RoboCup Rescue Simulation League

AIT-Rescue (Japan)

H. Uehara[1], H. Suzuki[1], J. Fujisawa[1], R. Maeda[1],
I. Matsunaga[1], K. Ito[1], A. Okamoto[1], K. Sasada[1],
Y. Sugisaka[1], R. Suzuki[1], K. Hayashi[1], Y. Shimada[1],
K. Ando[1], T. Uchitane[1], K. Iwata[2] and N. Ito[1]

[1]Department of Information Science, Aichi Institute of Technology, Japan
[2]Department of Business Administration, Aichi University, Japan

Agenda

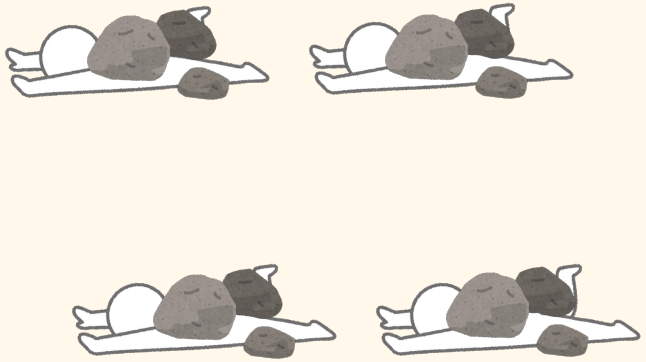
1. Scientific Contribution of Our Research (Layered DCOP)
2. Modules
   i. Search Order Module
   ii. Path Length Estimator Module
3. Strategies
   i. Ambulance Team
   ii. Fire Brigade
   iii. Police Force
4. Evaluation
   i. Result of AIT-Rescue 2023
   ii. Conclusion

Scientific Contribution of Our Research

An Important Issue in RRS

We need to appropriately assign the agents to the disasters

How to assign?



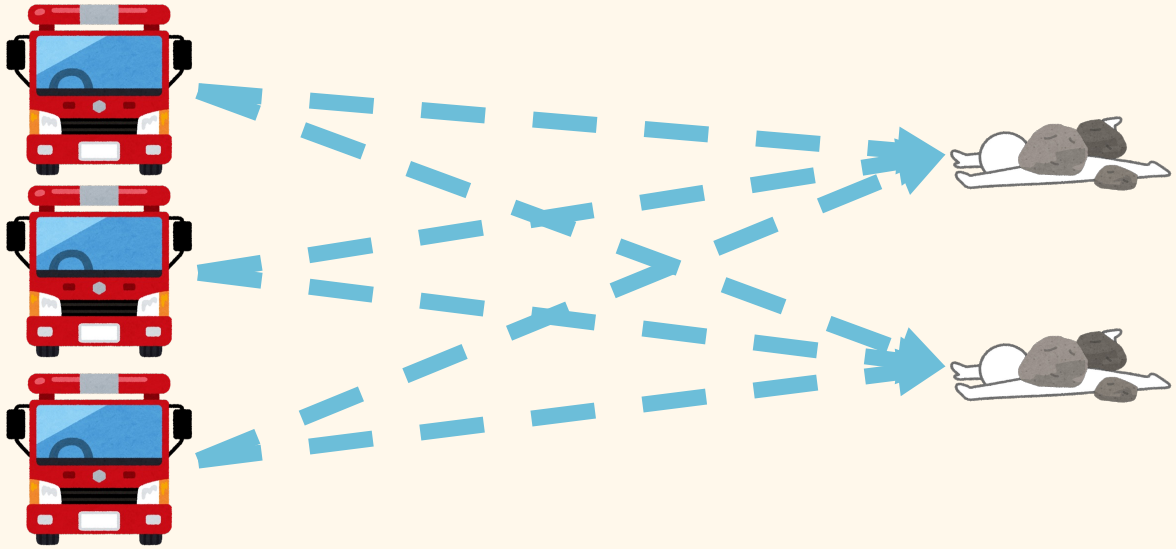
Agents

Disasters

- This issue can be modeled as a DCOP and solved using a DCOP algorithm

Distributed Constraint Optimization Problem(DCOP) 5

The DCOP is the problem of finding the optimal combination of variables that satisfies **the constraints** between agents and variables as a solution.

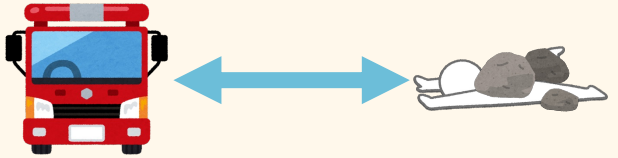


Agents

Variables(Tasks)

Which task to select?

Constraints



Agent-Task distance

Task execution time

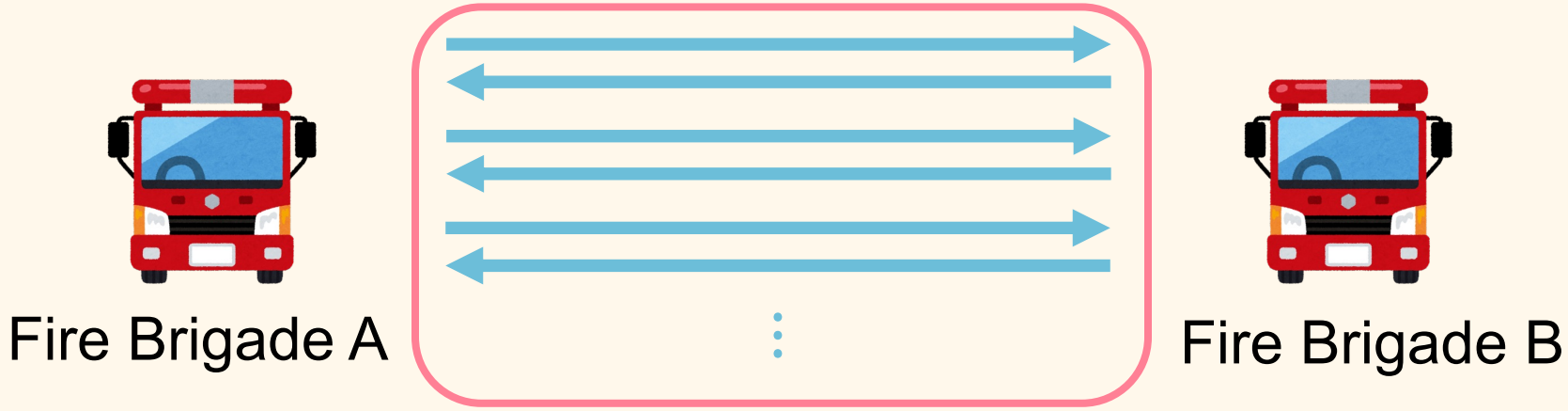
etc…

The Extended Environment for DCOP

It is difficult to run the DCOP algorithm in a normal RRS

→It allows agents to communicate for an arbitrary number within 1 simulation step[1]

Example) The assignment of civilians to fire brigades using Binary Max-Sum algorithm[2]



Modelization: Factor Graph on RRS

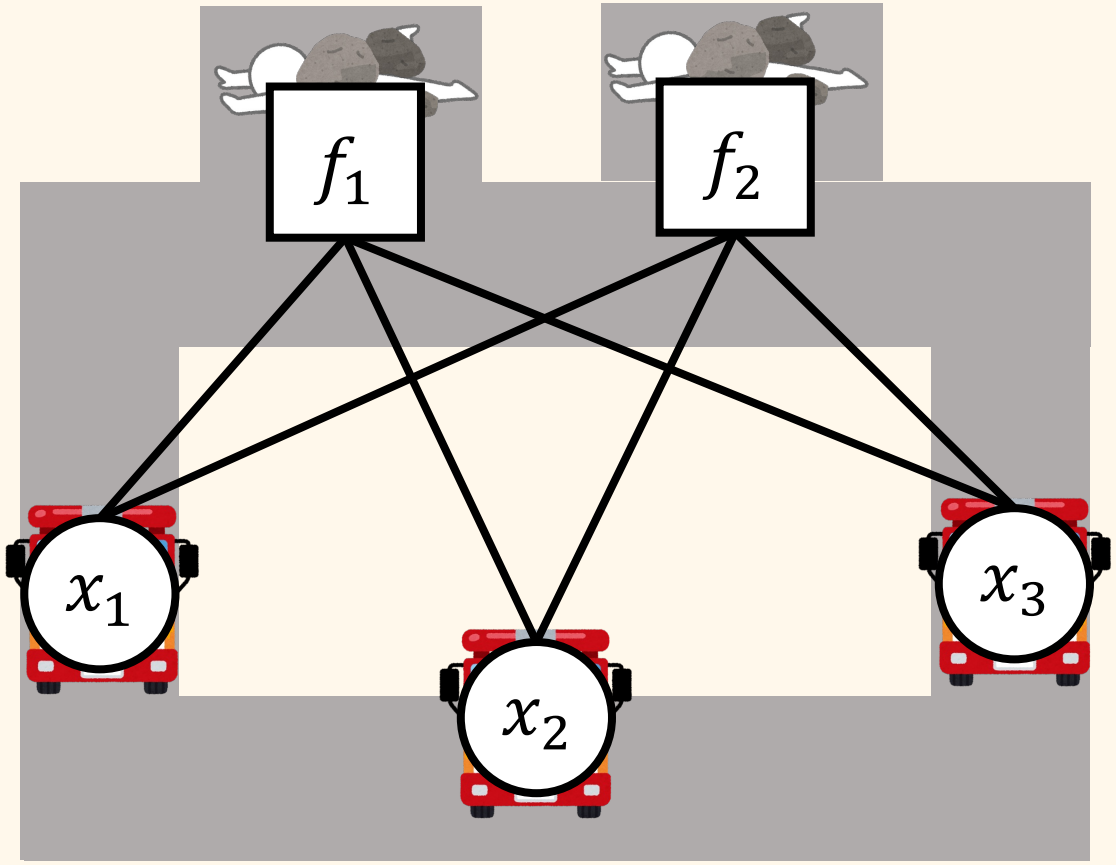
Agent → x_m Variable node

Which task to select

Task → f_k Factor node

Calculate the cost of the task

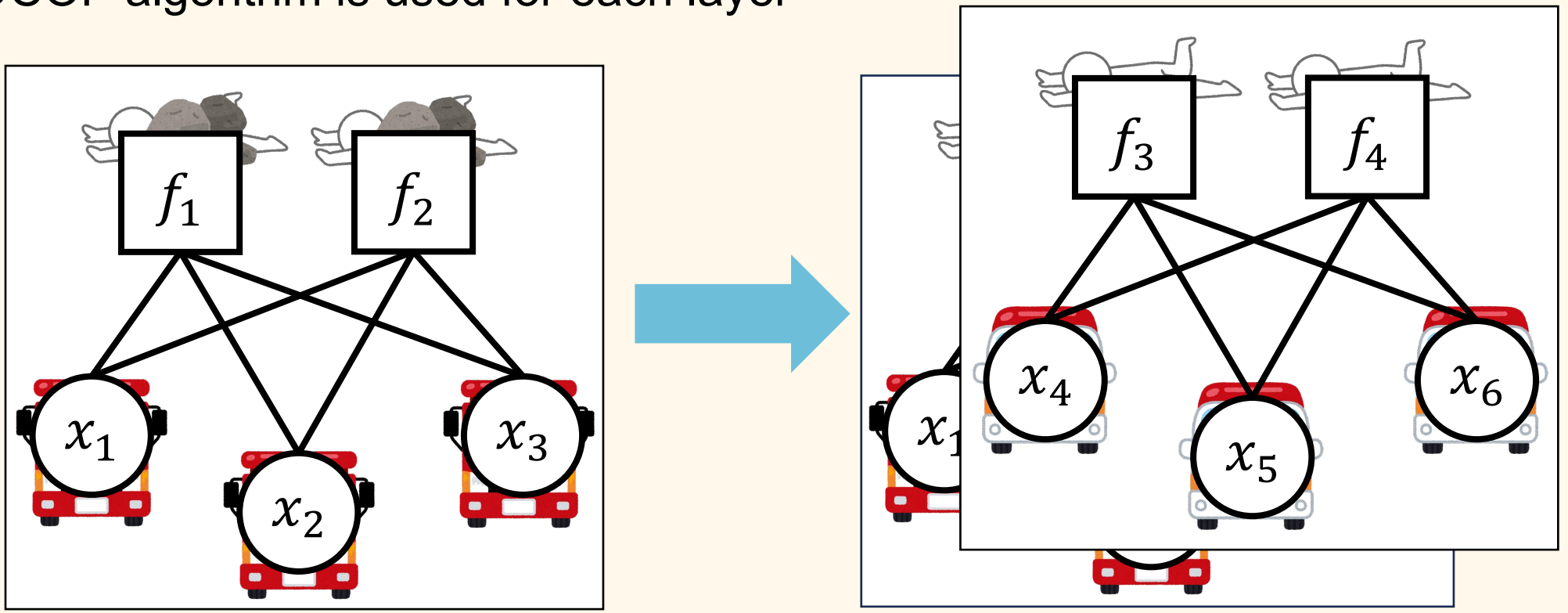
Edge : Assignable relationships



Layered DCOP(L-DCOP)

An extended DCOP called Layer DCOP (L-DCOP) is proposed to solve the task assignment problem with ordering and time window constraints.

- Tasks are stratified by ordering constraints
- The DCOP algorithm is used for each layer



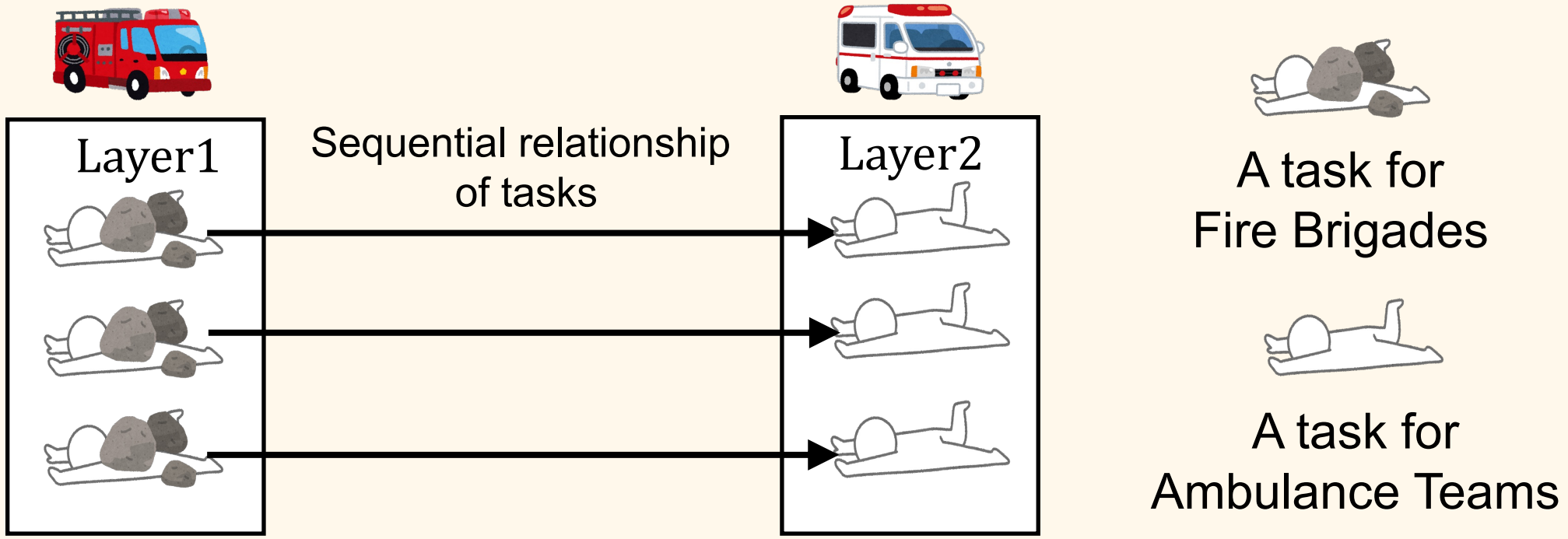
The processing steps in the L-DCOP

The processing steps in the L-DCOP are as follows:

1. Create a precedence graph
2. Create a factor graph for each layer
3. Assign the tasks and create STN
4. Determine the execution order

Step1:Create a precedence graph

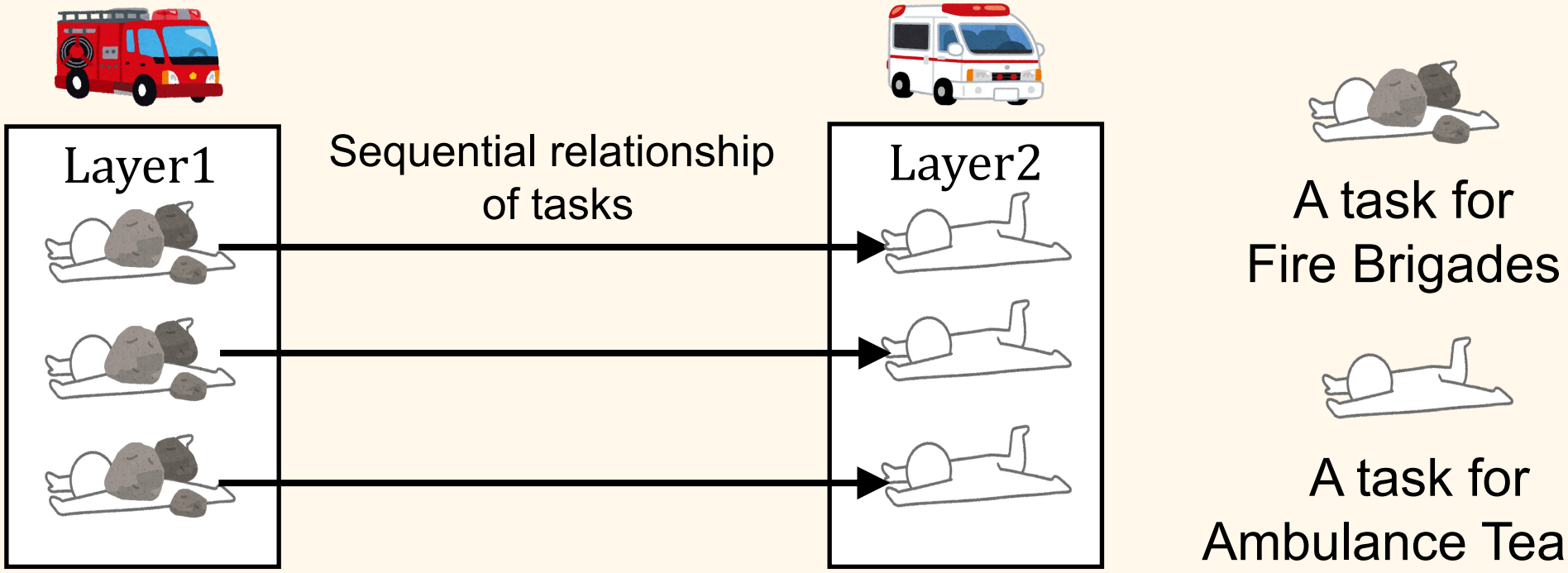
1. Tasks are assigned to each layer according to their ordering constraints, thereby creating a precedence graph.



Precedence graph

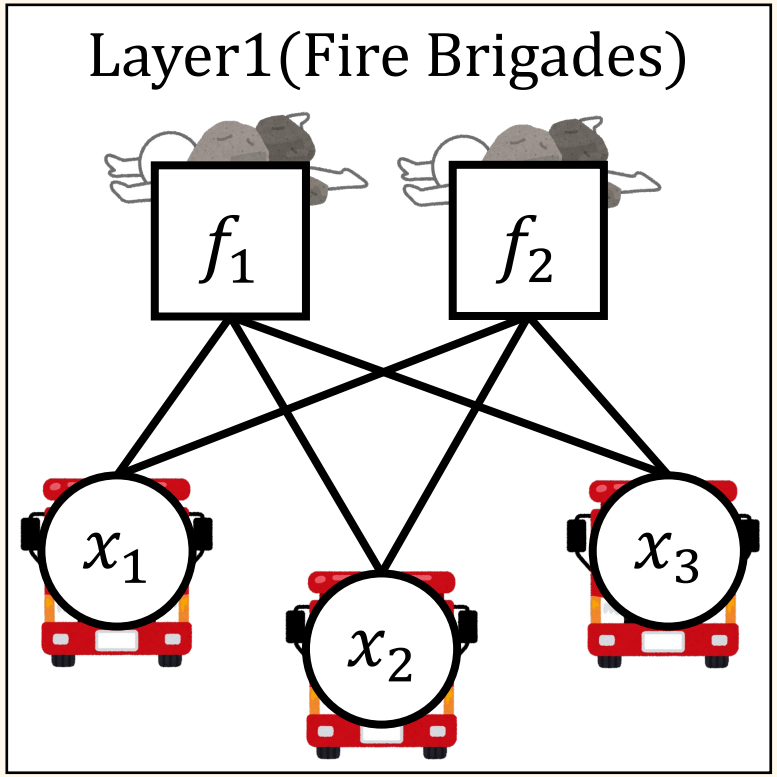
A directed acyclic graph that represents the execution order of tasks as a hierarchy

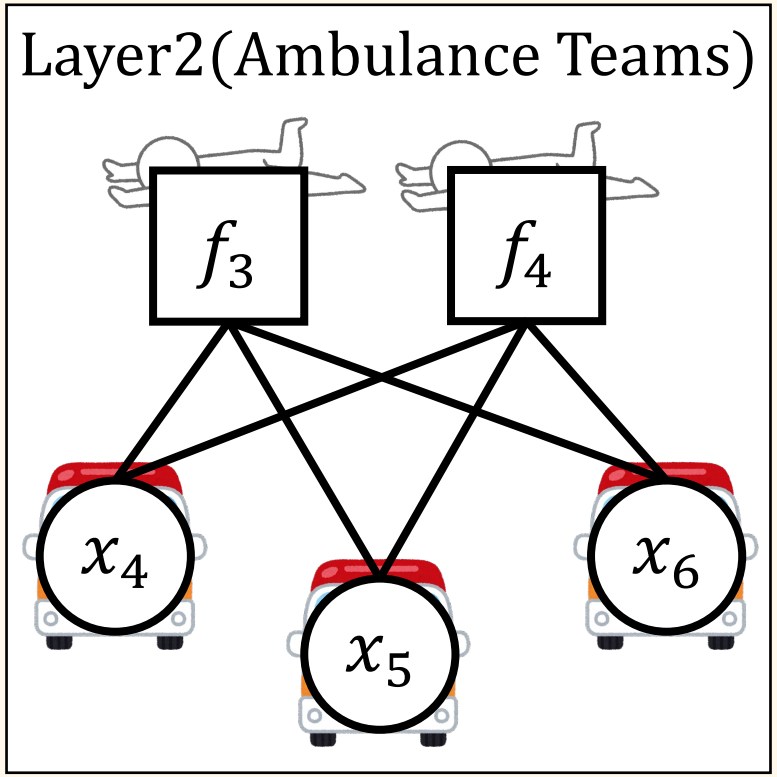
- ► The rescue task is one-to-one with the transport task
- ► Can consider ordering constraints between tasks



Step2:Create a factor graph for each layer

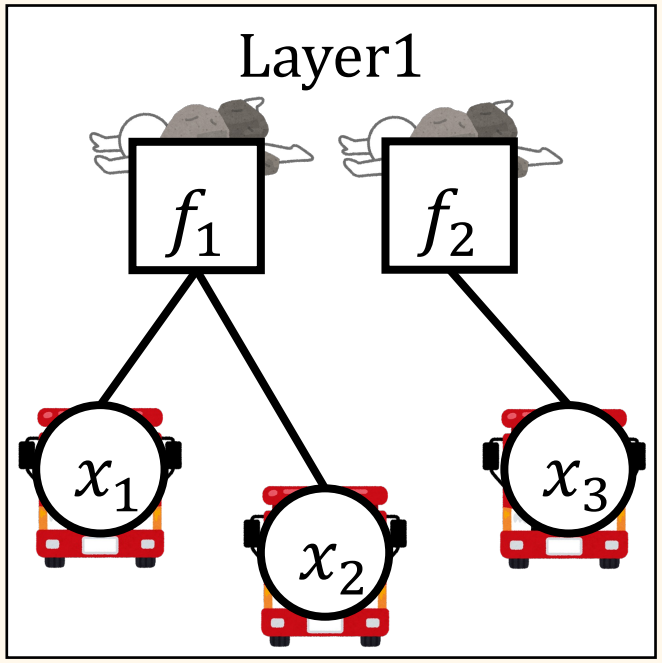
2. A factor graph is created for each layer and the DCOP algorithm is executed for each layer.



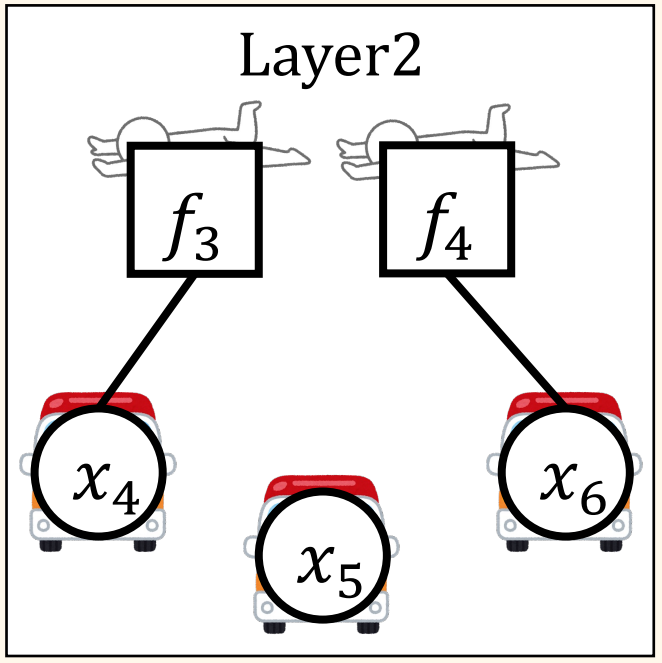


Step3:Assign the tasks and create STN

3. Task assignment is performed according to the factor graph. After the agent has been assigned a task, a simple temporal network(STN) is created.



STN

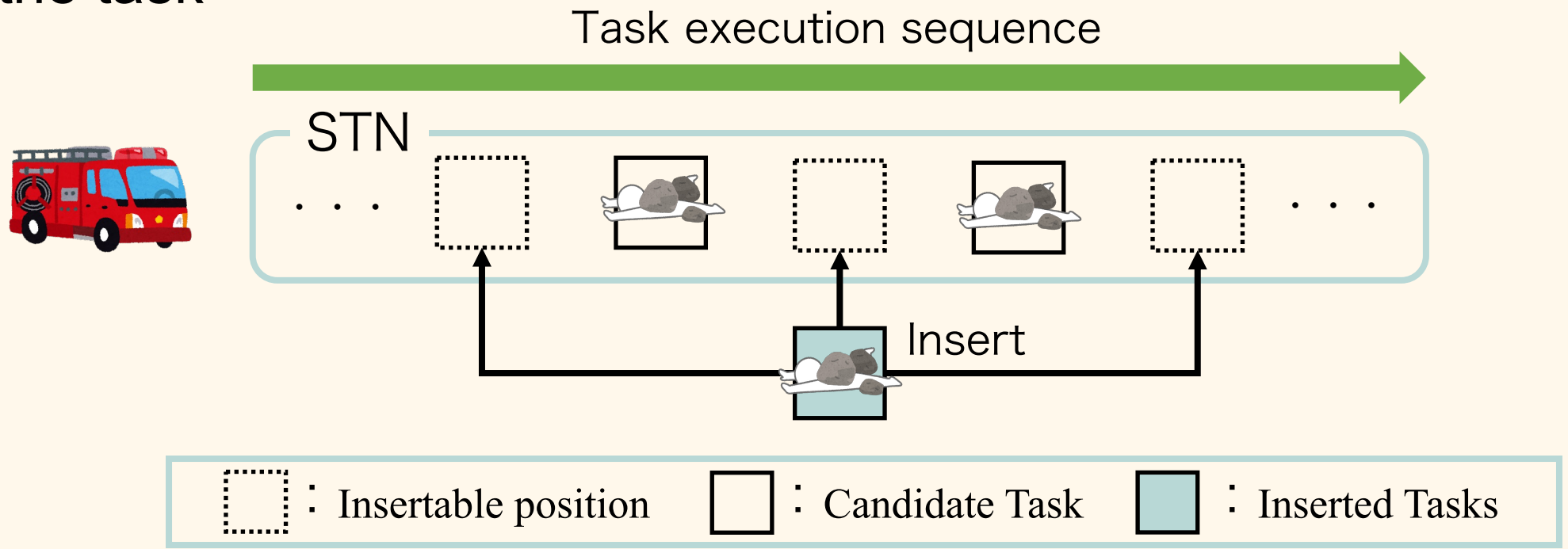


STN

Simple Temporal Network(STN)

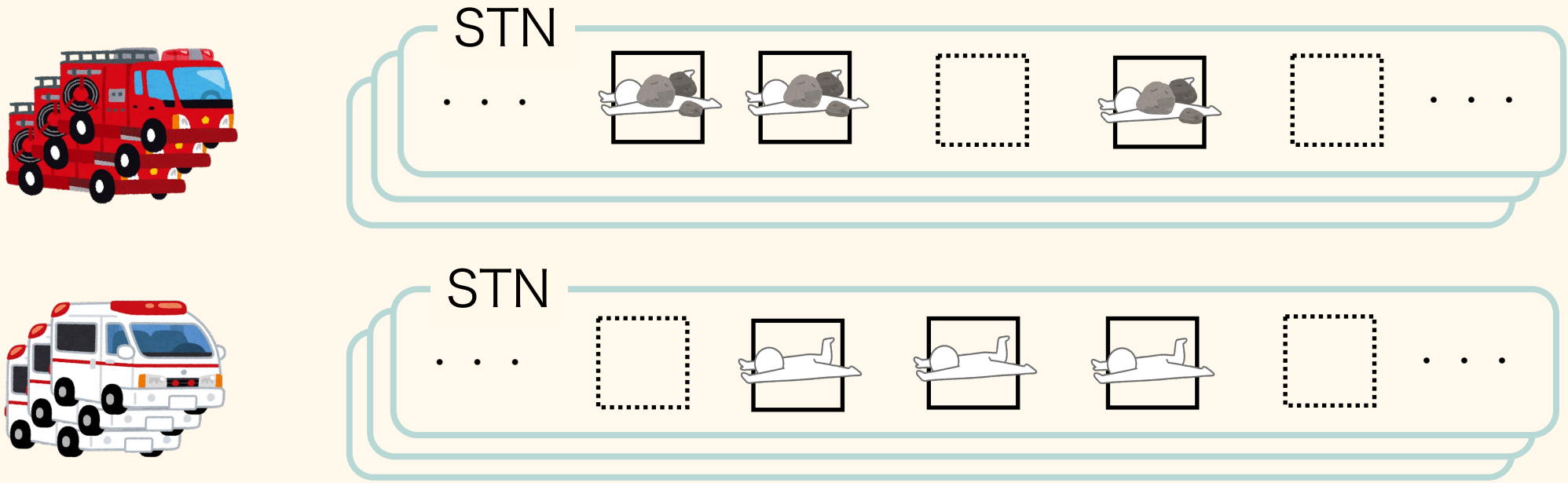
Graph for managing task execution order

- Insert a task into the STN each time it is assigned
- Maintain the shortest sequence that satisfies the time constraints of the task



Step4:Determine the execution order

4. The most efficient execution order is determined by STN.



Experimental Results(1/2)

Compare Agents :

- **agents that model the RRS task assignment problem as a DCOP (DCOP Agent)**
- **agents that model the RRS task assignment problem as an L-DCOP (L-DCOP Agent)**

Experimental condition : Measure the number of civilians rescued and transported

※The civilian was considered to have been transported to a refuge after the rescue by the Fire Brigade

Experimental Results(2/2)

Maps : Eindhoven, SF, and VC in RoboCup2022

Scenarios : 12 scenarios under various situations

Type of placement in scenarios		**DCOP Agent**		**L-DCOP Agent**	
Agent placement	Task placement	Rescued	Transported	Rescued	Transported
Centralized	Centralized	37	37	37	37
Centralized	Distributed	35	35	34	32
Distributed	Centralized	40	40	43	43
Distributed	Distributed	36	36	43	41

- ► L-DCOP Agent had a higher total number of rescued and transported civilians

Modules

Search Order Module

- This module calculates an optimal search order for short routes during the precompute phase.
- This module aims to let agents complete search buildings in a short time.

Fire Brigade

In which order should I search buildings?

Buildings

2-opt algorithm

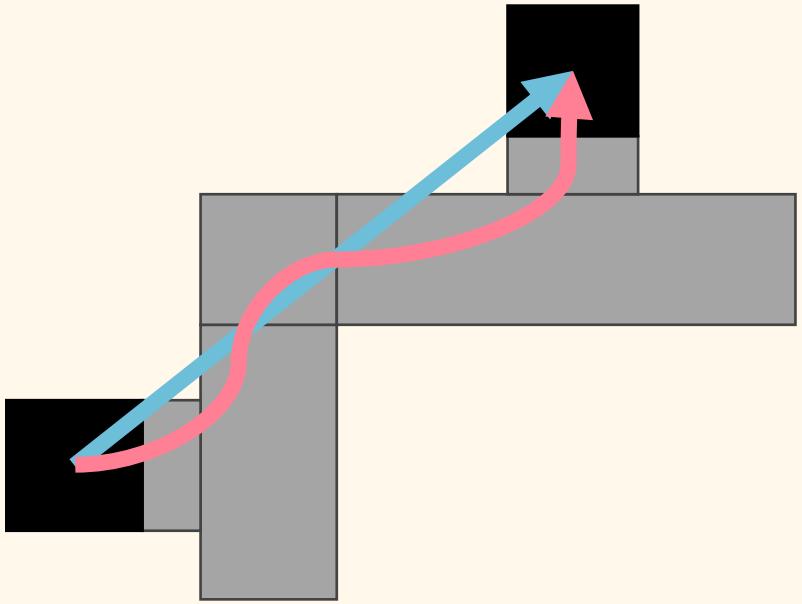
- Approximate algorithm for the traveling salesman problem (TSP)
- Improves an initial solution by swapping pairs of edges to reduce the total travel distance of a Hamiltonian path

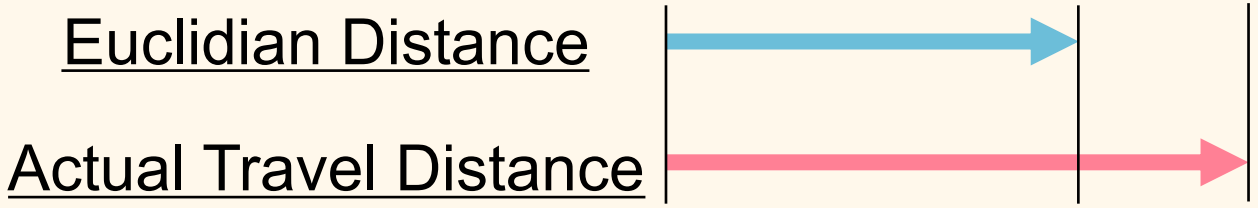
- The processing steps of the 2-opt algorithm are as follows:
  1. Generate a random Hamiltonian path.
  2. Randomly select two vertices within the path.
  3. If reversing the order between the two selected vertices results in a shorter path, perform the reversal.
  4. Repeat Steps 2-3 an arbitrary number of times.

The problem of the past Path Length Estimator Module 21

Euclidean distance between a starting point and a target point was used as estimating a travel distance in AIT-Rescue.

→ there may be a significant error between the Euclidean distance and the actual travel distance.





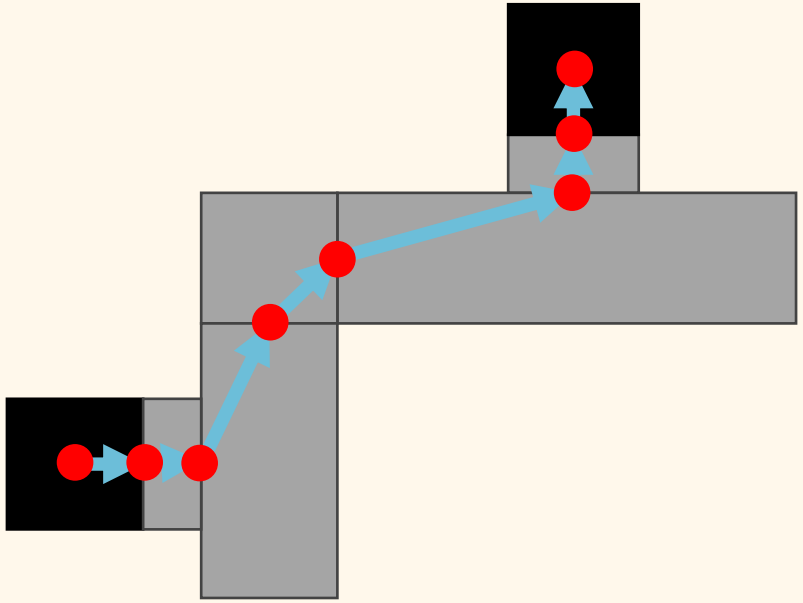
Path Length Estimator Module

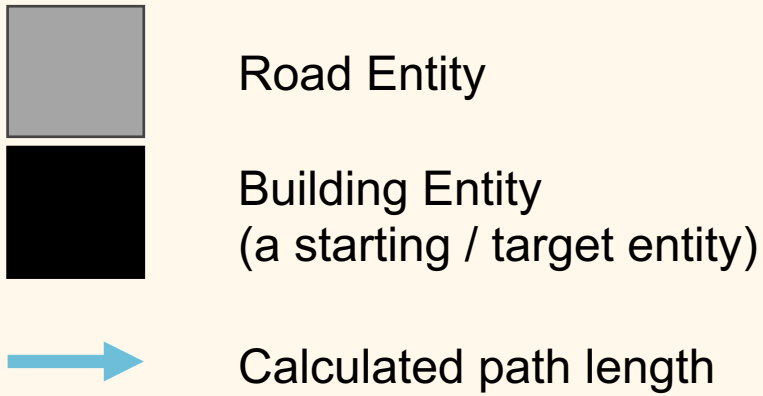
- This module calculates an accurate travel distance between buildings.
- This module aims to calculate an optimal search order accurately in determining a search order module.

How to calculate a path length

Consider a travel distance as a sum of the distances of lines connecting the following points:

- The center point of a starting entity
- The midpoint of the boundary line between entities
- The center point of a target entity



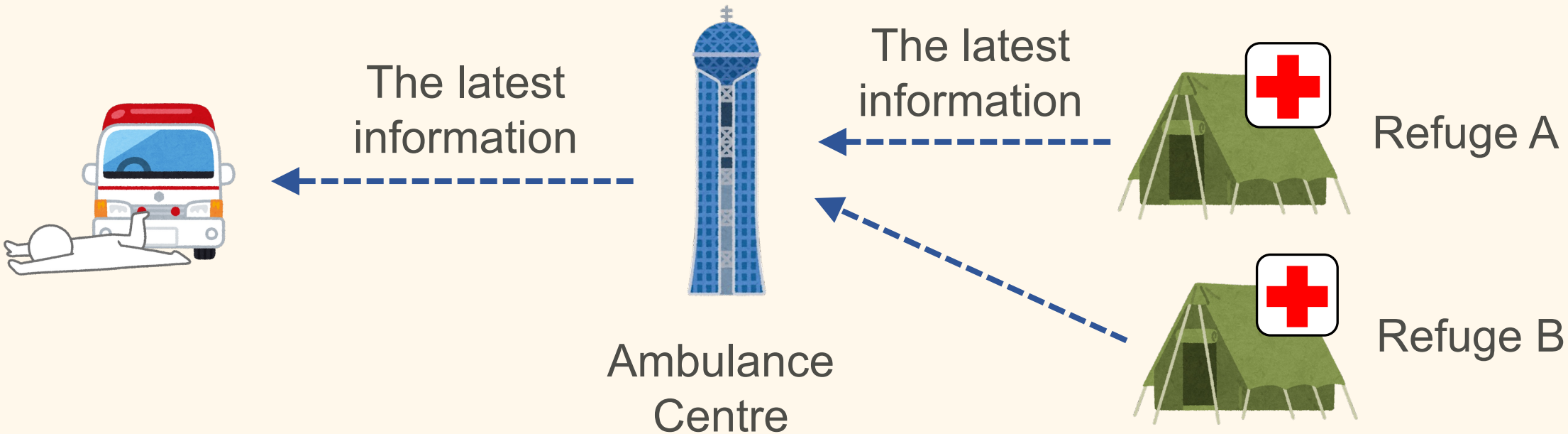


Strategies

Ambulance Team (Communication with the Ambulance Centre) 25

Ambulance Teams need to transport civilians to refuge with available bed

To obtain information on the refuges
- Perceive the refuges
- Receive information on the refuge from the command center



Ambulance Team (Transport Target Selection) 26

Ambulance Teams prioritize the lives that can be saved as much as possible

The following equation is used to determine whether or not transport is possible

$$\frac{agentToCivilianDist + civilianToRefugeDist}{agentAvgSpeed} < survivalTme$$

- $agentToCivilianDist$: Straight-line distance from the current location to the target civilian
- $civilianToRefugeDist$: Straight-line distance from the target civilian to the nearest refuge
- $agentAvgSpeed$: Average speed of the agent movement (parameter)
  - We found that the average value was 40,000
- $survivalTime$: Survival time of a civilian

Fire Brigade (Rescue Target Selection)

The following equation is used to determine whether or not rescue is possible

$$\frac{agentToCivilianDist + civilianToRefugeDist}{agentAvgSpeed} + rescueTime < survivalTime$$

$$rescueTime = \frac{buriedness}{fbNumbers}$$

- $fbNumbers$: Number of fire brigades involved in rescuing the civilians in question

fbNumber 1

fbNumber 2

Police Force (ExtActionClear)

- Decide on removal methods according to the size of the blockade
- the number of steps required to remove the debris is calculated from the RepairCost of the debris and the ClearRepairRate of the agent.

the number of steps is less than the threshold

remove the debris in a rectangular shape

the number of steps is more than the threshold

remove the debris by shrinking the debris

Evaluation

Result of AIT-Rescue 2023

Scenario	Team	
	AIT-Rescue 2022	AIT-Rescue 2023
kobe2	128.386	129.050
paris2	27.862	28.421
berlin2	8.147	7.995
vc2	43.875	45.624
sydney1	15.112	14.715
ny1	19.666	18.679
montreal1	48.397	47.487
eindhoven1	12.003	11.985
istanbul1	43.538	43.325
sf1	38.173	38.718
Sum	385.159	385.999

- AIT-Rescue 2023 are better than the AIT-Rescue 2022[3]
- The scores improved greatly for the kobe2 and vc2 scenarios

Conclusion

- AIT-Rescue 2023:
  - Applying L-DCOP to the RRS task assignment problem
  - Improvement of the agent search order
  - Improvement of agent travel distance estimation
  - Implementation of refuge selection using communications

- Future work:
  - Implementation of the L-DCOP algorithm in normal RRS
  - Improvement the clustering of the agent's search ranges

References

1. Yuki, M., Taishun, K., Yuki, O., Kazunori, I., Nobuhiro, I.: RoboCupRescue 2019 TDP Infrastructure AIT-Rescue (Japan) (2019)
2. Marc Pujol-Gonzalez, Jesu´s Cerquides, Pedro Meseguer, Juan Antonio Rodr´ıguez-Aguilar, and Milind Tambe. Engineering the Decentralized Coordination of UAVs with Limited Communica- tion Range. In Advances in Artificial Intelligence, pp. 199–208. Springer Berlin Heidelberg, 2013.
3. Hiroya, S., Akira, H., Haruki, U., Joe, F., Itsuki, M., Ryoya, M., Yuki, S., Iwata, K., Ito, N.: RoboCupRescue 2022 TDP Agent Simulation AIT-Rescue (Japan) (2022)

Thank you for your attention!