Evacuation Guidance System Using UAVs of Multiple Types at Disaster

Kozaburo Ibuki[1], Noriaki Kamiyama[2]

Graduate School of Information Science and Engineering,Ritsumeikan University[1]
College of Information Science and Engineering, Ritsumeikan University [2]

Background: UAV Utilization in Disaster Situations

- During disaster, it is necessary to check the damage and search for missing people
- When it is difficult to approach the disaster site, the use of Unmanned Aerial Vehicle (UAV) is effective
- Evacuee guidance system using UAV [1].
  - Obtains information on surrounding disasters from sensors installed on the ground
  - Control UAVs based on acquired information
  - Creation of evacuation routes that avoid the risk of secondary disasters
  - Efficient search and guidance of evacuees by UAV

[1] K. Katayama, et al.,H. Takahashi, N. Yokota, K. Sugiyasu, “Evacuation Guide Supporting System using UAV for Coastal Area”, Life Tech 2021, pp 1-2

Challenges in Disaster Support Using UAVs

- When ground sensor devices are damaged
  - Lack of information from sensors makes it difficult to control UAVs.
  - Evacuation guidance using UAVs becomes more difficult

- The maximum flight time for a battery-powered UAV is approximately 30 minutes.
  - Not suitable for long-time and wide-area operation

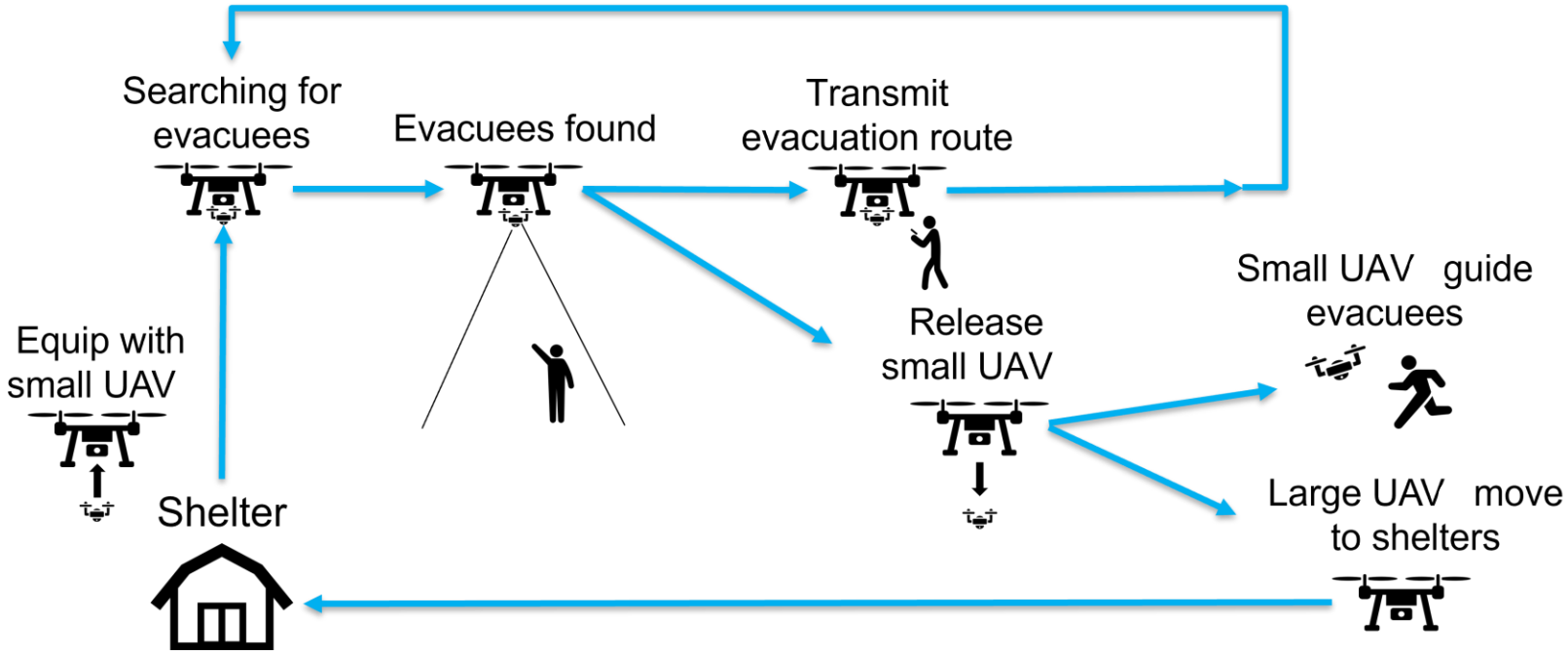
- There is a need for a disaster relief system that does not rely on information from ground-based sensors and is less susceptible to flight time constraints.

Proposed Method

- Evacuation Guidance System Using UAVs of Multiple Types at Disaster
  - This system uses large UAVs, small UAVs, and smartphones or other mobile devices
  - Large UAV is powered by a gasoline engine
    - Flight duration is about 2 hours, load capacity is about 10 kg
  - Small UAV is powered by batteries
  - Large UAV will search for evacuees and assess damage in the disaster area while carrying a small UAV.
  - Small UAV guides evacuees to safety
  - The system does not require ground sensors
  - The system can be operated for long periods of time and over a wide area.

UAV Operations

- **Searching for evacuees while carrying a small UAV with a large UAV**
  - Assess disaster conditions from aerial footage
  - Upon discovering evacuees → Create evacuation routes considering impassable areas
  - Evacuation route transmission or small UAV guiding evacuees
  - Recharging UAV batteries and reloading small UAVs at shelter



Related Research

- Technical conditions to realize the proposed method
  - A large UAV capable of carrying a small UAV and flying for a long period of time [2]
  - Aerial separation of small and large UAVs [3]
  - Detection of people on the ground by UAVs [4]
  - Assess road surface conditions from aerial images and create safe evacuation routes [5]
  - Guidance of evacuees by small UAVs [6]
  - Communication between UAVs and mobile terminals [7]

- Simulator creation and performance evaluation under prerequisite conditions

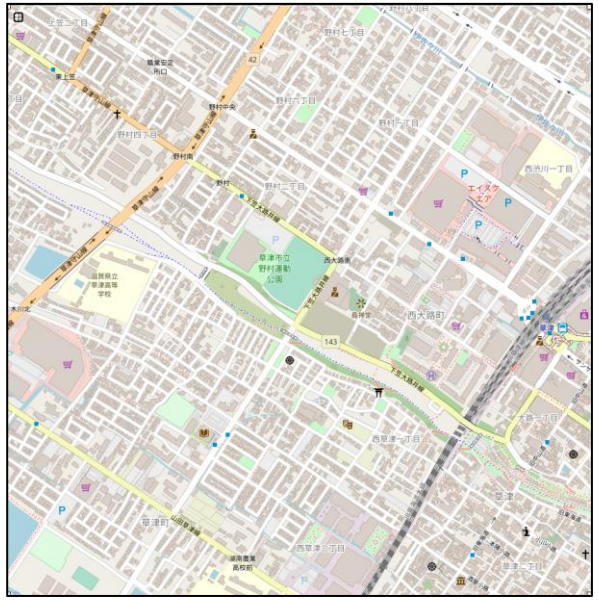
https://www.aaa-llc.jp/az-1000-catalog

https://www.imeko.org/publications/tc17-2018/IMEKO-TC17-2018-018.pdf

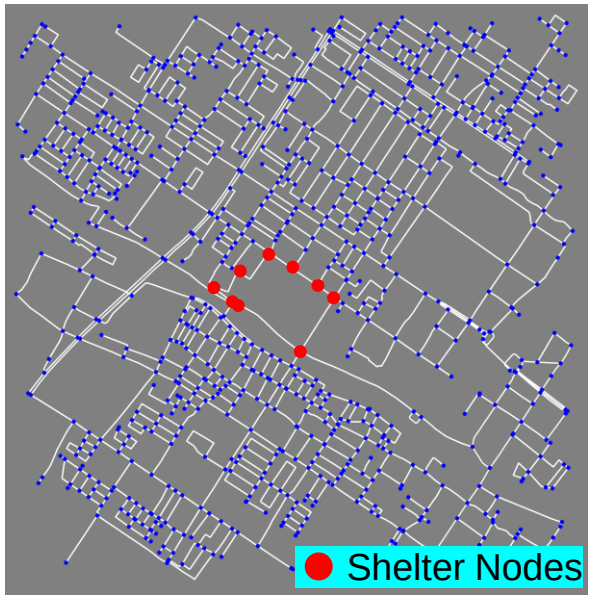
[2] https://www.aaa-llc.jp/az-1000-catalog
[3] N. Nauwynck, et al., H. Balta, G. D. Cubber, H. Sahli, " In-flight launch of unmanned aerial vehicles", ISMCR 2018
[4] N. Bhattarai, et al.,T. Nakamura and C. Mozumder, "Real Time Human Detection and Localization Using Consumer Grade Camera and Commercial UAV", Nov 2018
[5] C. Liu et al.,and T. Szirányi, " Road Condition Detection and Emergency Rescue Recognition Using On-Board UAV in the Wildness ", Remote Sensing, Vol.14, 2022
[6] K. Katayama, et al.,H. Takahashi, N. Yokota, K. Sugiyasu, G. Kitagata, T. Kinoshita, "An Effective Multi-UAVs-Based Evacuation Guidance Support for Disaster Risk Reduction", IEEE ICBDSC 2019, pp 1-6
[7] M. Suzuki, K. Hama and T. Nakamura, "Evacuation Support System Used by Cooperation Drone",Transactions of the Society of Instrument and Control Engineers, vol. 56, no. 1, pp. 24-30, Feb. 2020.

Simulation (1/3)

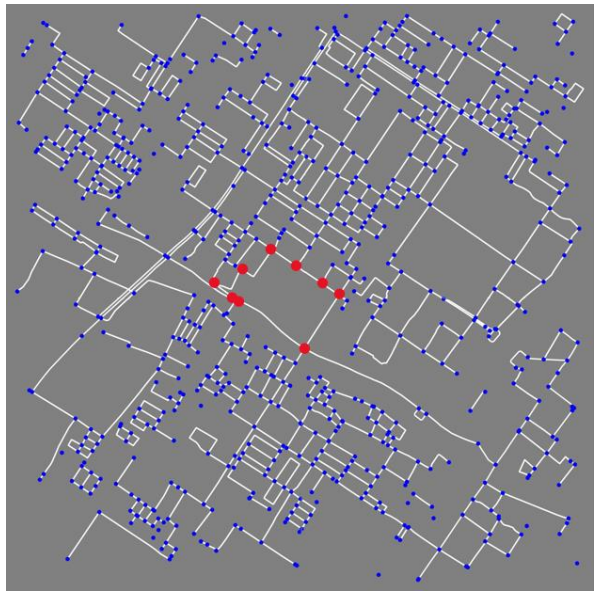
- Use map data provided by Open Street Map
- **Disaster Area:** 2 km square area centered on the shelter
- **Road network:** Consists of 865 nodes representing intersections
- **Damaged road network:** Delete any node and recreate impassable areas due to disaster
- **Initial location of evacuees:** On a randomly selected node from the Dameged road network
- Evacuees remain at their initial location until detected by a large UAV
- Once detected, they follow the evacuation route to the shelter



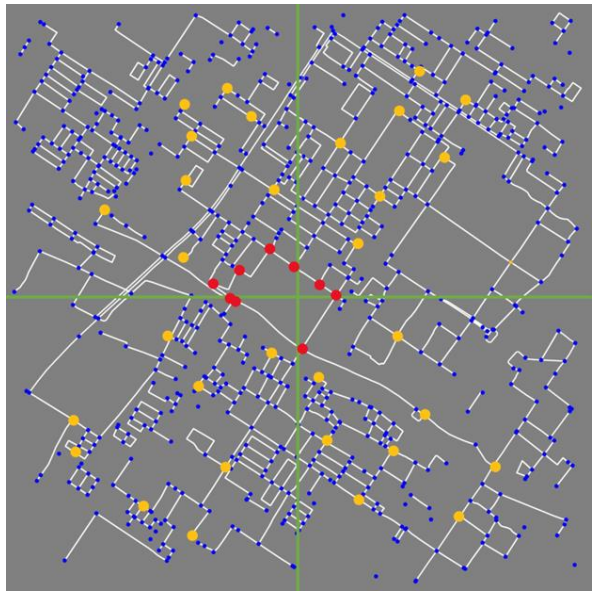
Disaster Area



Road Network



Damaged Road Network



Location of evacuees

Simulation (2/3)

	Method X (**Proposed method**)	**Method Y** (**If the damaged area is known**)	**Method Z** (**Guide after exploring all areas**)
State of ground sensors	Not usable	Usable	Not usable
Updating damaged road network	Large UAV identifies road damage during flight and updates accordingly	Before starting the search, identify all damaged areas based on information from ground sensors	Large UAV explores all areas and identifies all damaged locations
Evacuation guidance strategy	Guide evacuees whenever they are found	Guide evacuees whenever they are found	Guide evacuees after completing the exploration of all areas

Simulation (3/3)

- 4 large UAVs and 16 small UAVs will be used.
- Number of evacuees 32

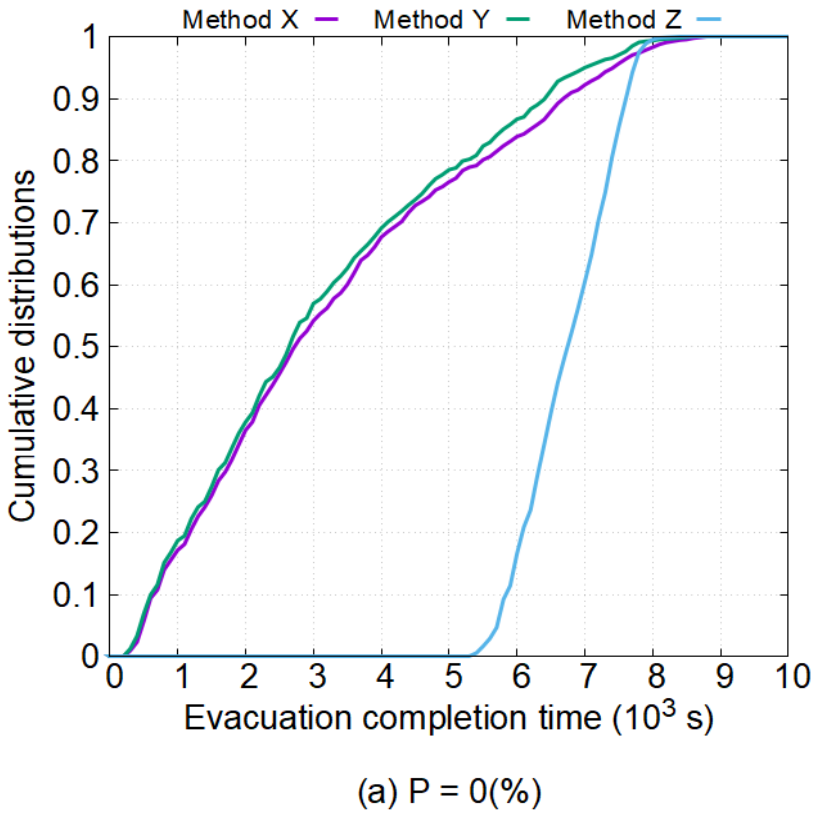
- Large UAV flight speed
  - Searching for evacuees: 20 km/h
  - While moving to the shelter: 60 km/h

- Evacuees speed, Small UAV flight speed: 4 km/h

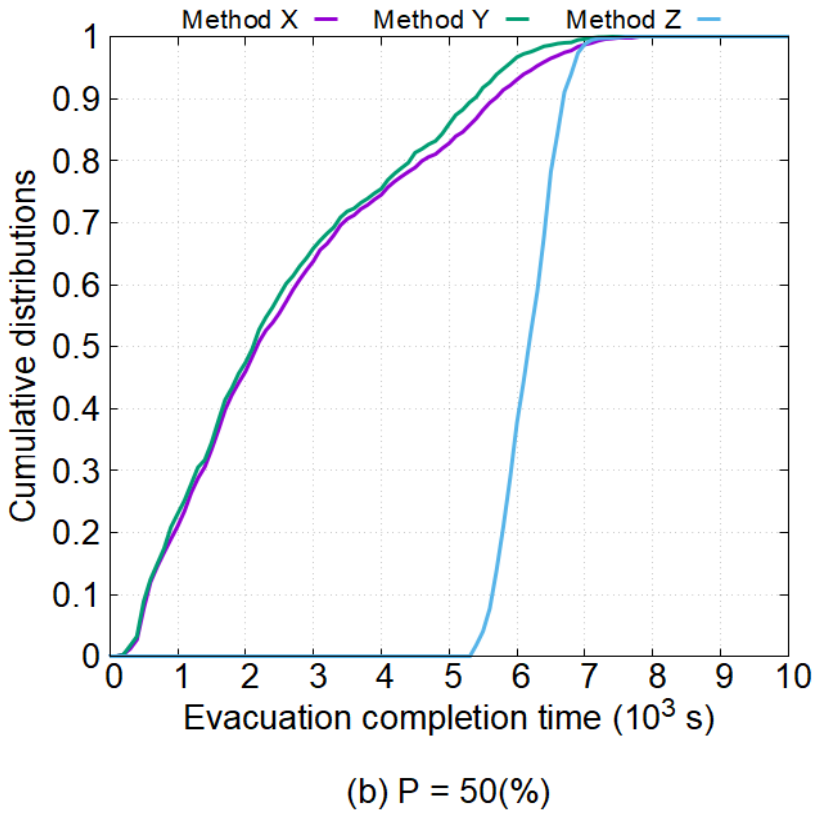
- Percentage of evacuees who can communicate with large UAVs
  - 0%, 50%, 100%.

- Measure the total time to complete evacuation for all evacuees for 100 different evacuee location patterns

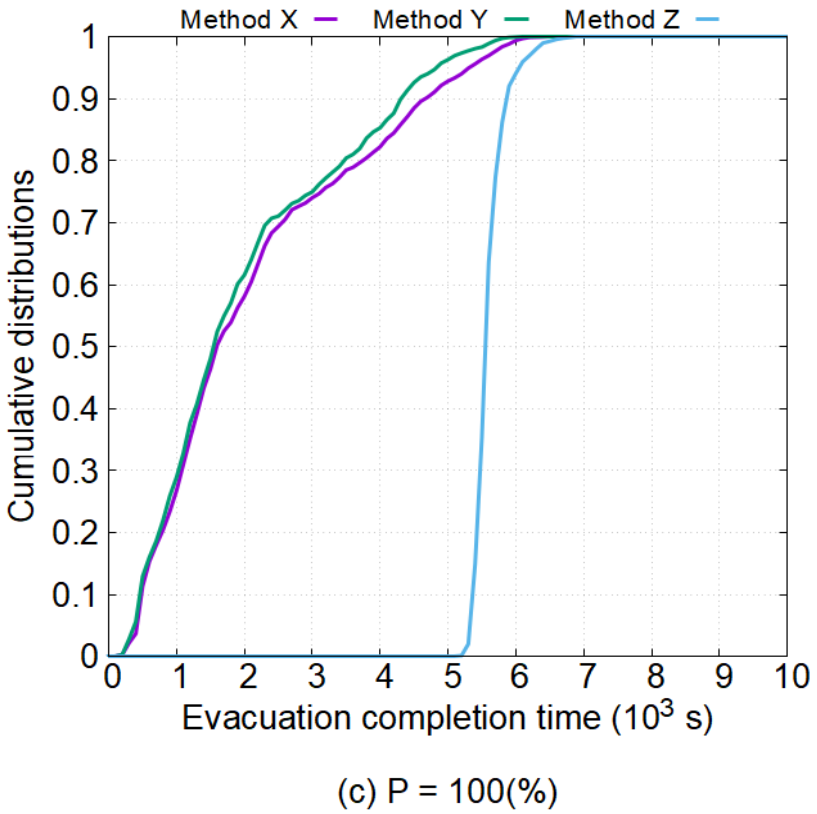
Cumulative Distribution of Evacuation Completion Time



(a) P = 0(%)



(b) P = 50(%)



(c) P = 100(%)

- Method X (Proposed method)
  - Achieve the same evacuation time as Method Y, in which the damaged parts are already known in advance.
  - Evacuation completion time can be reduced compared to Method Z by providing guidance each time an evacuee is found.

Conclusion

- We proposed an evacuation guidance system using multiple types of UAVs and mobile terminals.
  - The performance of the proposed system was evaluated by simulation.

- The proposed method achieved the same evacuation time as that of the case where the obstacle is already known in advance.
  - It can be operated even when information cannot be collected from ground-based sensor devices.
- Evacuation completion time
  - It takes less time to guide evacuation for each found evacuee than to guide evacuation after the search of the entire affected area is completed.

- Future Works
  - Adapting to changes in the number and location of shelters
  - Optimizing flight paths for large UAV

Thank you for your attention

This presentation is supported by the
“Society for the Advancement of Science and Technology at Ritsumeikan”