Accommodating spatial correlation in local-interaction formation model under a heavy rain disaster

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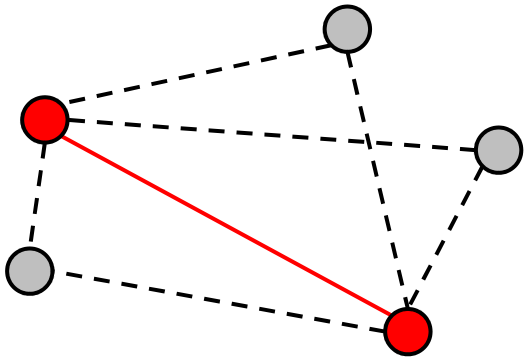
Research Background

- focusing on making interaction
  - interactions are important for evacuation and evacuees start earlier by interactions

    cf. Baker(1979), Pamela and Wolshon (2013), Urata and Hato(2012)

- focusing on making interaction in a group
  - A interaction between two people are influenced not only by two but also by others in group.



Review

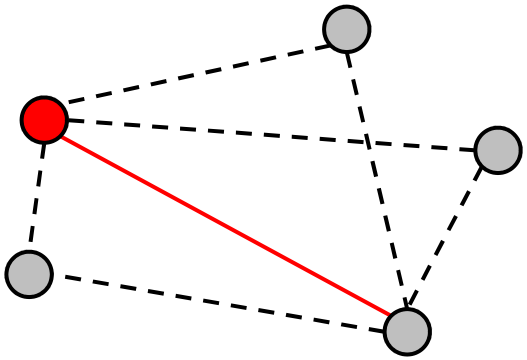
Classification of Interaction model

	Existence of Interaction	Decision Making	Influence of Interaction
Collective model Chiappori(1988)	Given In household	Household	Weight Utility
Global Interaction Model Brock and Durlauf(2000)	Given Whole to one	Individual	Probability (whole to one)
Local Interaction Model Brock and Durlauf(2000)	Given one to one	Individual	Probability (one to one)
Network Formation Barabasi and Albert(1999)	Not given (formate) one to one	No (group)	Number of interaction

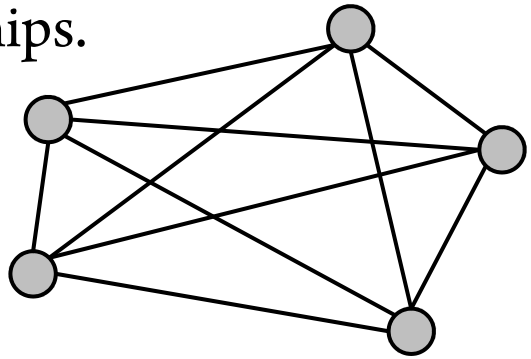
One to one relationship

What is group influence?

- Personal decision-making model is too complex
  - This is many-bodied problem
  - Utilities are constructed by the relationships and differences of the two



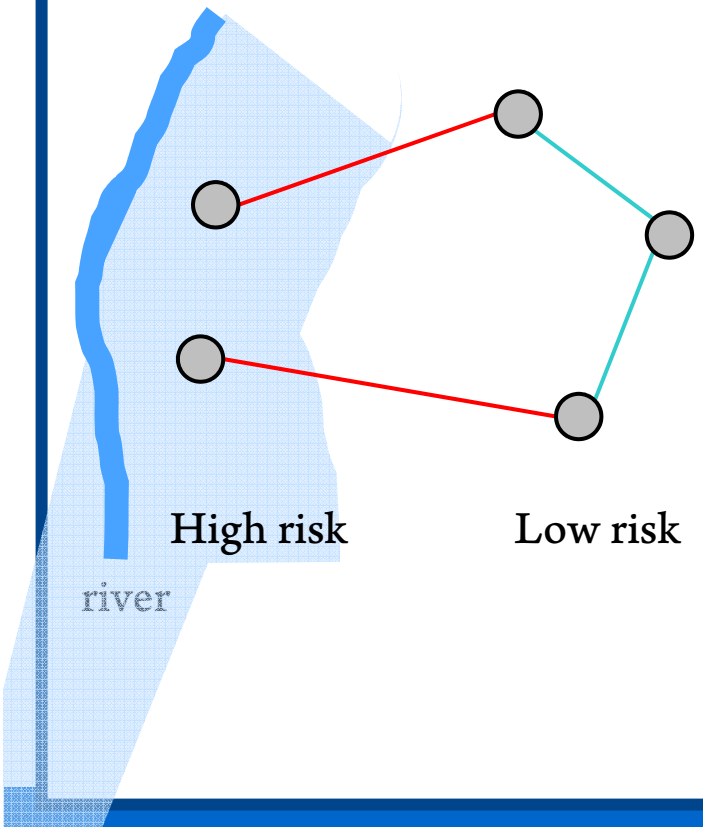
- Introduce group decision-making model
  - Comparing with whole interactions of the group and choosing one
  - A choice probability of a interaction is influenced by the relationships of the two and others' relationships.



Capturing correlations of interactions?

- Discrete choice model for interaction choice
  - The errors of these utilities have correlations between some interactions
  - The correlations arise from similarities of the states of interactions

What is similarities of interactions?



- Focus on "spatial risk"
- The difference of the risks of two nodes is bigger, interactions are easier to be formed because of altruistic preferences
- The similarity of the difference is caused by spatial risk.
- The correlation of observation errors of the difference is also caused by spatial risk.

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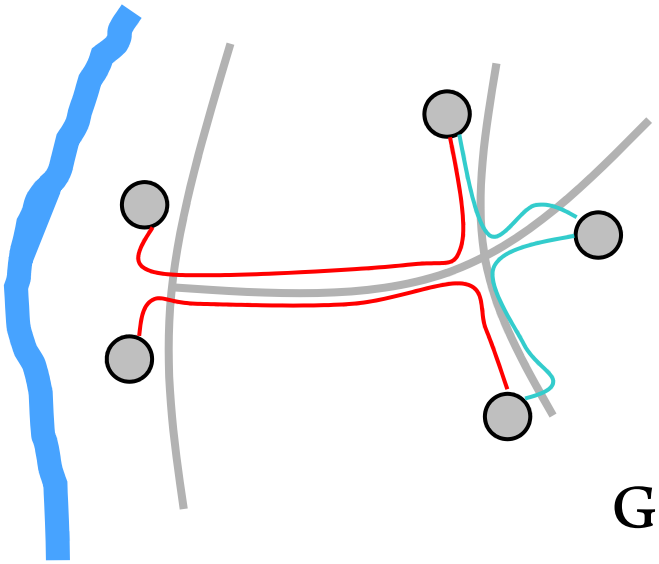
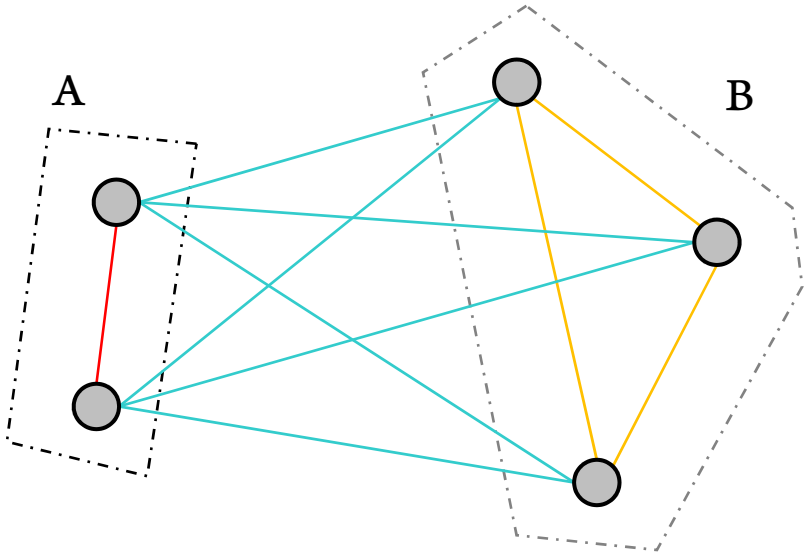
What is similarities of interactions?



- Travel costs for interactions are important factors
- The costs are spatial factor and the error term is correlated by space.

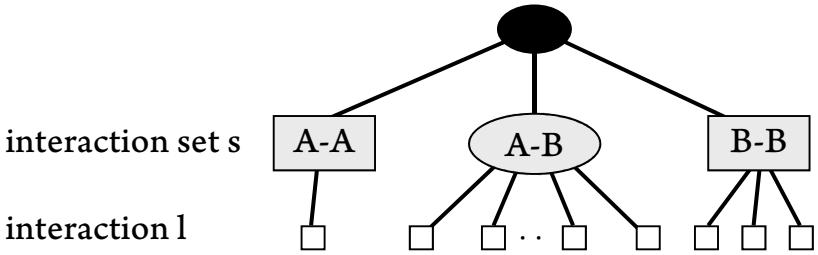
Give each interactions the spatial correlations

Introduction of spatial division

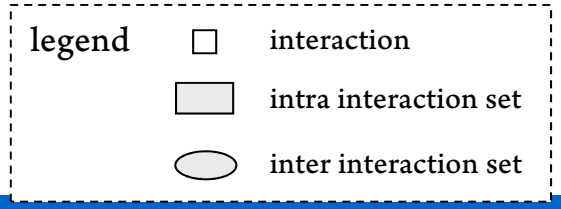


1. All nodes are divided by spatial characteristics

2. The interactions are distinguished by their divisions which two nodes belonged to.
   - Intra interaction set (A-A, B-B)
   - Inter interaction set (A-B)

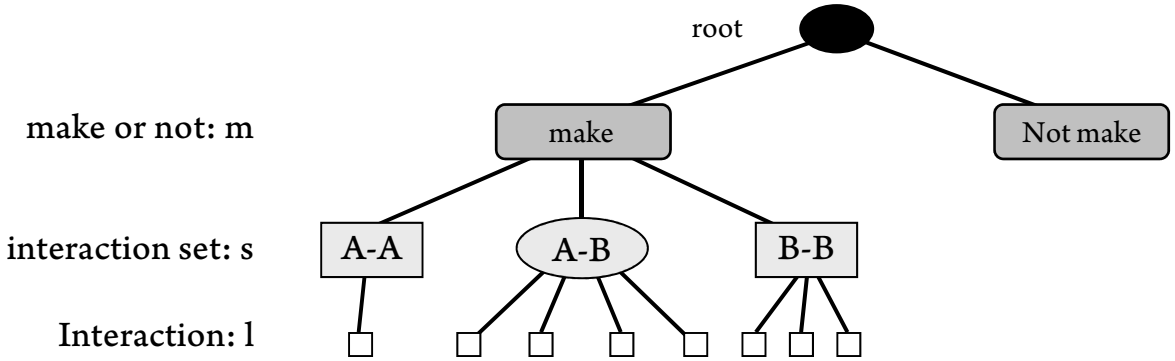


3. The interactions which belong to the same set have a correlation.



Formulation

Discrete choice model for interaction choice



Choice probability
$$P(m,s,l) = P(l \mid s)P(s \mid m)P(m) \quad (1)$$

Conditional probability of l
$$P(l \mid s) = \frac{\exp(v_l / \mu_l)}{\sum_{l \in s} \exp(v_l / \mu_l)} \quad (2)$$

Conditional probability of s
$$P(s \mid m) = \frac{\exp(V_s / \mu_s)}{\sum_{s \in m} \exp(V_s / \mu_s)} \quad (3)$$

Logsum variables of s
$$V_s = \mu_l \ln \sum_{l \in s} \exp(v_l / \mu_l) \quad (4)$$

Marginal probability of m
$$P(m) = \frac{\exp((V_m + v_m)/\mu_m)}{\sum_m \exp((V_m + v_m)/\mu_m)} \quad (5)$$

Logsum variables of m
$$V_m = \mu_s \ln \sum_{s \in m} \exp((V_s + v_s)/\mu_s) \quad (6)$$

Specific Utility v_l, v_m

Scale parameter $\mu_l \le \mu_s \le \mu_m = 1$

Error terms are given as
the i.i.d extreme value (TypeI)

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

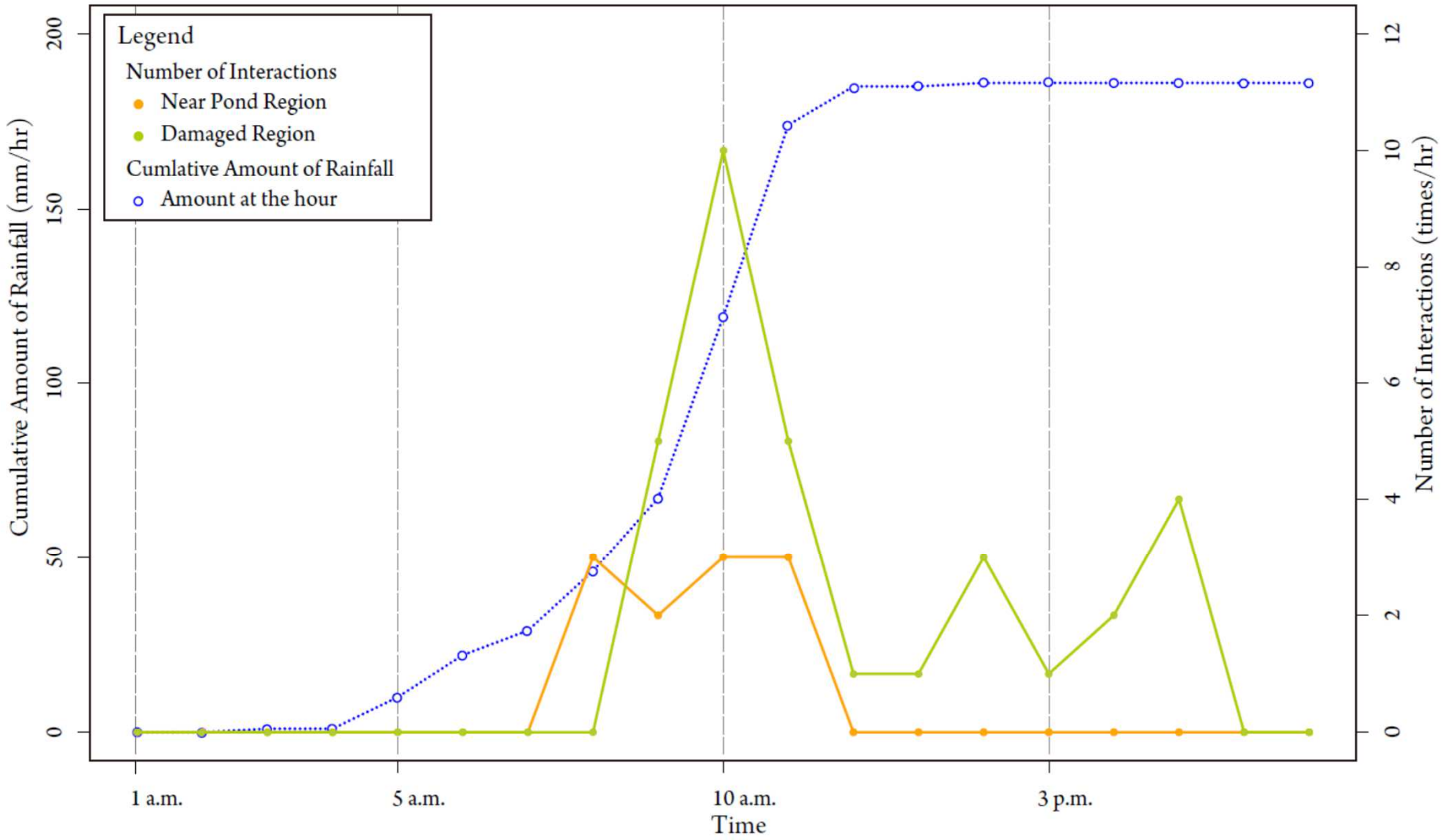
Survey(2004.9-10)

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

Illustration of Collective Behaviors

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

Number of interactions and rainfalls



Setting utility

Making Interaction Utility

$$v_{l=ij,t} = \beta_{dis} d_{ij} + \beta_{hou} h_{ij} + \beta_{road} r_{ij} + (1-\sigma) A_{ij,t} - \sum_{ij} A_{ij,t} \quad (7)$$

Altruistic Utility (inequality)

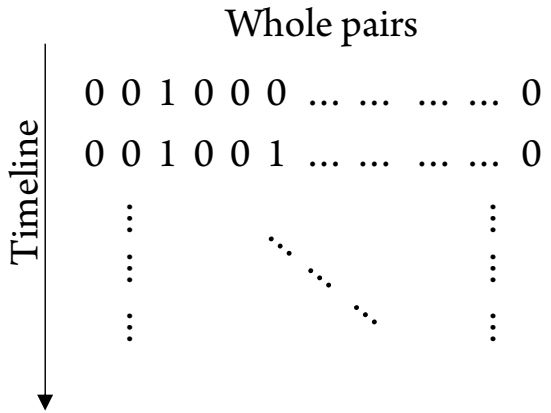
$$A_{ij,t} = \left\{ \beta_{dam} \left| D_{i,t} - D_{j,t} \right| + \beta_{weak} \left| W_i - W_j \right| + \beta_{man} \left| man_i - man_j \right| + \beta_{one} \left| one_i - one_j \right| \right\} \sigma^{k_{ij,t}} \quad (8)$$

Making Utility

$$v_{m=make,t} = 0 \quad (9)$$

$$v_{m=no,t} = \beta_{rain} \exp(-r_t) - \sum_{ij} A_{ij,t} \quad (10)$$

Dataset: Each group choice every 15 minutes



i, j : Household

d_{ij} : Path distance ij

h_{ij} : Density of house on the path ij

r_{ij} : Main road proportion of the path ij

$D_{i,t}$: Risk of household i

W_i : Number of children and elderly

man_i : Dummy: one man in household i

one_i : Dummy: Number of household is one

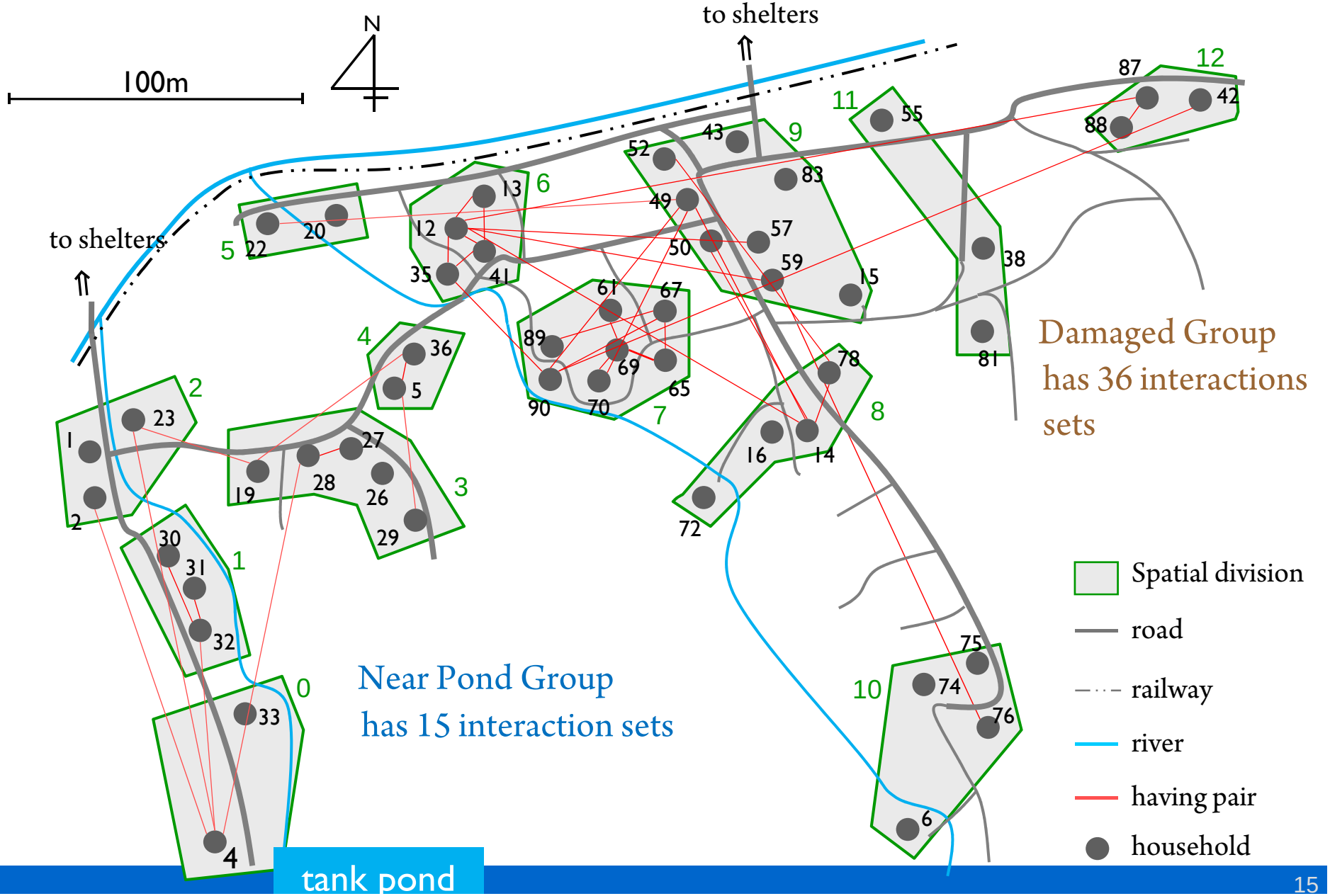
k_{ij}^t : Number of making interaction ij

r_t : Hourly amount of rainfall

σ : Parameter of unequal breaking

β : Estimation parameter

Spatial division



Estimation Result

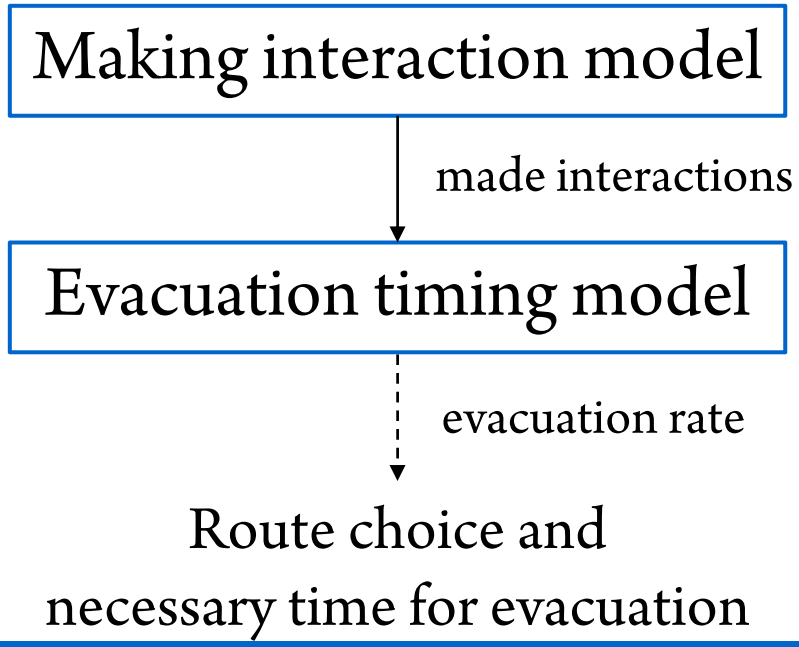
	N-GEV		NL	
	推定値	t値	推定値	t値
Path Distance β_{dis}	-0.00173	-2.512**	-0.00159	-2.560**
Density of house β_{hou}	3.782	1.941*	3.780	2.127**
Main road β_{road}	-0.111	-1.230	-0.111	-1.296
Dif of risk (intra) $\beta_{dam.s}$	0.131	2.644**	0.130	2.673**
Dif of risk (inter) $\beta_{dam.d}$	0.117	2.214**	0.120	2.347**
Dif of weak (intra) $\beta_{weak.s}$	-0.0425	-0.543	-0.0420	-0.546
Dif of weak (inter) $\beta_{weak.d}$	0.0213	0.255	0.0210	0.259
Dif of one man (intra) $\beta_{man.s}$	-0.0946	-1.206	-0.0940	-1.223
Dif of one man (inter) $\beta_{man.d}$	0.0211	0.266	0.0210	0.278
Dif of one person (intra) $\beta_{one.s}$	0.00376	0.045	0.00370	0.047
Dif of one person (inter) $\beta_{one.d}$	0.228	1.616	0.230	1.718*
Rainfall β_{rain}	1.710	3.530**	1.710	3.583**
Altruistic σ	0.200	—	0.200	—
Scale parameter (interaction) μ_1	0.141	2.822**	0.140	3.183**
Scale parameter (set) μ_s	0.153	3.140**	—	—
Number of choices		102		102
Log likelihood(0)		-587.39		-587.39
Log likelihood(conv)		-284.69		-284.71
Likelihood ratio ρ^2		0.515		0.515
Adjusted likelihood ratio ρ^2		0.491		0.493

Note: --- = not applicable
** = significant at .05
* = significant at .10

Conclusion and future works

- Modeling one to one interactions in group.
- The correlations of interactions are given by spatial characters and this method can give the correlations relatively easily.
- Applicate a real data and estimate the parameters

- Evaluate evacuation rate with interaction using this making interaction model and evacuation timing model.



References

Baker, EJ. (1979) Predicting response to hurricane warnings: a reanalysis of data from four studies, Mass Emergencies, Vol. 4, pp. 9 -24.

Urata, J. and Hato, E. (2012) Modeling the Cooperation Network Formation Process for Evacuation Systems Design in Disaster Areas with a Focus on Japanese Megadisasters, Leadership Manage. Eng., Vol.12, pp.231-246.

Pamela, M-T., Wolshon, B. (2013) Evacuation transportation modeling: An overview of research, development, and practice, Transportation research Part C, Vol. 27, pp. 25-45.

Chiappori, PA. (1988) Rational household labor supply, Econometrica: Journal of the Econometric Society, Vol. 56(1), pp. 63-90.

Brock, WA., Durlauf, SN. (2000) Interactions-based models, National Bureau of Economic Research, Technical working paper No. 258.

Barabasi, A.-L., Albert, R. (1999) Emergence of Scaling in Random Networks, Science, Vol. 286, pp. 509-512.