A study on radiological consequence analysis using agent-based protective action modeling

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01

Introduction

Introduction

Background

- There are lots of elements involved in the radiological emergency
  - e.g., evacuees, communication system, road
- Interactions between those make it harder to estimate the consequences
- The current consequence analysis is being conducted based on a simplified model with conservative assumptions
- **Agent-based modeling (ABM)** can be a solution to reflect various situations that may arise during the emergency phase

In this study,

- A method for simulating emergency phase using agent-based modeling is presented
- A case study was conducted to perform consequence analysis by combining an atmospheric dispersion model and an agent-based emergency phase model

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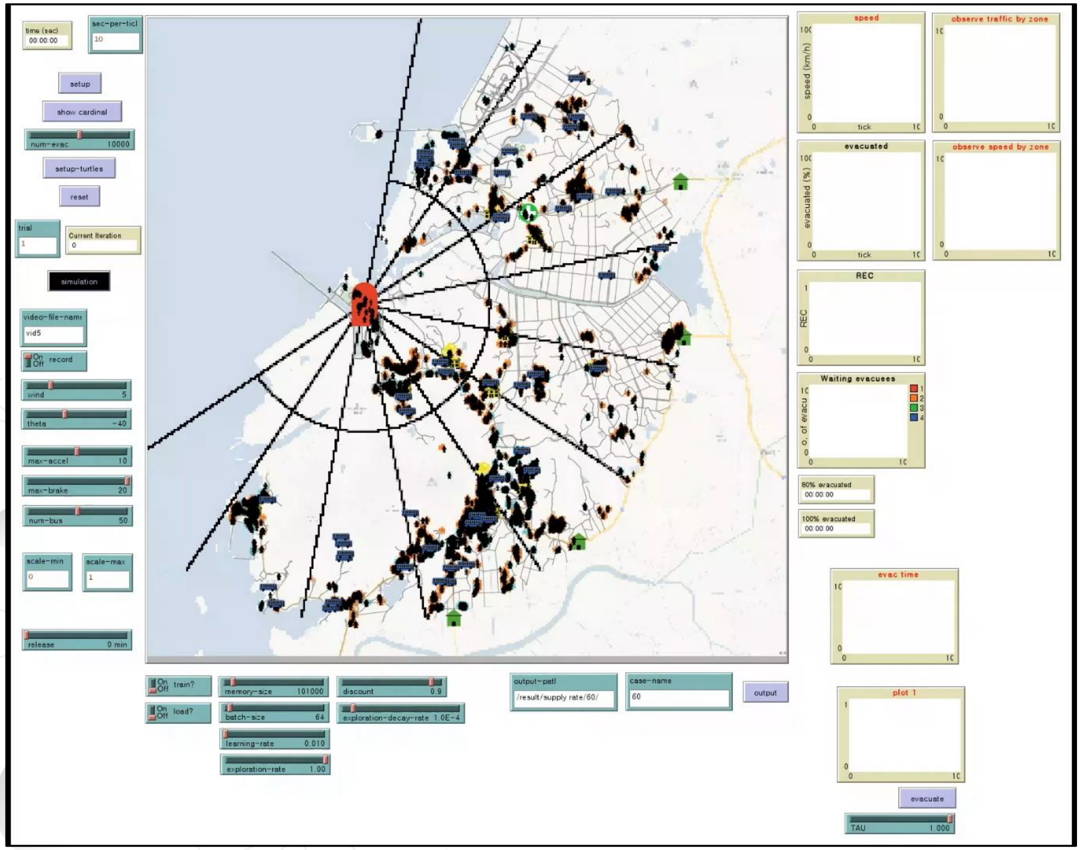
Agent-based emergency phase model

Agent-based emergency phase model

Preview

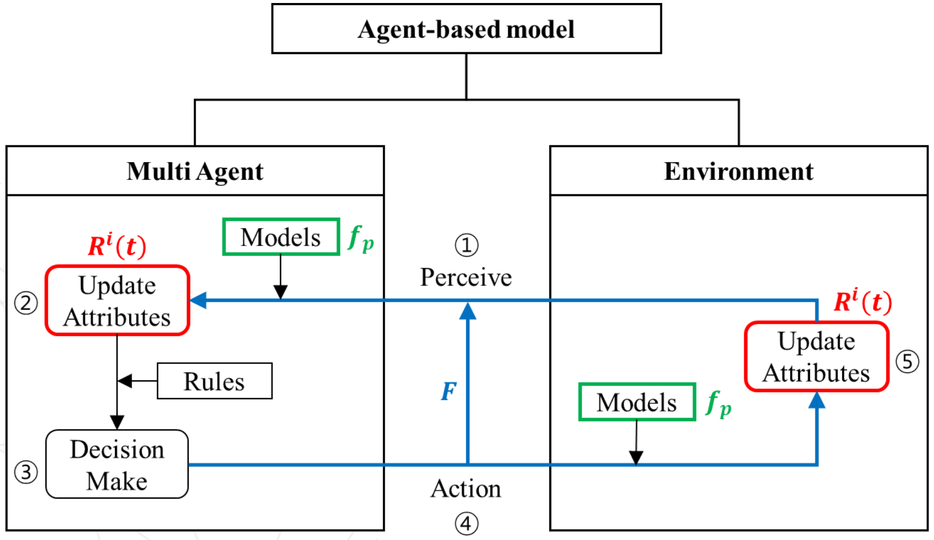


- Example
  - ‘Netlogo’ ABM tool
  - Environments
    - Road network
    - Residential & Business area
    - Plant location
    - Primary assembly area
  - Agents
    - Evacuee
    - Radioactive material

Agent-based emergency phase model

Agent-based modeling

- Explain complex macroscopic phenomena as interactions of microscopic actors with relatively simple behavioral rules



① **Perceive:**
Perceive and be influenced by the surrounding environment and the actions of other agents

② **Update attributes:**
Update attribute values using some models from recognized information

③ **Decision make:**
Determine the next action based on updated property values and behavioral rules

④ **Action:**
Influencing the surrounding environment and other agents by performing an action

⑤ **Update attributes:**
Update the attribute values of the environment affected by the agents

Agent-based emergency phase model

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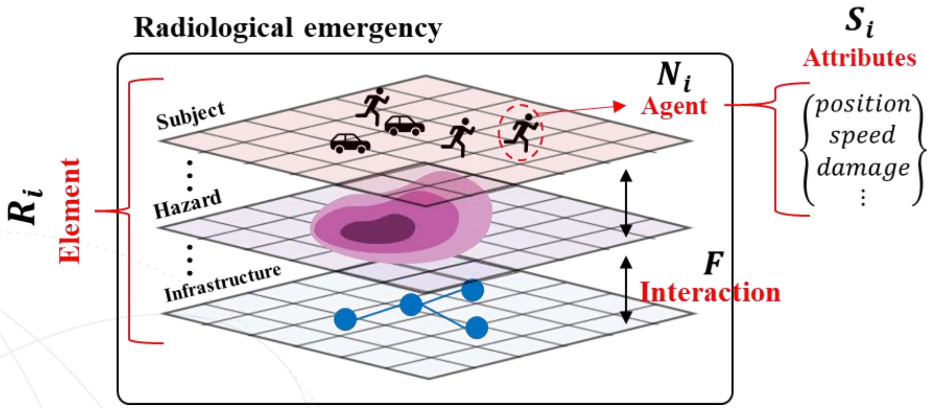
Agent-based modeling

- facilitates modeling various characteristics (attributes) and behavior rules of individual agents

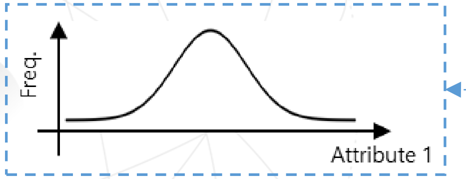


Ex)

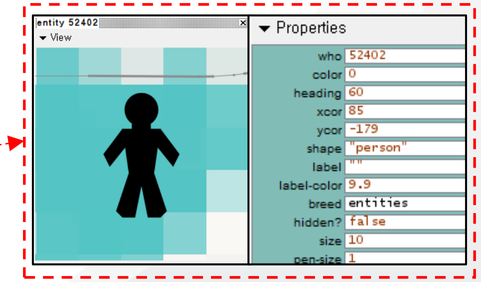
$$r_{10,Speed}^{Evacuee} = 30\ km/h$$

→ 10th evacuee's speed is 30 km/h

$$R^i(t) = \begin{array}{cc} \text{attributes} \rightarrow & \\ \begin{bmatrix} r_{1,a_1}^i(t) & \cdots & r_{1,a_{m_i}}^i(t) \\ \vdots & \ddots & \vdots \\ r_{n_i,a_1}^i(t) & \cdots & r_{n_i,a_{m_i}}^i(t) \end{bmatrix} & \downarrow \text{No. of agents} \end{array}$$



→ **column: Distribution of all agent's value of attribute i**



→ **raw: Agent *j*'s all attributes**

Agent-based emergency phase model

Agent modeling

Evacuee

- Randomly located on residential & business area
- Evacuates to the nearest road located at a 5km boundary
  - Shortest path finding
    - A* algorithm ➔ **Where to?** → $r_{j,path}^{Evacuee}$
  - Traffic model
    - NS-CA (Nagel-Schreckenberg cellular automata) model ➔ **How fast?** → $r_{j,speed}^{Evacuee}$
- Dose

Agent-based emergency phase model

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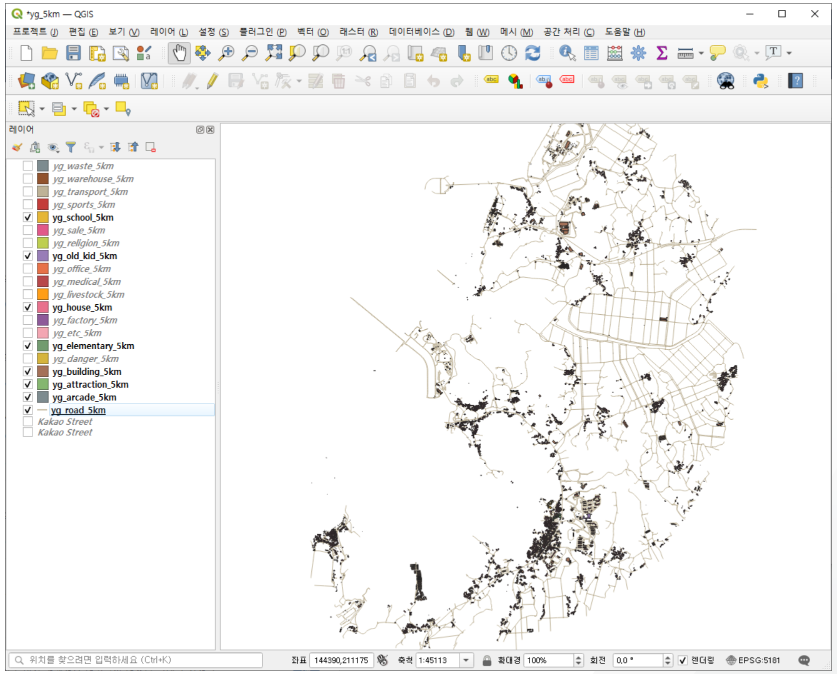
Environment modeling

Based on GIS database

- NPP,
- Residential & Business area, and
- Road network distribution was modeled
  - Number of lanes
  - Speed limit



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Case study

Case study

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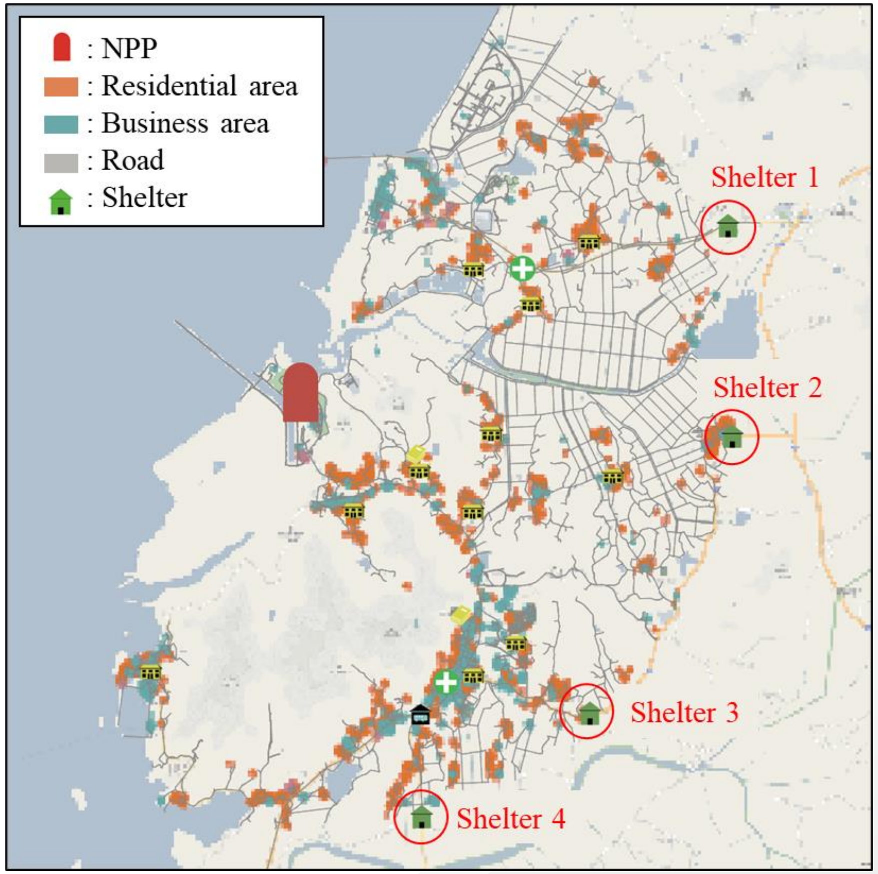
Agent-based emergency phase simulation

- Imaginary NPP site was selected
- Area within a radius of 5 km of the NPP was modeled (PAZ)
- Assumed that 4 exit road point are located at the 5 km boundary



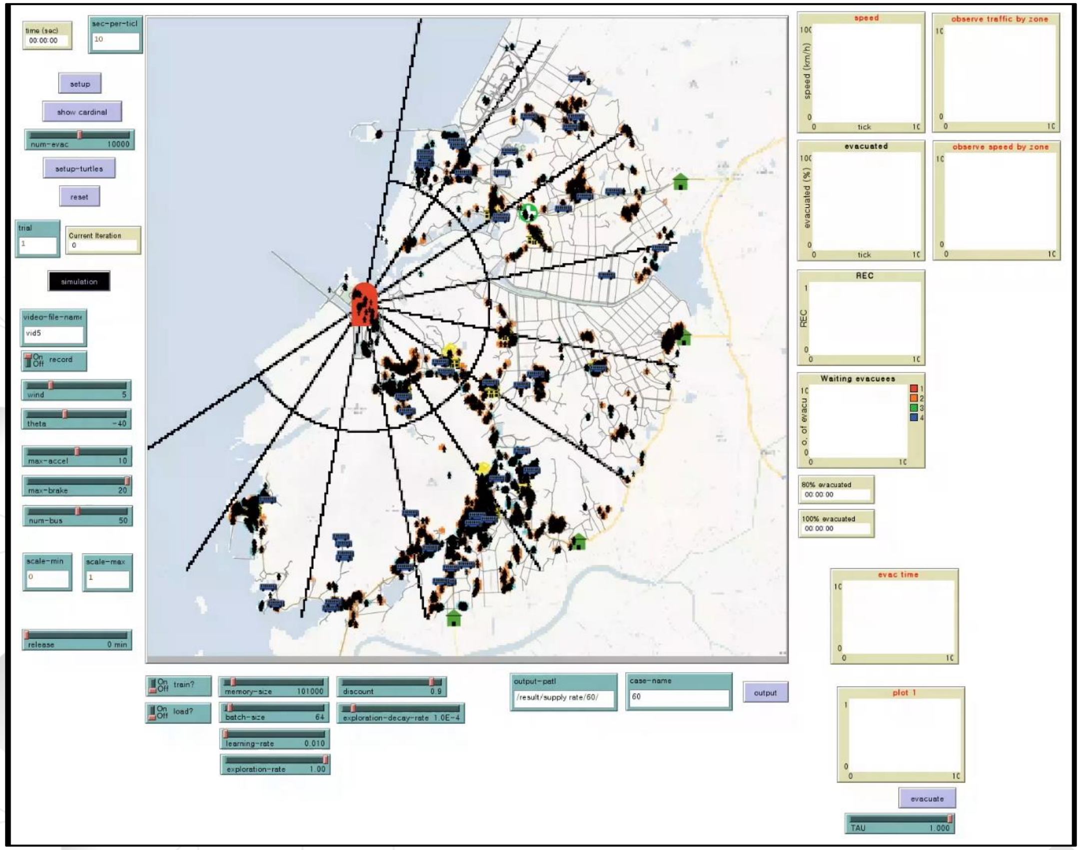
Case study

Agent-based emergency phase simulation

Simulation timeline

- The simulation start time $t_{release}$
- Each evacuee begins to move after t_{alarm}
  → the time when evacuation order is issued
- Each evacuee begins sheltering after a preparation (delay) time
  → $t_{sheltering\ delay}$
- Each evacuee begins evacuating after a preparation (delay) time
  → $t_{evacuation\ delay}$

Agent-based emergency phase simulation



Name	Value
Number of simulations	100
Time step	10 seconds
t_{alarm}	$U(30,90)$ [min]
$t_{sheltering\ delay}$	$U(30,90)$ [min]
$t_{evacuation\ delay}$	$U(30,90)$ [min]
Limit speed of road nodes	30, 50, 80 km/h
Number of lanes of road nodes	2, 4, 6, 8
Number of evacuees ($n_{evacuee}$)	**1,000**

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Summary and Conclusions

Summary and Conclusions

- ABM can be used for integrated modeling for a emergency phase involving many elements and attributes

- Emergency phase simulation was performed with less conservative assumptions
  - Alarm/Sheltering/Evacuation delay distribution
  - Realistic evacuation route based on GIS data
  - Evacuation speed based on traffic model (considering traffic jam)

- Future works
  - To consider more attributes and behavior rules
  - To minimize (optimize) computational cost

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THANK YOU

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