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Disaster response simulation by drones using group decision making model BRT

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Abstract: In recent years, the use of drones in harsh environments has attracted attention. There is an expectation that a human's complex work can be substituted by integrating the limited capability of drones by forming a swarm by making use of their high mobility. To achieve this system we discuss corrective decision making of swarm. When instructions from a human operator cannot be obtained, the drone swarm needs to judge the situation on the site and take appropriate coordinated action. In this paper, it is shown that disaster response can be dealt by drones that perform tasks continuously while changing the three priorities of patrol, firefighting, and supply depending on the energy status of the drone. The conventional BRT model lacks a part to estimate the evaluation of options, and it has not been easy to use for practical problems as discussed here.

Keywords: a collection of drones, best of n, distributed decision making

1. INTRODUCTION

In recent years, the use of drones in harsh environments has attracted attention. There is an expectation that a human's complex work can be substituted by integrating the limited capability of drones by forming a swarm by making use of their high mobility. Generally speaking, to act as a swarm is strong against failure of a unit while it can keep enough powers and resilience to solve various tasks. To achieve this system, we discuss corrective decision making of swarm. When instructions from a human operator cannot be obtained, the drone swarm needs to judge the situation on the site and take appropriate coordinated action.

In this paper, we use a simulation of disaster scene as a place where drones act. The drones in this simulation are required to switch various subtasks that surpass individual drone's ability, such as fire and rescuer detection, firefighting, injured rescue, and information transfer, to calm down the situation. Here, it is necessary to properly assign each drone to one of the subtasks. In addition, if the drone's energy is not sufficient for the working time, the drone needs to supply its own energy simultaneously.

So far, this theme is considered to be one of the role assignment problems, and so much researches have been reported, for example, Fixed response theory [1], [2], and so on. These approaches are methods of assigning tasks to agents. They can allocate agents sufficiently and accurately, if the relationships among tasks are known in advance. On the other hand, these approaches divide the agents into too small groups, so they may lose the above merits of the swarm generating, which they are working near each other geographically.

Therefore, in this paper, we think about a method to response to disasters by achieving the same subtask while always a large number of agents form a group. We use BRT model as a decision-making model of drone for this swarm system.

BRT [3] is a method for the distributed agents choose the best of n options, and it is possible for the agents agree to one of the best choices out of three or more options, even if there is no leader. We extend this model and apply this to the drones responding to disasters and show drones can use BRT to select appropriate actions from the three subtasks of patrol, firefighting, and supply, and can response to disasters.

So far, researches on BRT have been conducted, such as when communication between agents is limited locally [4], and an example to the El Farol Bar problem [5]. These models lack a part to estimate the evaluation of options, and it has not been easy to use for practical problems as discussed here. In the following, we show that the swarm of drones can calm a disaster situation down. They choose tasks together continuously while changing the three priorities of patrol, firefighting, and supply depending on the energy status of the drone.

In the next chapter, we describe a model of cities assumed as a disaster scene and drones using Unity. In the chapter 3, we propose a BRT model that determines the situation at the disaster scene and selects appropriate group behavior. In the chapter 4, by computer experiments, we confirm the drones are performing patrols and firefighting while properly supplying them so that their energy does not reach zero, and drones can perform tasks continuously while switching priorities appropriately.

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† Naoya Horio is the presenter of this paper.

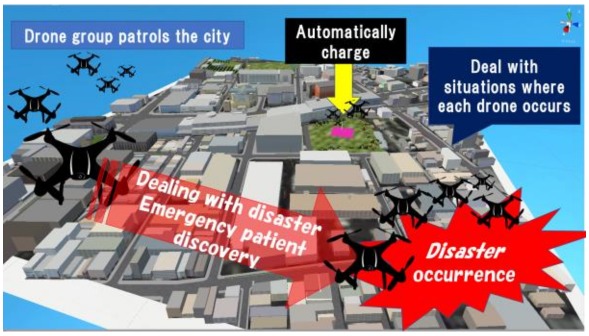

Fig.1 Future image of disaster response by drones.

2. DRONES SIMULATION USING VIRTUAL ENVIRONMENT

We create a simulation of disaster scene using Unity[unity.com], one of game engines. The following describes the modeling of each object and task.

2.1 Disaster response by drones

Fig.1 shows about future disaster scene coping by drones. Drones patrol in the town and discover disasters and emergency patients without human instruction. And if possible, each drone will respond to the disaster. If the drone's energy is low, the drone will go to supply itself. The residents of the city can live with peace of mind more than ever.

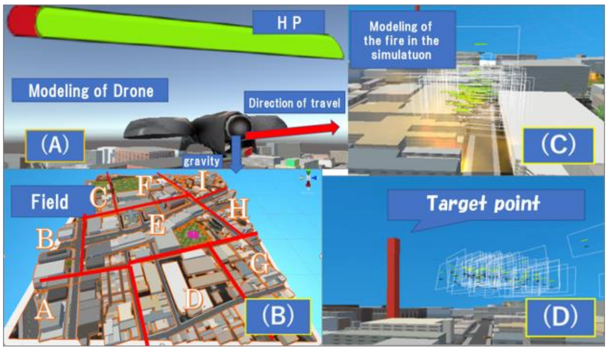

Fig.2 Modeling of the simulation.

2.2 Modeling of drones

Fig.2(A) shows the modeling of drones in this simulation. one drone has 10000 energy and is displayed in real time on the HP gauge. DHP(Drones Health Point) is the total energy of a drone. Each drone consumes 30 energy each turn. In addition, drones are equipped with a fire radar, and the closer the distance to fire, the higher the possibility of detection.

2.3 Modeling of the field

As shown in Fig.2(B), The field is divided into nine blocks of A to I, and drones patrol each section.

2.4 Modeling of the Charging station

At the charging station, as each drone approaches, 1000 energy are charged each turn.

2.5 Modeling of the fire

Fig.2(C) shows an example of fire occurrence. Fire occurs with a certain probability and does not spread. A fire cannot be extinguished unless it is found. One fire has 500 points, and when one drone approaches a fire to a certain distance, perform firefighting activities and reduce the object's points by about 1-1.2 each step. The fire goes out when it reaches 0 points. The amount of the fire reduced in the whole drone group is taken as FHP.

2.6 Modeling of Patrol

Patrol task occurs in the area that requires the most patrol. Necessary patrol amount is made to appear in each district and indicated by the patrol gauge (red). As each area is approached, 1-1.2 points decrease in every step. When the gauge reaches 0, it occurs in another area. Fig.2(D) shows an example of a gauge.

3. PROPOSED METHOD

3.1 BRT [3]

BRT can handle more than two-choice problem of the group decision-making model.

$$\frac{n(A_i(t))}{N} \geq \theta_i + \tau \cdot c_i(t) \cdot (t - t_{i,last}(t)) \qquad (1)$$

Each agent has a personal attribute bias value θ_i. τ is the increase in the number of supporters, $c_i(t)$ is a function that is 0 when a suitable option can be found, and $t_{(i,last)}(t)$ is the time to keep selecting the same option. The left side is the proportion of agents who have the same action choice as their own, and changes the current option when the right side exceeds the left side. It is known that this formula causes the population to trial and error and transition to a suitable state.

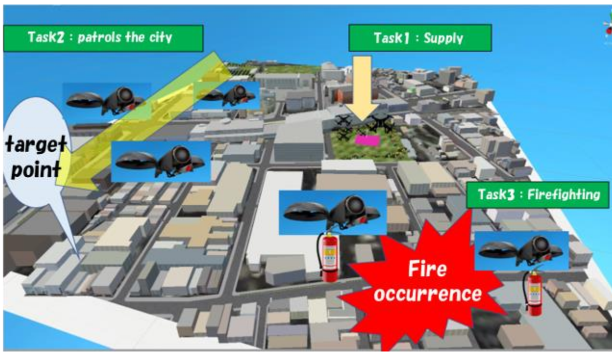

Fig.3 Three tasks in the simulation.

Table 1 Switching c by three tasks.
(X and Y are constant)

Current behavior	When a fire has been found	When a fire has not been found
(1)Supply	c=energy/10000	c=energy/10000
(2)Patrol	c=X×6000/energy	c=6000/energy
(3)Firefighting	c=6000/energy	c=Y×6000/energy

3.2 Proposed method

Three tasks in the simulation is as shown in Fig.3. In the proposed method, we focus on the fact that the importance of three tasks is not equivalent and decide c. Specifically, the following points were considered.

In order to drones perform the task continuously, do (1)supply so that the energy of drones does not become zero. When a fire has not been found, (2)patrol is prioritized. When a fire has been found, (3)firefighting is prioritized.

Based on the above, we decided c as shown in Table 1 so that each task can be switched appropriately.

3.3 Best action selection by proposed method

The problems with conventional research are as follows.

- Dealing with sudden fires is delayed. And we want the drone to prioritize firefighting, but the drone cannot.
- Supply of energy cannot be made in time, and the task cannot be performed.

Based on the above, we examined the following solution.

- By setting the denominator of the evaluation function c to energy, the evaluation function c becomes larger as energy becomes smaller, and it becomes easy to change the action selection to the supply.
- While patrolling, If they find a fire, multiply Patrol by X. It was possible to switch the action to firefighting.
- When they selected fire extinguishing activity when there was no fire by mistake, they promoted the switch of action selection to the patrol by multiplying Y times.

The evaluation function c was determined as shown in Table 1 reflecting the above.

4. EXPERIMENT

In this chapter, we use the proposed method to check whether the drone group can properly perform the three tasks. First, it was tested whether basic operation could be performed. The number of agents N = 50, the increase in the number of supporters $\tau = 0.003$, and one simulation is 3000 steps . A fire occurs at 1/1500 per step at random locations on the field.

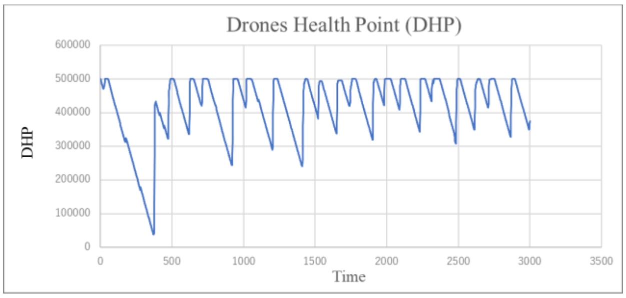

Fig. 4. Transition of DHP

As shown in Fig. 4, it can be seen that the appropriate refueling operation is selected so that DHP does not become 0.

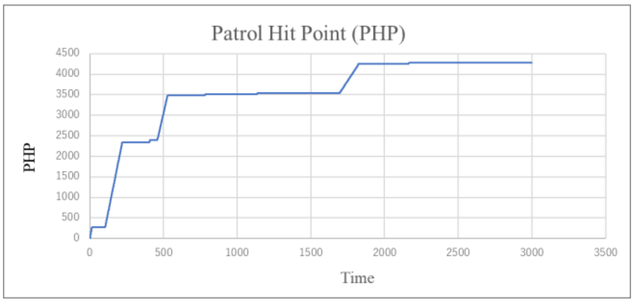

Fig. 5. Transition of workload of patrol

As shown in the Fig. 5, PHP is rising and it turns out that patrol is being performed properly.

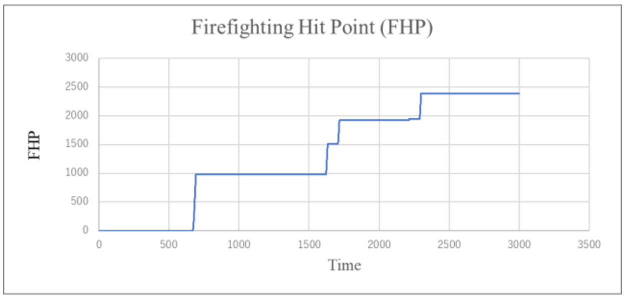

Fig. 6. Transition of firefithing task

As shown in the Fig. 6, FHP is rising and it turns out that it corresponds to a sudden fire.

Fig. 7. Switch action when a fire occurs

Finally, we show the cases where priority tasks have occurred in Fig.7. Drone group chooses patrol at first, but switches to firefighting activity when they detect fire. It turned out that it can respond to a sudden situation from this thing.

5. CONCLUSION

In this paper, we focus on the fact that the importance of the three tasks is not equivalent. By changing the evaluation function according to the drone energy and drone selection, it was found that an agent with three action options can perform task while switching the action options appropriately in the virtual space with reality. In this method, the importance of each task must be determined in advance, and drones cannot change the importance. In the future, the importance of each task should be learned by drones.

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