behavior of the aged, the viewpoints of whether evacuation aid is necessary and whether the aged can get assistance are very important [KATADA T. et.al, 2002]. In the simulation, the self-help and mutual assistance happen among two types of agents including the potential rescuer and the aged. According to “Crossroad” game, we understand the communication process as shown in Fig.7 and Fig.8. The potential rescuer will help the aged if they received help requests from the aged, if not they will provide support with probability. There are three kinds of attitudes toward evacuation for the aged including independent evacuation, wishing for an evacuation with assistance and no evacuation. Moreover, for those who wish for an evacuation with assistance, only some of them will actively send help request to others but the rest will negatively wait for help. For those who have no intention to evacuate, we suppose that even if they can receive evacuation support from neighbors but they still prefer no evacuation. The research by KATADA T. in 2002 found that only about 5% of the aged carried out an independent evacuation, and 60% of them wished for an evacuation with assistance and about 35% of them did not evacuate in Koriyama area [KATADA T.2002].

When agents arrive at the node that represents the position of target shelter, the evacuation is viewed as completion status. The mutual aid between potential rescuers and vulnerable people are considered in this research. If a potential rescuer decides to help some one nearby in need, then a group is created as a moving unit.

In this case, the two models are combined together and the group will follow the decision by the rescuer. When the group arrives to the target node, every member in this group is deemed to finishing the evacuation.

3.4 simulation interface

In this research, based on KKMAS, the simulation system is developed. Fig.9 shows the main simulation interface.

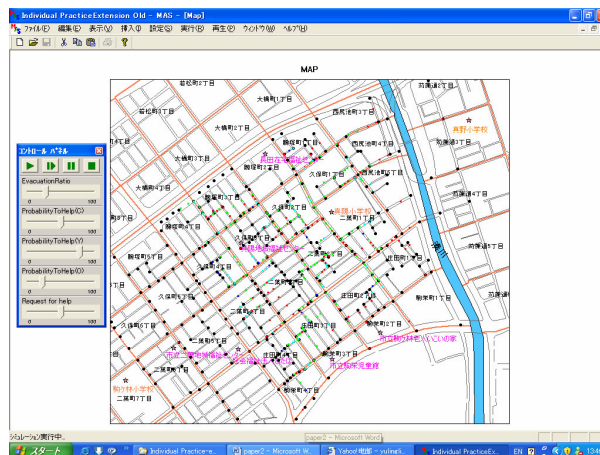


Figure 6 Simulation interface

4. Conclusion and Discussion

In this paper, we present an approach that addresses the knowledge acquisition process through a collaborative modeling which builds in a multi-agent based evacuation simulation system (EvaSim). Especially, though the “Crossroad” game conducted in Nagata Ward, Kobe, we get the residents’ opinion on mutual aid in neighborhood. Results show that 69.7% people will provide support to the old person living in their neighborhood. Conditionally rescue reflects that the biggest concern of people is the safety of their families. The main reason for no rescue focuses on family priority over other people. So both views may be changed depending on the safety situation of their families. So it is necessary to investigate the process of communication and cooperation among family members during evacuation to evaluate their ability to provide help to others. In the future, the MAS simulation based on above understanding will be shown to residents regarding mutual aid issue. Based on feedbacks from respondents, the simulation rules and models will be further improved and extended to incorporate more specifically residents’ evacuation behaviors and concerns.

Table 6. List of shelters in the research

Shelter Type	Name
Accommodation shelter	Municipal Shinyo elementary school
	Municipal Mano elementary school
	Municipal Kamachehayashi elementary school
Temporal shelter	Shinyo Municipal Welfare Center
	Nagata Municipal Welfare Center
	Futaba Municipal Welfare Center
	Komae Municipal Hall for Children
	Futaba Social Welfare Corporate
	House of Municipal Kamachehayashi for the Aged

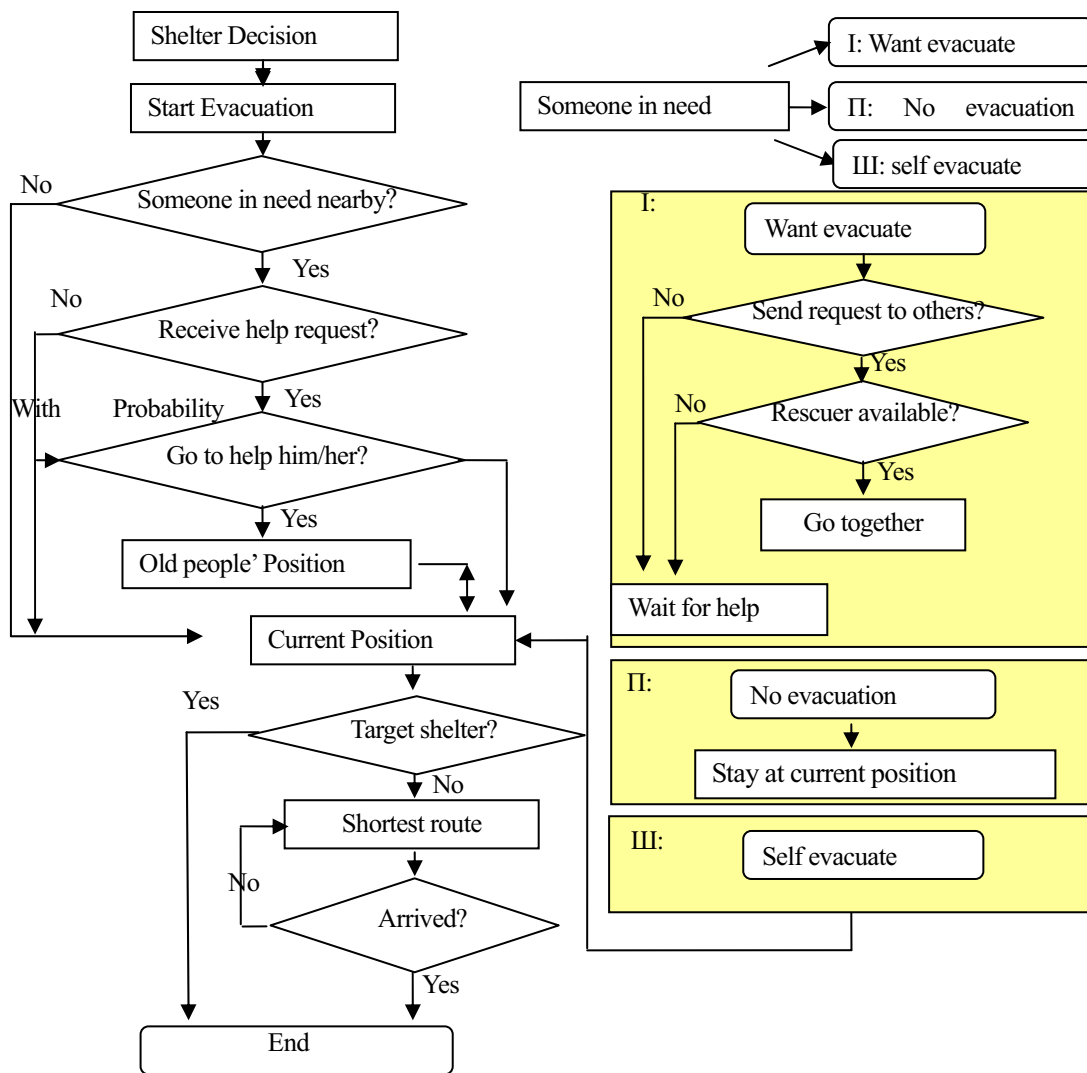


Figure 7 Rescuers' activity rule

Figure 8 activity rule for someone in need

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マルチエージェントシミュレーションを用いた協働洪水避難モデルに関する研究
-神戸市長田区を事例として

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要 旨

この研究では、個人でマイクロレベルの避難の振舞いに基づく共同体全体の領域と家庭のレベルにおける集合避難の振舞いを考えて、シミュレートするために、私たちは多エージェントの体格が基礎づけた協力的なモデルを通して知識獲得の過程を記述するアプローチに避難シミュレーションシステム(EvaSim)を提案する。この論文では、EvaSimシステムを構築して、改良するのに協力的なモデルを使用する過程を示す。EvaSimは人々の避難の振舞いをシミュレートすることで計画されている地方の避難を分析して、改良する多エージェントのシミュレーションのツールです。

キーワード:協働的モデル化, 多-エージェントシミュレーション, 互助, 「Crossroad」ゲーム