RoboCup Rescue Simulation League

AIT-Rescue (Japan)

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Agenda

1. Scientific Contribution of Our Research
2. Module
3. Strategies
    I. Police Force
    II. Ambulance Team
    III. Fire Brigade
4. Evaluation
5. Conclusion

Scientific Contribution of Our Research

Background

- In task allocation under conditions where global communication is unavailable, a common approach is using **a greedy algorithm.** Greedy algorithms have been a popular choice among teams in competitions
- Another applicable technique under the same conditions is **the response threshold method**

Introducing the Response Threshold Method and Confirming Its Effectiveness

What is the response threshold method?

Urgency based on citizen survival time

Urgency of citizen needing rescue

1. Sense **stimulus** (s)

2. Decide whether to execute task based on stimulus (s) and **response threshold** (θ)

$s \not> \theta$

Civilian

Fire Brigade

Building

3. Execute task

3. Search for other civilians

→ Proper adjustment of s and θ is required for effective operation

Hypothesis for Response Thresholds in RRS

FireBrigade response threshold hypothesis:

response threshold is related to the number of tasks and the number of agents

- Large number of agents relative to number of tasks

→ response threshold should be set high and tasks with high urgency should be executed.

- Low number of agents relative to number of tasks

→ Lower reaction thresholds, even less urgent tasks should be performed

Determining Stimulus in RRS

The urgency of rescuing a civilian can be determined based on their survival time and the estimated rescue time

→ Rescue Task Stimulus: **(Civilian's Survival Time)** + **(Estimated Rescue Time)**

The degree to which each factor is considered varies depending on the scenario

→We introduce **weights for both survival time and rescue time**

Stimulus and Response Threshold Adjustment

It is necessary to adjust the weights and response thresholds in order to achieve an optimal rescue score

Adjusted parameters in disaster scenarios with varying numbers of tasks and agents, where **civilians and agents were scattered**

Objective of the Experiment

To verify the effectiveness of the **Response Threshold Method** in RRS

- To conduct experiments in multiple scenarios within RRS where agents **cannot communicate**
- To compare and evaluate the rescue performance against the **Greedy Algorithm agent** for each scenario

Experimental Conditions

- Number of Agents and Civilians:
  - Fire Brigade Agents : 75
  - Ambulance Team Agents : 25
  - Civilians : 100, 150, 200, 250, 300

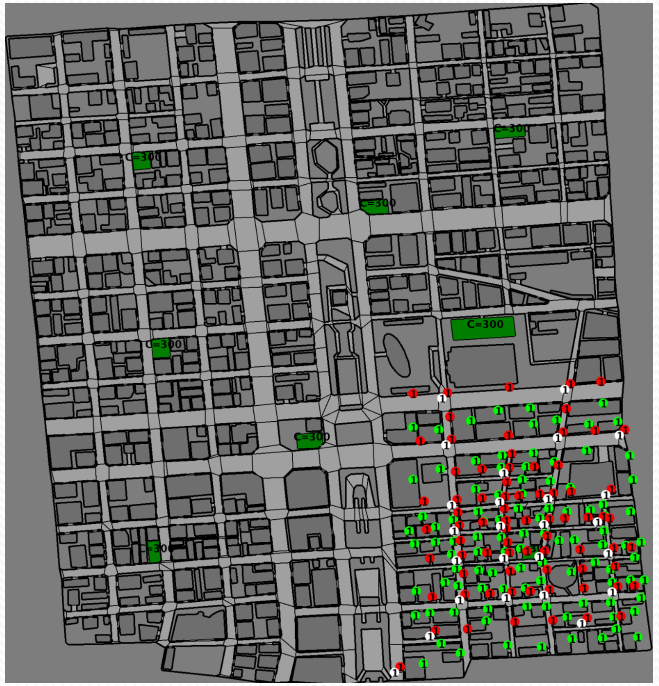
    ➡ Number of civilian was varied to evaluate the effectiveness of exploring for **higher-priority tasks**

- Inter-Agent Communication: None

Placements of Agents

Purpose: To adjust the difficulty according to the degree of dispersion of the placement and to assess the performance of each

Scattered placement(Sakae)



Crowded placement (Sakae)

Agents Used in the Experiment

Response Threshold Method Agent

- Stimulus: $Stimulus = SurvivalTime + RescueTime$
- Response Threshold: A value optimized for the most difficult scenario in the experiment

Greedy Algorithm Agent

- Only task selection function is changed to the Greedy Algorithm
- Cost: $Cost = (SurvivalTime + RescueTime)^2$

Experimental Results

Relative Rescue Score of the Response Threshold Agent (Compared to the Greedy Algorithm Agent)

Type of placement in scenario		**Number of civilians**				
Agent placement	**Civilian placement**	100	150	200	250	300
Crowded	**Crowded**	0.942	1.114	0.975	0.880	0.981
	Scattered	1.065	1.020	0.863	0.889	1.011
Scattered	**Crowded**	0.844	0.808	0.933	0.867	0.852
	Scattered	0.860	0.855	1.016	0.946	0.969

Red Text : Scores where the Response Threshold Method had an advantage

Comparison of Agent (1/3)

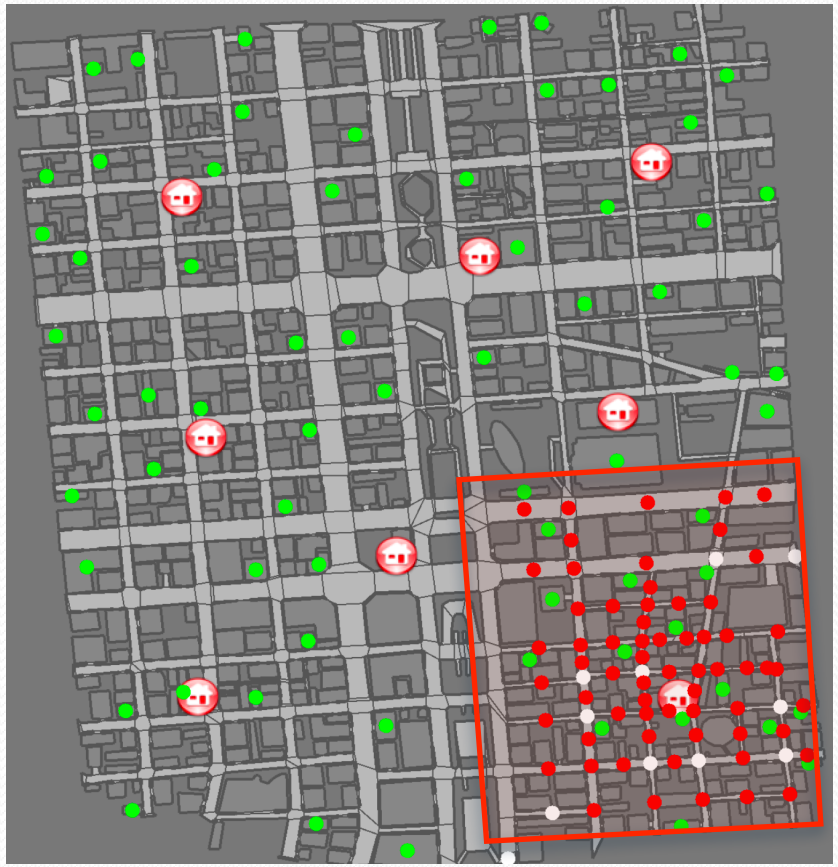
Scenario: Crowded Agents,
Scattered Civilians

Response Threshold Method Agent:

The property of exploring for more important tasks prevents agents from over-concentrating on civilians near their initial positions.

Efficiently rescue **civilians far from agent's initial positions**, achieving a higher score against the Greedy Algorithm.

Comparison of Agent (2/3)



Scenario: Crowded Agents, Scattered Civilians

Greedy Algorithm Agent:

Because it reliably executes high-priority tasks, agents concentrate on **civilians near its initial position**

This delays the rescue of civilians far from its initial position, leading to a lower score than the Response Threshold Model

Comparison of Agent (3/3)

Scenario with Scattered Agents and Crowded Civilians:

Greedy Algorithm completely outperformed the Response Threshold Method across all numbers of civilians

Other scenarios:

In most cases, **Greedy Algorithms** is superior, but Response Threshold Method becomes advantageous depending on the number of civilians

Summary

- The effectiveness of the response threshold method is **highly dependent on the disaster scenario**
- While potentially effective with concentrated agent and civilian placement, its performance typically falls below that of greedy algorithms in general environments

Future Tasks

- Challenge: It is necessary to **identify the optimal response thresholds for each environment**
- Current Status: The relationship between response thresholds and environmental characteristics is not yet clear
- Future Goals:
  - To elucidate the relationship between environmental characteristics and optimal response thresholds
  - To enable **the pre-calculation of optimal response thresholds for specific maps,** facilitating their use in competitions

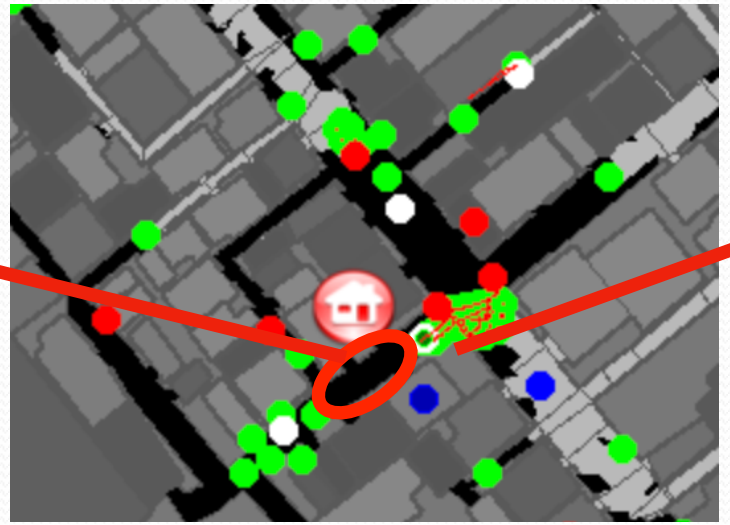
Modules

Performance Issues of the Police Force in RoboCup 2024

Transportation routes to the refuge were not secured, preventing the transport of injured civilians

Uncleared transport route

Ambulance team transporting civilians



Kobe2, step 160

The route needs to be cleared preferentially by the police force

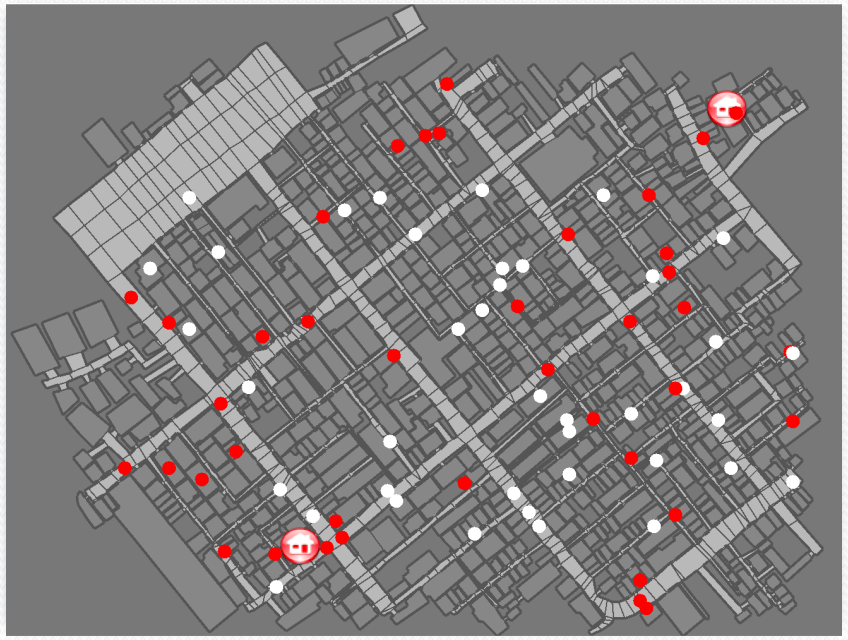
→A system to **select and prioritize the clearing of roads critical for civilian transport** is essential

Lifeline Graph Module

Module to detect **frequently used roads for civilian transport**

→ Sub-module of PoliceForceDetector

Input



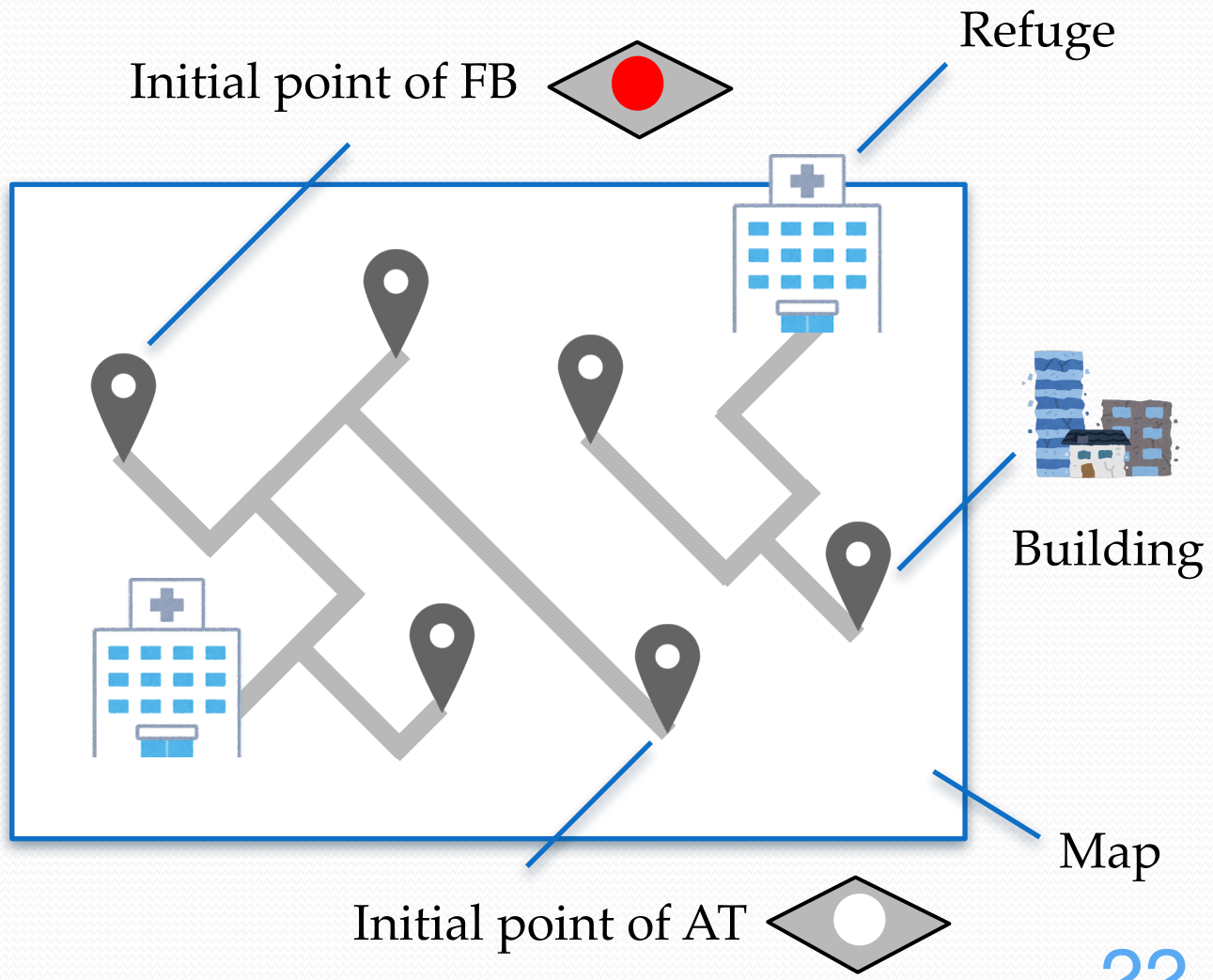
Pre-computed

Detected road segments

Detection Method (1/3)

1. Randomly pick potential civilian rescue locations

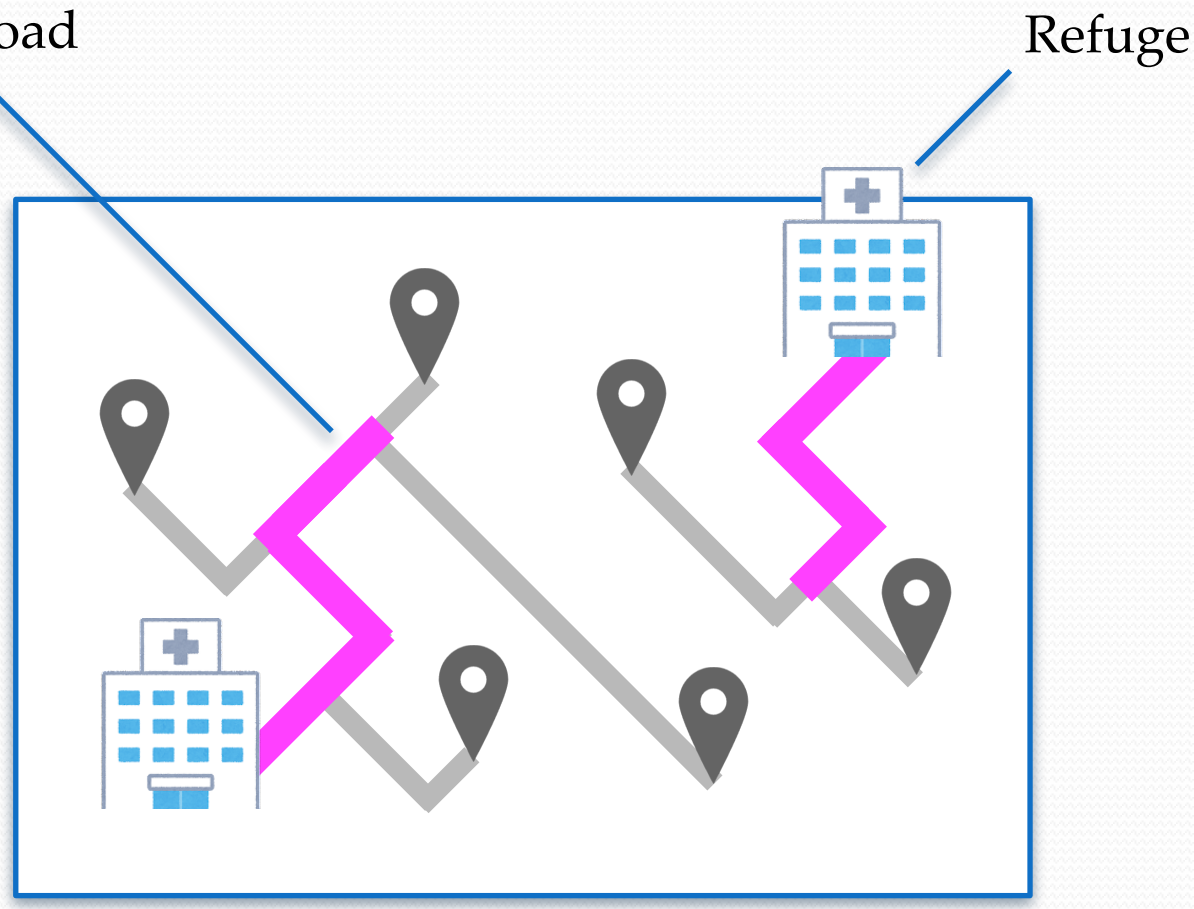
2. Calculate transport routes from the selected locations to the refuge



Detection Method (2/3)

3.From the calculated routes, roads that occur frequently are decided as priority roads

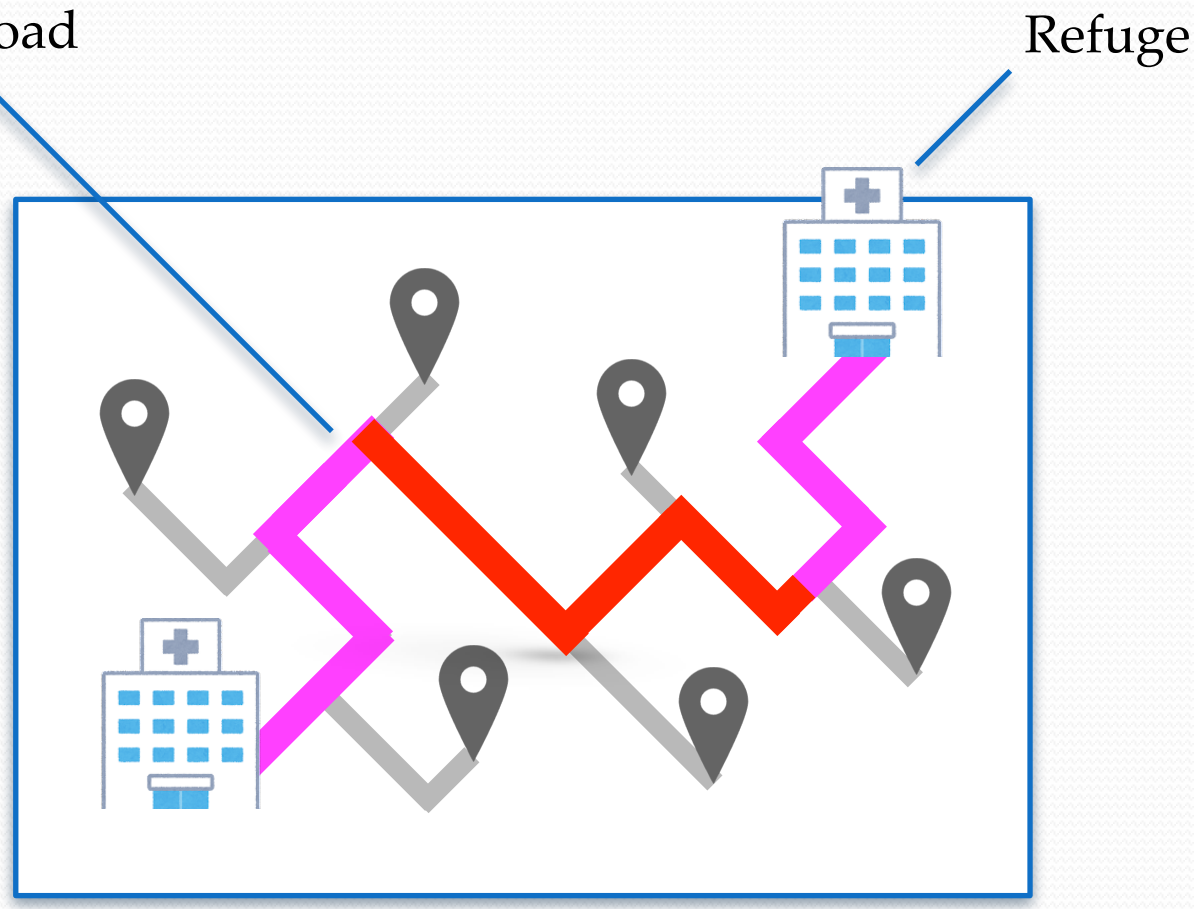
Estimate roads with high probability of being used for transport



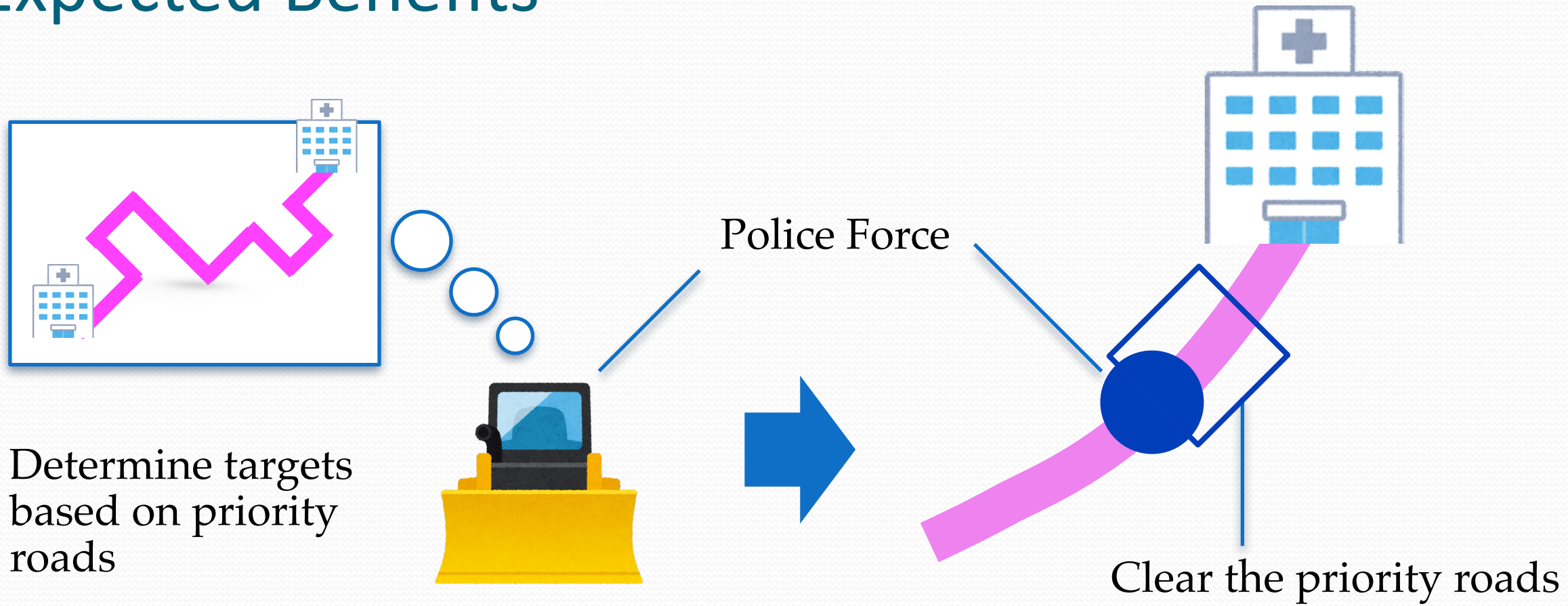
Detection Method （3/3）

4.Designate roads connecting nearby priority roads as priority roads as well

Each priority road provides access to all refuges



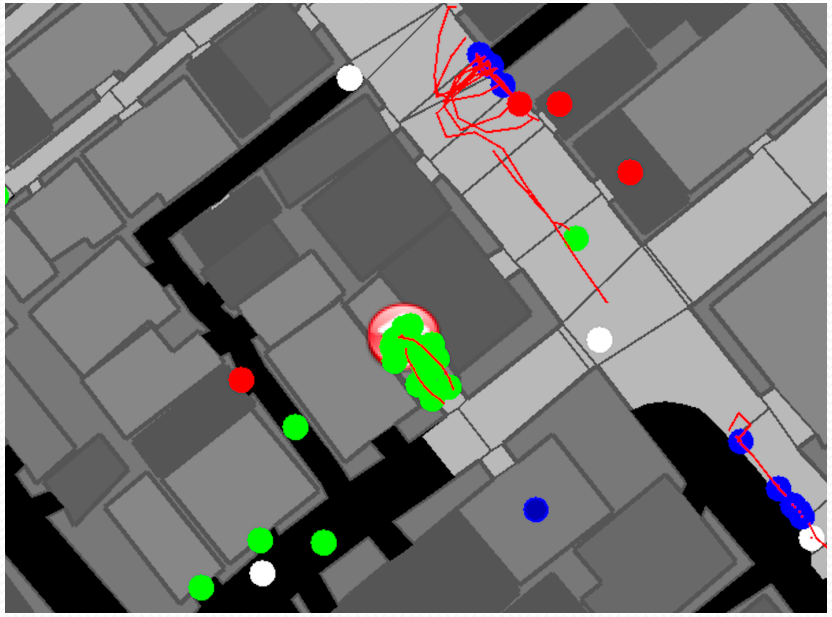
Expected Benefits



→ Enables the securing of critical transport routes.

Evaluation

Confirm if we addressed the issues from RoboCup 2024 in Kobe 2

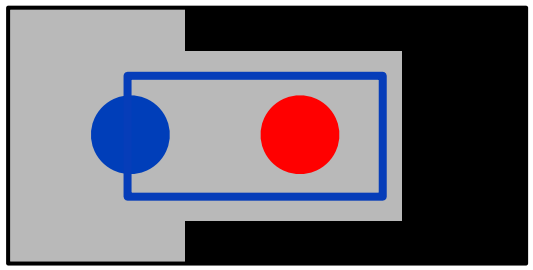


→ Checked that the area around the refuge was cleared early in the simulation, and injured civilian were transported to the refuge

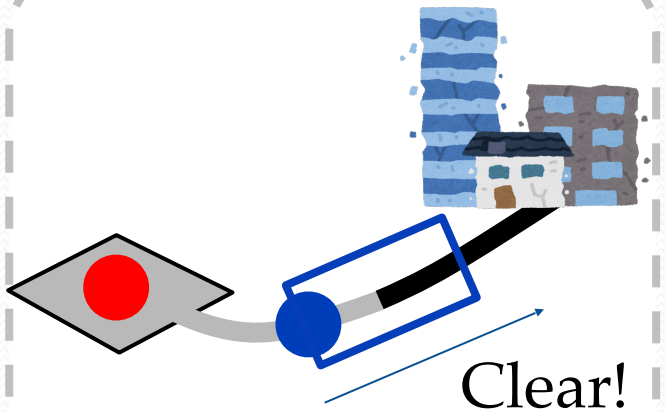
Strategies

Purpose of Police Force

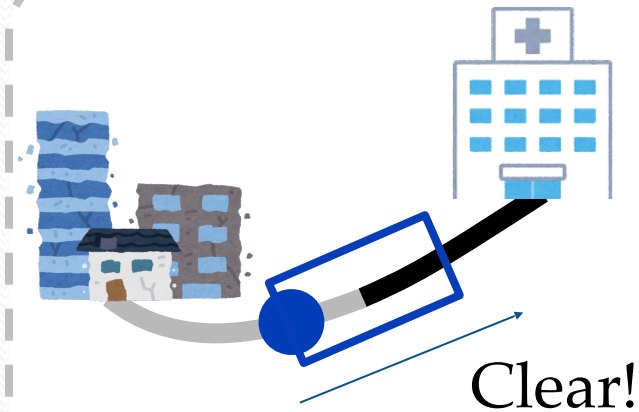
PoliceForce aims to support the activities of other agents



resolving stuck



Securing access from agents to buildings



Securing access from buildings to refuges

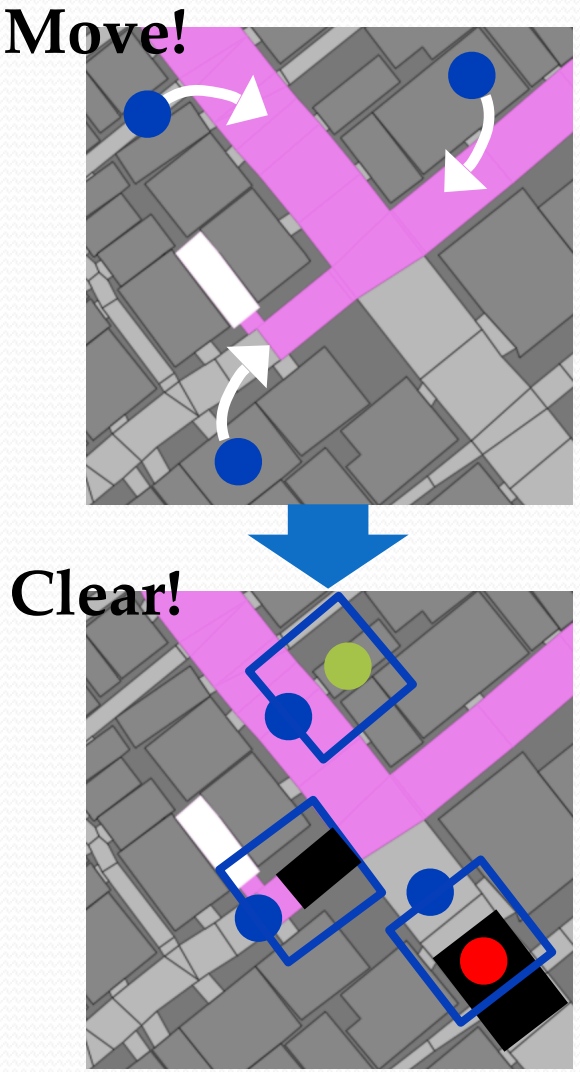
→ The PoliceForce in this strategy will proceed with clearing debris with these support activities in mind

Police Force Strategies

PoliceForce clears debris along the lifeline graph

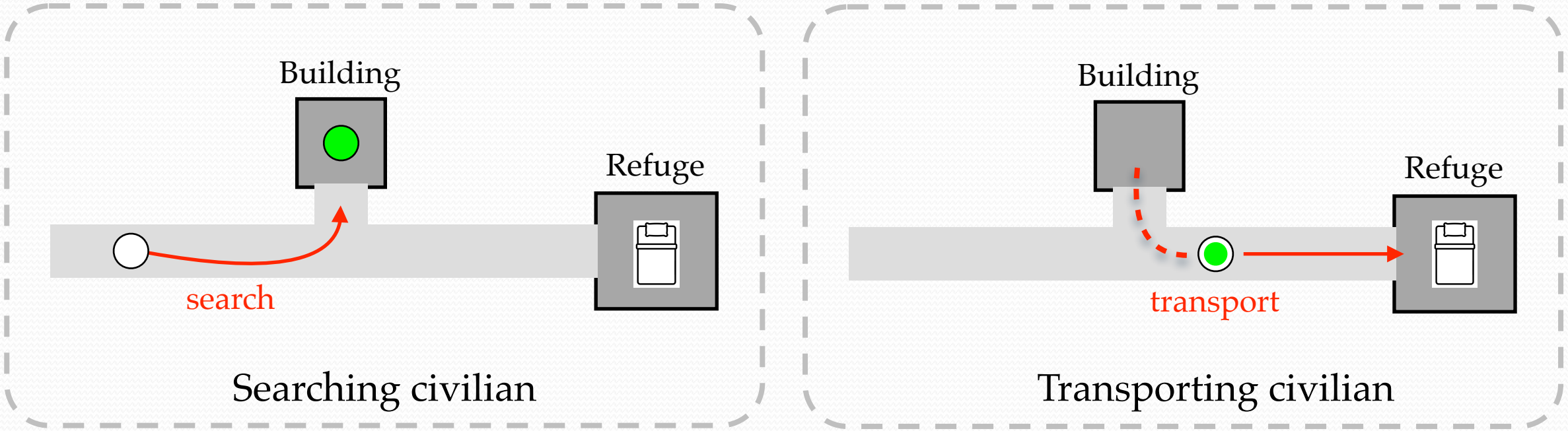
1. Gathering on lifeline graph
2. The following tasks are executed in parallel
   - Clearing debris on the lifeline graph
   - Resolved stuck
   - Clearing debris at the entrance

→ Agents will likely be able to move to buildings and refuges



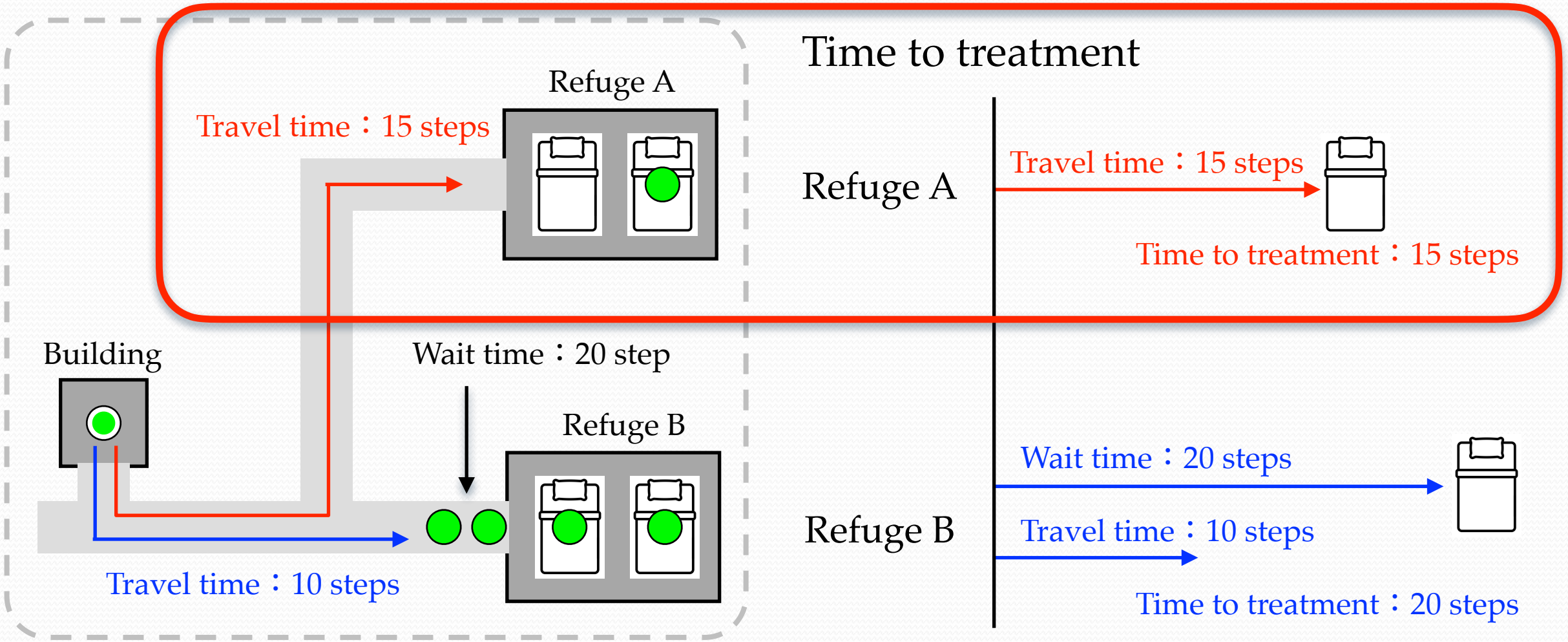
The Role of the Ambulance Team

The role of the Ambulance Team is to search civilians and transport them to a refuge



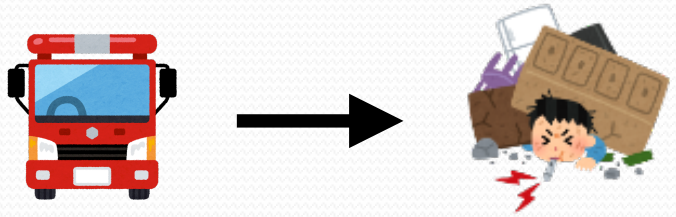
→When designing the strategy for an Ambulance Team, it is important to determine how to search for civilians and which refuges they should be transported to

Refuge Selection Strategy

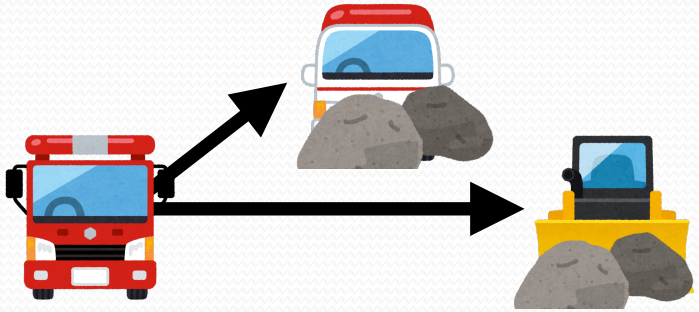


The Role of the Fire Brigade

The Fire Brigade restores disaster relief agents to an operational state and ensures civilians are ready for transport



Rescuing Civilians from Buriedness



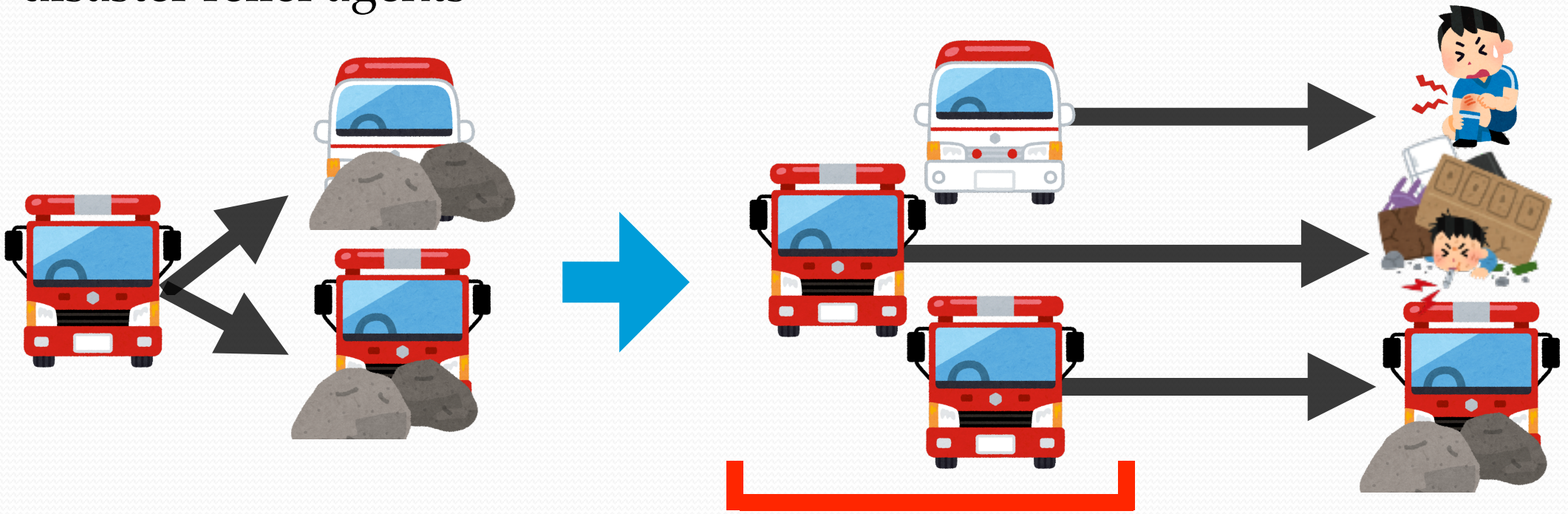
Ensure a sufficient number of active disaster relief agents

→The Fire Brigade does more than simply rescue civilians. Crucially, **it also has the ability to restore other rescue units to an operational state**. This capability is essential for the overall efficiency of the rescue operation

Fire Brigade Rescue Target Selection Strategy

Prioritize rescuing disaster relief agents

→**Aim to improve rescue efficiency** by increasing the number of operational disaster relief agents



More disaster relief agents become operational

Evaluation

Results

Team	Maps（RSL2024）		
	Kobe2	Paris1	Montreal1
AIT-Rescue 2025	189.36	57.83	32.05
AIT-Rescue 2024	184.59	58.17	31.83
Ri-one 2024	183.84	57.08	31.60

- AIT-Rescue 2025" achieved a higher score in certain scenarios.
- The **number of shelters** appears to be a contributing factor

Conclusions

Conclusions

- AIT-Rescue 2025:
  - Introduction of a prioritized road graph for the Police Force
  - Improvement of refuge selection for the Ambulance Team
  - Improvement of rescue target selection criteria for the Fire Brigade

- Future Activities:
  - Identifying the relationship between response threshold parameters and the environment
  - Implementing the response threshold method in RRS

References

- Visser, A., Ito, N., & Kleiner, A. (2015). *RoboCup Rescue Simulation Innovation Strategy*. In *RoboCup 2014: Robot World Cup XVIII* (pp. 661-672). Springer.
- Bonabeau, E., Dorigo, M., & Theraulaz, G. (1999). Swarm Intelligence: From Natural to Artificial Systems. Oxford University Press.

Thank You!