Modeling Social Interactions Between Households For Evacuation Behaviors In The Devasted Areas

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What is Social Interactions?

Social Interactions' examples are

In Daily Lives

- Drop and pick someone up
- Make joint purchase
- Patrol in neighborhood

In Disasters

- Evacuate with others
- Rescue
- Exchange Information

Social interactions help vulnerable traffic users in their daily lives
Social interactions help people who can not evacuate on their own

Objective:
Modeling the mechanism of making social interactions
Making to plan to evacuate quickly by group interactions

What are problems?

Problem1 : Why do people make social interactions?

people take rational behaviors

→ choice their behaviors by depending **on only their gain**

BUT

choice their behavior **for others**

→helpers' utilities **include helped people's losses**

→**Other-Regarding Preference**

What are problems?

Problem2 : Who people make social interactions for?

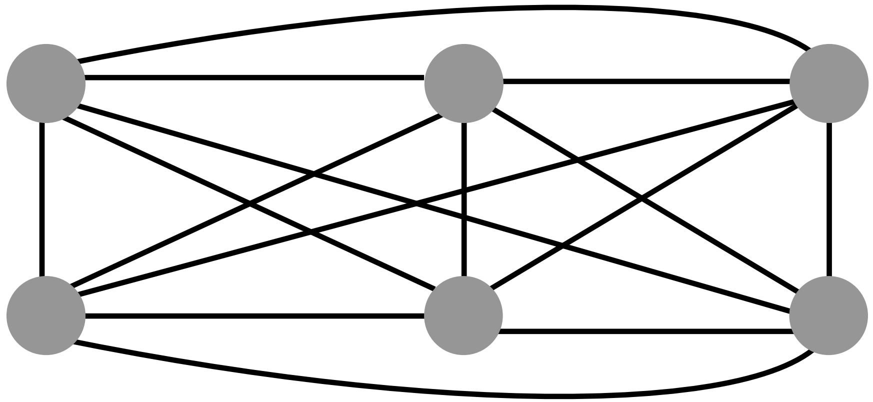
Social interactions pairs are made by **one-to-one pairing**

BUT

- if there are n people, the number of pairs is n(n-1)/2
- choice model of pairs have **huge choice set**

→choice sets composed candidate pairs should be limited

→**Choice set generation**



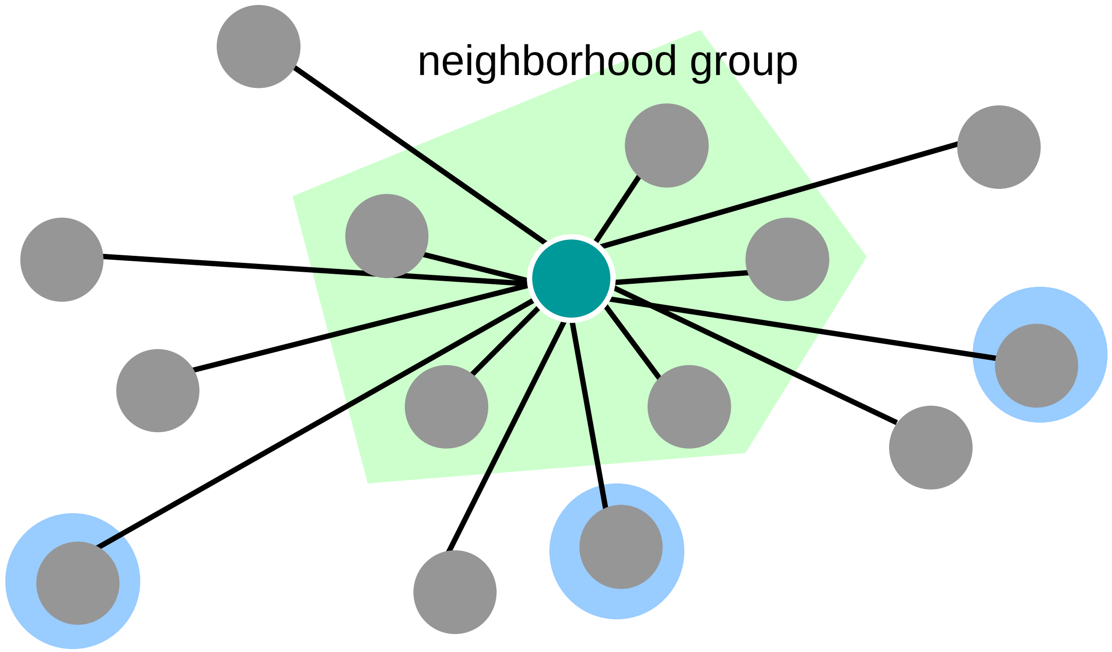
6 people

→15 pairs

Making social interactions in group

Choice set generation problem

- form a pair of 2 people in all members



Algorithm of Choice set generation

Target all group members

-Target all neighborhood group members
(familiarity members)
-Target easy recognition member outside neighborhood members

non-compensatory choice set generation
using influence of familiarity and recognition

One-to-One pairs' utility

Other-Regarding Preference problem

Definition of Other-Regarding Preference

by experimental economics (Fehr and Schmidt(1999))

Disutility as the difference of the gain of the opponent and gain their own

$$u_i = x_i - \alpha_i \cdot \max\{x_j - x_i, 0\} - \beta_i \cdot \max\{x_i - x_j, 0\} \quad (1)$$

u_i: the utility of player i x_i: the gain of player i

α : a parameter if player i is helped β : a parameter if player i help player j

Inequality avoidance preference

Making social interactions utility derive from Inequality avoidance

- Making One-to-One pairs' utility is composed by the difference of their gains.
- The gains is defined by behavioral constraints

Occurrence Probability of Social Interactions

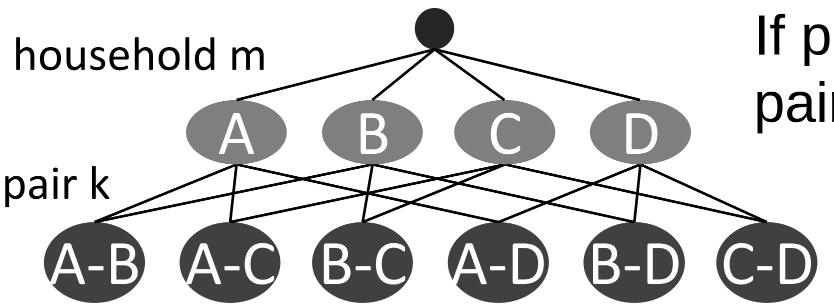
The utility is composed by the difference of their gains
The gains is defined by behavioral constraints

Utilities(OR_{ij}) from Other-Regarding Preference

$$OR_{ij} = \sum_n \beta_n \left| a_i^n - a_j^n \right| \quad (2)$$

a_i : **Behavioral constraint gain**
n : Explanatory factor β : a parameter

Occurrence Probability of Social Interaction pairs

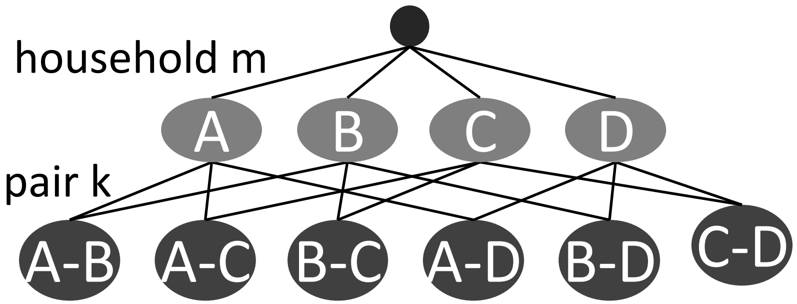


If pairs have common households,
pairs' observation errors are correlation

→ **Cross Nested Logit model**

Occurrence Probability of Social Interactions

upper nest: household, lower : pair



C : choice set
M : the number of household
V_k : the value of choice k
μ_m : scale parameter of household m
μ : scale parameter of pair k
($0 < \mu < \mu_m$)

Abbe et al.(2007)

G function
$$G(y_1,\cdots,y_n) = \sum_{m=1}^{M}\left(\sum_{j\in C}^{n}(\alpha_{jm}^{1/\mu}y_j)^{\mu_m}\right)^{\frac{\mu}{\mu_m}} \quad (3)$$

Probability of pair k
$$P(k|C) = \sum_{m=1}^{M} P_m P_{k|m} \quad (4)$$

Probability of household m
$$P_m = \frac{\left(\sum_{j\in C}\alpha_{jm}^{\mu_m/\mu}e^{\mu_m V_j}\right)^{\frac{\mu}{\mu_m}}}{\sum_{m'=1}^{M}\left(\sum_{j\in C}\alpha_{jn}^{\mu_{m'}/\mu}e^{\mu_{m'}V_j}\right)} \quad (5)$$

Probability of pair k in household m
$$P_{k|m} = \frac{\alpha_{km}^{\mu_m/\mu}e^{\mu_m V_k}}{\sum_{j\in C}\alpha_{jm}^{\mu_m/\mu}e^{\mu_m V_j}} \quad (6)$$

condition of allocation parameter α
$$0 \le \alpha_{km} \le 1, \ \sum_{m}^{M}\alpha_{km} = 1, \forall k \quad (7)$$

About scale parameters

Conditions : $0 < \mu < \mu_m$

If the upper nests' scale parameters are larger, probability of pair k is larger in eq.6 if the value of Vk is large

About allocation parameters

α_{km} : allocation parameter of pair k to household m

Hypothesis : Degree of allocation is different from helper and helped

$$\alpha_{(k=ij)(m=i)} = \frac{1}{1+\exp(\beta_\omega \omega_{ij}^i)} \quad (8)$$

$$\omega_{(ij)(i)} + \omega_{(ij)(j)} = 0$$

ω : dummy of helped

CASE STUDY
-Social Interactions under disasters-

The 2004 mudslide disasters in Niihama

•Two disasters were caused by typhoons on August 18 and September 29 in 2004

The August typhoon

•a maximum rainfall of 55mm per hour

•Mudslides left 3 people dead

The September typhoon

•281mm of rainfall

•Mudslides left 5 people dead

The Survey in Niihama

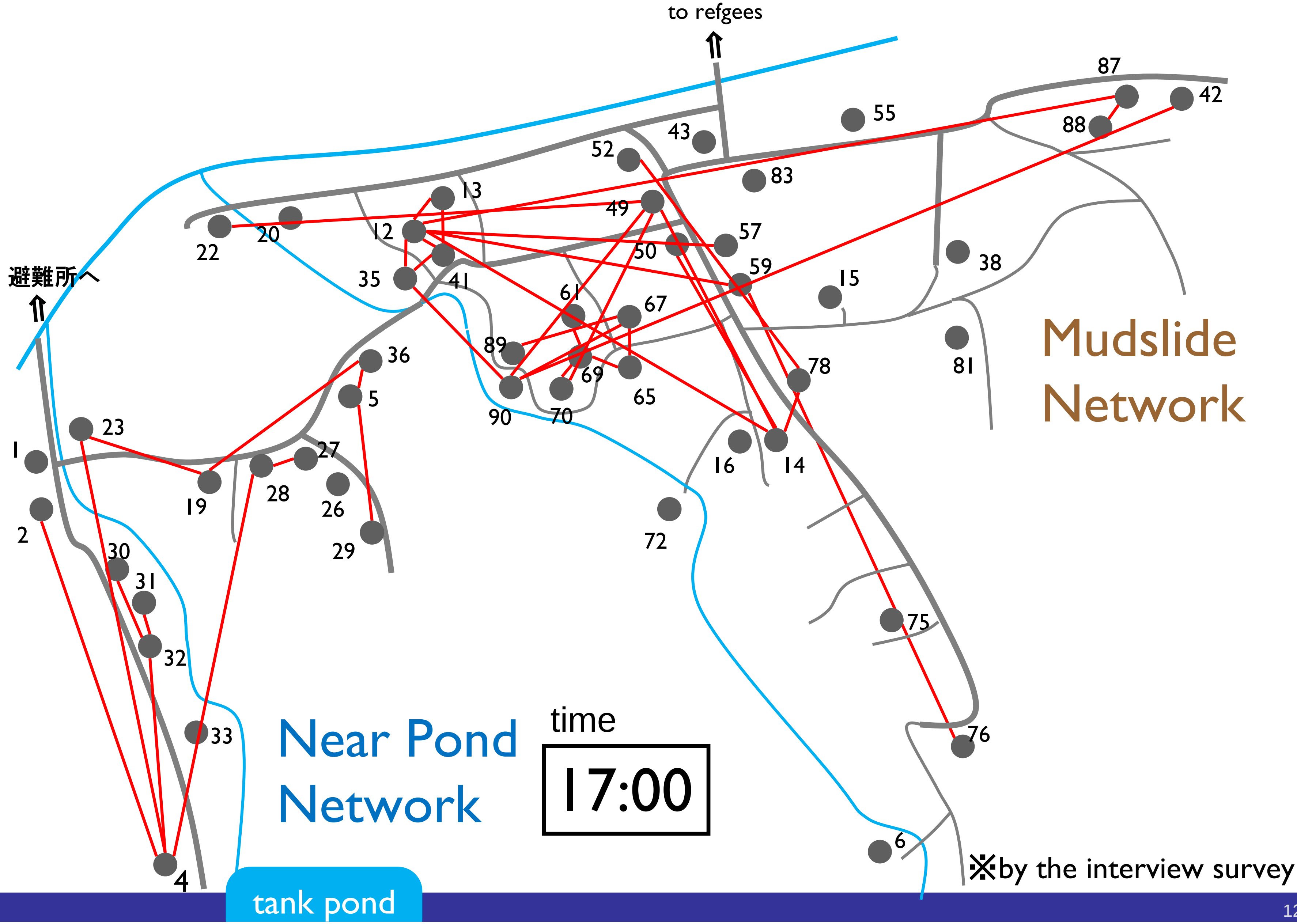
Survey(2004.9-10)

- Surveyed residents' bahaviors during these disasters by interviews (Oral communication)
- Interviewed them about their awareness of the danger, risk management behaviors, and cooperation behaviors
- Cooperative behaviors include rescuing others, evacuating with others, accommodating evacuees, meeting and exchanging information.

Network

- Nodes show households
- Links show cooperative behaviors between the households

The result of Social Interactions



The Value Function

the value function of pair ij

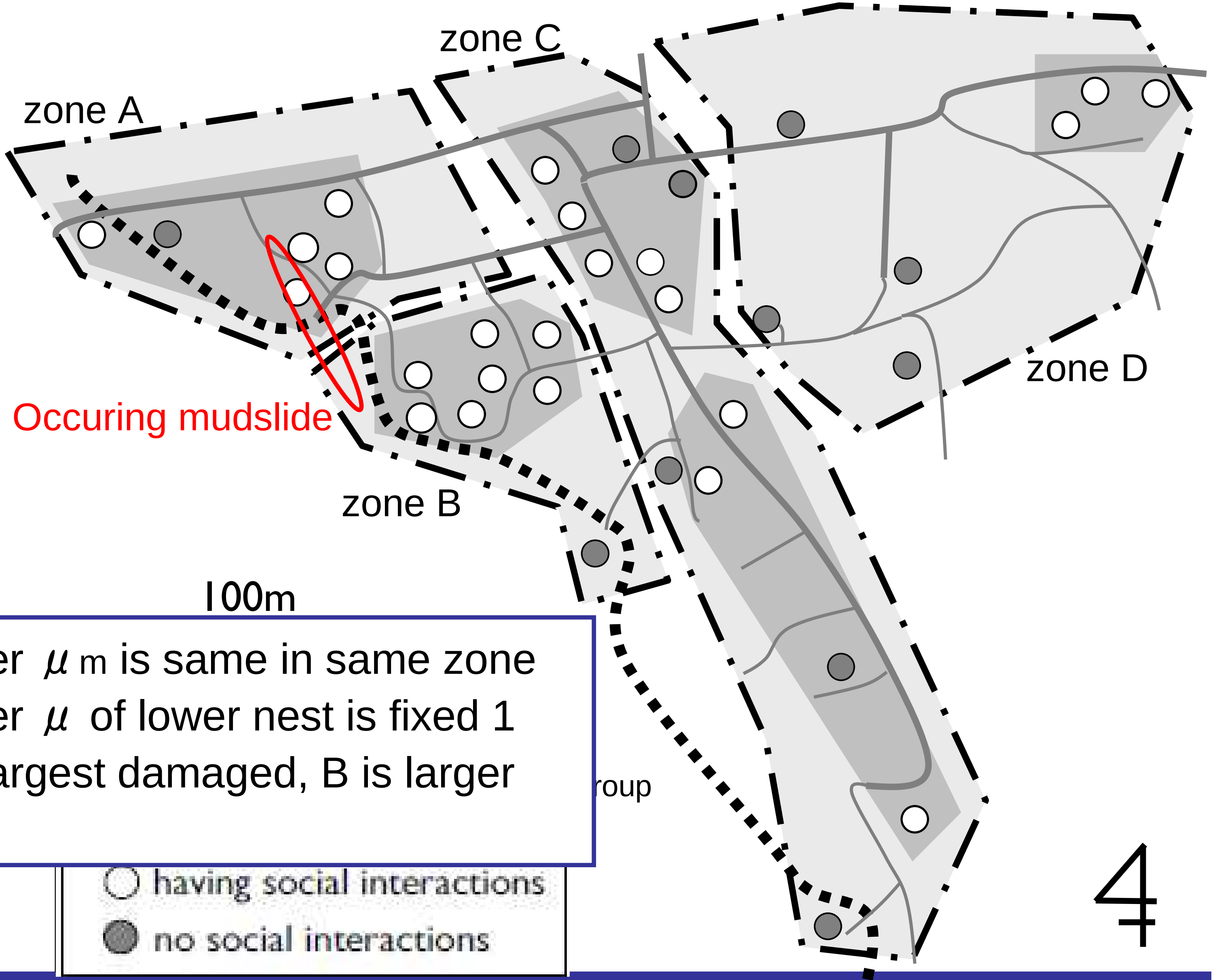
Other-Regarding **Other-Regarding** **making cost**

$$V_{ij,t} = \beta_{dam}\left|dam_{i,t} - dam_{j,t}\right| + \beta_{old}\left|old_{i,t} - old_{j,t}\right| + \beta_{d} d_{ij}$$
$$+ \beta_{belo}\left(belo_{i} + belo_{j}\right) + \beta_{ab} abzone_{ij} + \beta_{res} Rs_{ij} \quad (9)$$

Table 1 The list of variables

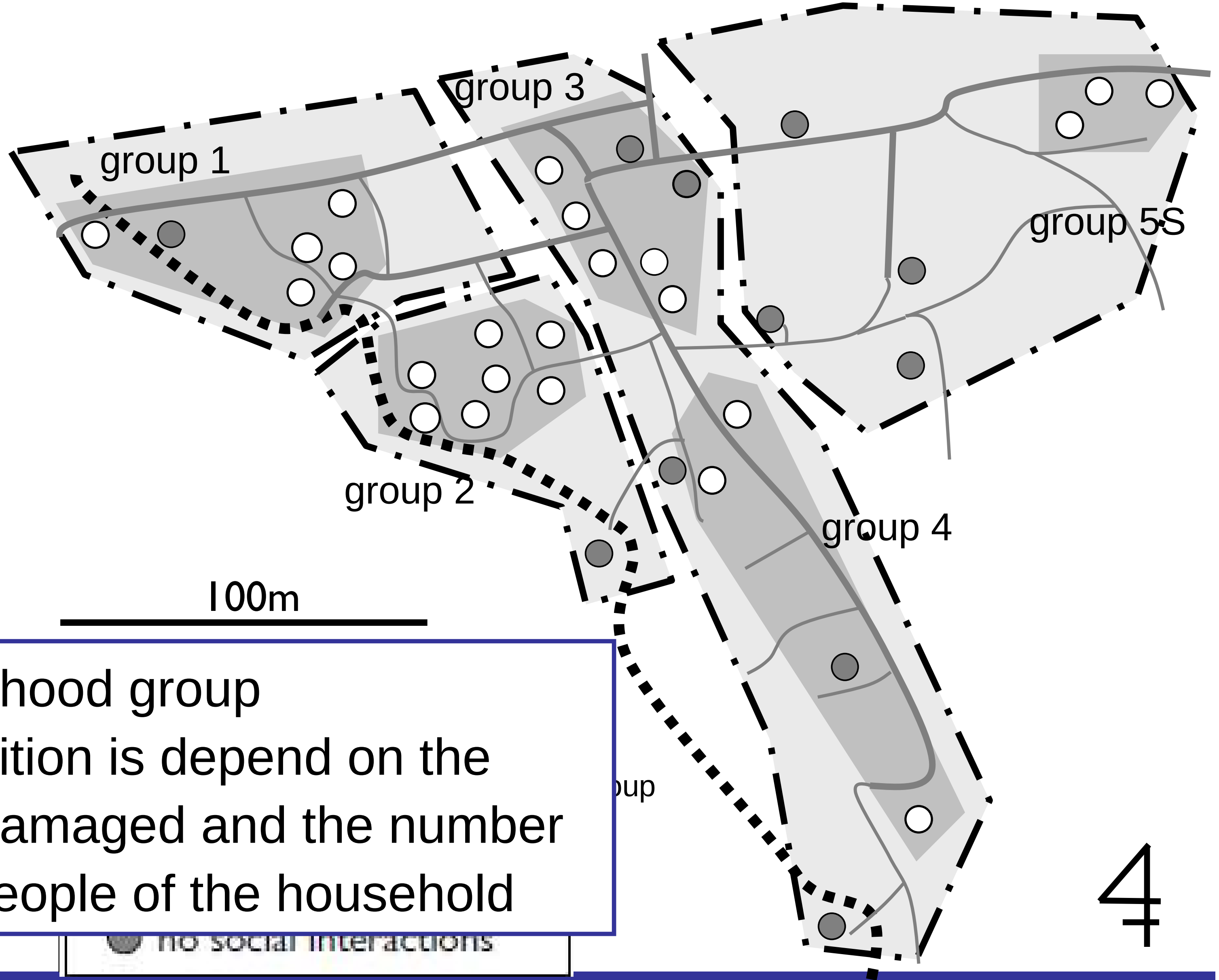
variables	contents
$dam_{i,t}$	The degree of the house damage of household *i* at time *t*
$old_{i,t}$	The number of elderly people of household *i* at time *t*
d_{ij}	The distance from household *i* to household *j*
$belo_{i}$	The belongingness for this area of household *i*
$abzone_{ij}$	1 if the pair *ij* are from zone a and zone b (Fig. 4 show zones)
Rs_{ij}	1 if household *i* or *j* were rescued by others
ω_{ij}^{i}	1 if $dam_{i,t} > dam_{j,t}$, -1 if $dam_{i,t} < dam_{j,t}$. When $dam_{i,t} = dam_{j,t}$, 1 if $old_{i,t} > old_{j,t}$, -1 if $old_{i,t} < old_{j,t}$. The others is 0.
μ_{i}^{zone}	The scale parameter of household *i* in a zone.

Zoning for scale parameter



- scale parameter μ_m is same in same zone
- scale parameter μ of lower nest is fixed 1
- zone A is the largest damaged, B is larger than C, D.

Setting the neighborhood group



- 5 neighborhood group
- the recognition is depend on the degree of damaged and the number of elderly people of the household

the estimation result

Table 2 The estimation result

		No Choice set generation		Choice set generation	
		Coeff. *B*	*t*-Stat	Coeff. *B*	*t*-Stat
Other-regarding	β_{dam}	0.515	2.05*	0.485	2.30*
	β_{old}	0.539	2.09*	0.392	1.91^{+}
Cost	β_{d}	- 0.759	- 2.31*	- 0.827	- 2.42*
	β_{belo}	0.997	1.22	0.941	1.38
	β_{ab}	- 1.308	- 0.79	- 1.199	- 0.61
	β_{res}	0.690	1.98*	0.789	1.57
allocation parameter	β_{ω}	- 0.740	- 1.21	- 0.651	- 1.80^{+}
	μ^{A}	1.654	1.39	1.357	0.95
	μ^{B}	5.331	0.61	5.292	1.53
	μ^{C}	1.683	2.05*	1.098	3.19*
	μ^{D}	2.000	-	2.000	-
	Observations		30		30
	Likelihood at 0		- 155.0		- 135.7
	Final likelihood		- 121.8		- 115.7
	Adjusted ρ^2		0.150		0.073

* : significant at 0.05, $^{+}$: significant at 0.10

Conclusions

Future works

- Formulated the occurrence of social interactions by other-regarding preferences and estimated using the behavior data of the mudslide and heavy rain disaster.
- The utilities of other-regarding preferences defined as the difference of their own gain and the gains of others.
- The occurrence probabilities of social interactions are shown by a cross nested logit model.
- The utilities of the other-regarding preferences are composed by the behavioral constraints of the households and there are the correlations of the error term among the pairs including the same households.

Future works

- Introduce the behavioral choice models the time transitions. Many people will be acting in anticipation of the future disasters.
- Choice set generation algorithm need improvement by compensatory method.

Thank you for your listening.