Multi-UAV Observation for Tsunami Evacuation Drills

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Abstract

Evacuation drills are used to assess the behavioral characteristics of people to improve evacuation plans. Therefore, we used an unmanned aerial vehicle (UAV) to record visuals of all scenes of an evacuation drill. However, the requirement for changing batteries of the UAV every 15 min caused a lack of footage during this unrecordable time. Thus, in this research, we propose multi-UAV observations for tsunami evacuation drills to reduce unrecordable time.

UAVs used for shooting can be replaced in several manners. In this research, we use two UAVs, one in a waiting position right above the other, in a shooting position. The UAV at the shooting position leaves for a battery replacement such that it would again be available for shooting. After the UAV reaches far enough from the shooting position, the other UAV at the waiting position heads down to the shooting position.

Two rules for safety are strictly followed: First, an operator does not move their operating UAV without a declaration about the next operation; second, operators use determined declaration statements for all types of operations.

The unrecordable time, *T,* is divided into three categories: First, t_1, the travel time from the shooting position to the safety position for the shooting UAV; second, t_3, the travel time from the waiting position to the shooting position for the waiting UAV; and third, t_2, the time taken for communication between the two operators. The unrecordable time, *T,* depends on the distance between the shooting position and the waiting position, and the distance is determined in consideration with safety and effect.

In this research, we established the relation between the unrecordable time and the distance between the shooting and waiting positions by conducting test observations for the distances of 30, 20, 10, and 5 m; the unrecordable time for these distances were found to be 19, 16, 11, and 8 s, respectively. This result is useful for an observer to determine the optimal distance for their observation. In tsunami evacuation drills conducted in Minamiawaji city, we could reduce the unrecordable time from 4 min 30 s with a single-UAV observation in 2017 to 13 s with a multi-UAV observation in 2018.

Keywords: Tsunami evacuation drill, UAV, Unrecordable time, Battery change

1. INTRODUCTION

Mega tsunami disasters like the 2011 Tohoku tsunami do not happen so frequently. Therefore, evacuation drills have to be used to assess the behavioral characteristics of people to improve evacuation plans. We have used an unmanned aerial vehicle (UAV) to record visuals of all scenes of an evacuation drill. However, the requirement for changing batteries of the UAV every 15 min caused a lack of footage during this unrecordable time. Thus, in this research, we propose multi-UAV observations for tsunami evacuation drills to reduce unrecordable time.

2. METHOD

2.1 Continuous Observation

UAVs used for shooting can be replaced in three manners, depending on the way of moving from the waiting position to the shooting position for the waiting UAV, as shown in Fig. 1; down-in style, up-in style and horizontal-in style. In this research, we used the down-in style continuous observation with two UAVs, one in a waiting position right above the other, in a shooting position, because it is safer and more efficient than the other two styles.

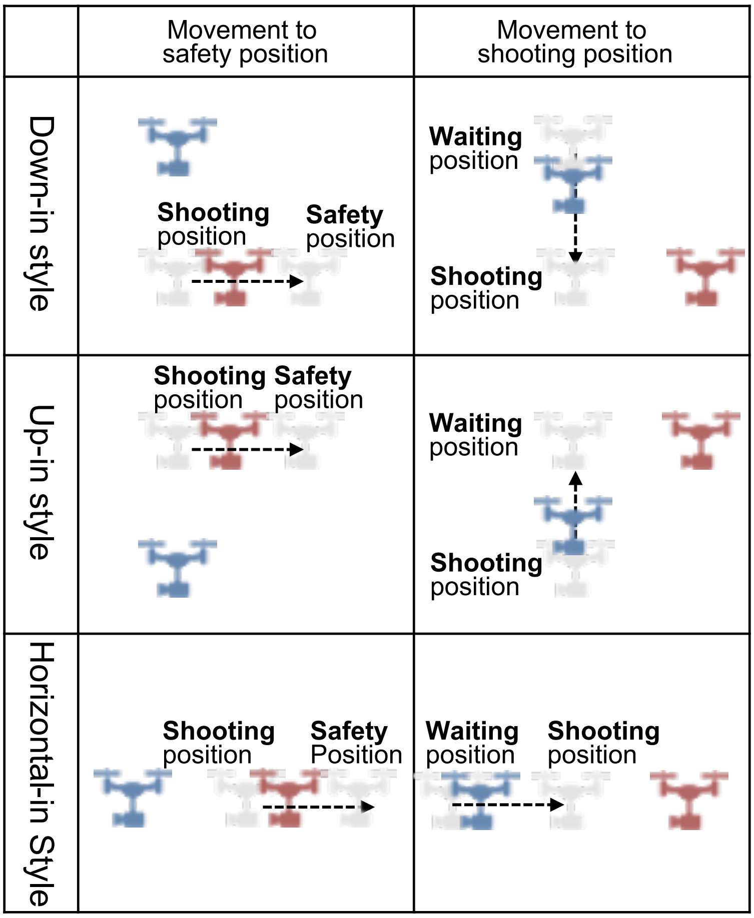

Fig. 1 – Various styles of continuous observation

2.2 Rules for Safety and Down-in style Continuous Observation

Two rules for safety are strictly followed: First, an operator does not move their operating UAV without a declaration about the next operation; second, operators use determined declaration statements for all types of operations. Procedure of down-in style continuous observation is shown in Fig. 2.

The unrecordable time, T, is divided into three categories: First, t_1, the travel time from the shooting position to the safety position for the shooting UAV; second, t_3, the travel time from the waiting position to the shooting position for the waiting UAV; and third, t_2, the time taken for communication between the two operators. The unrecordable time, T, depends on the distance between the shooting position and the waiting position, and the distance is determined in consideration with safety and effect.

$$T = t_1 + t_2 + t_3 \quad (1)$$

The footage at the waiting position covers the whole range of the footage at the shooting position in the down-in style continuous observation, as shown in Fig. 3. It means that the waiting UAV can be used as a second shooting UAV from the time of leaving the shooting position for the shooting UAV to the time of reaching the shooting position for the waiting UAV.

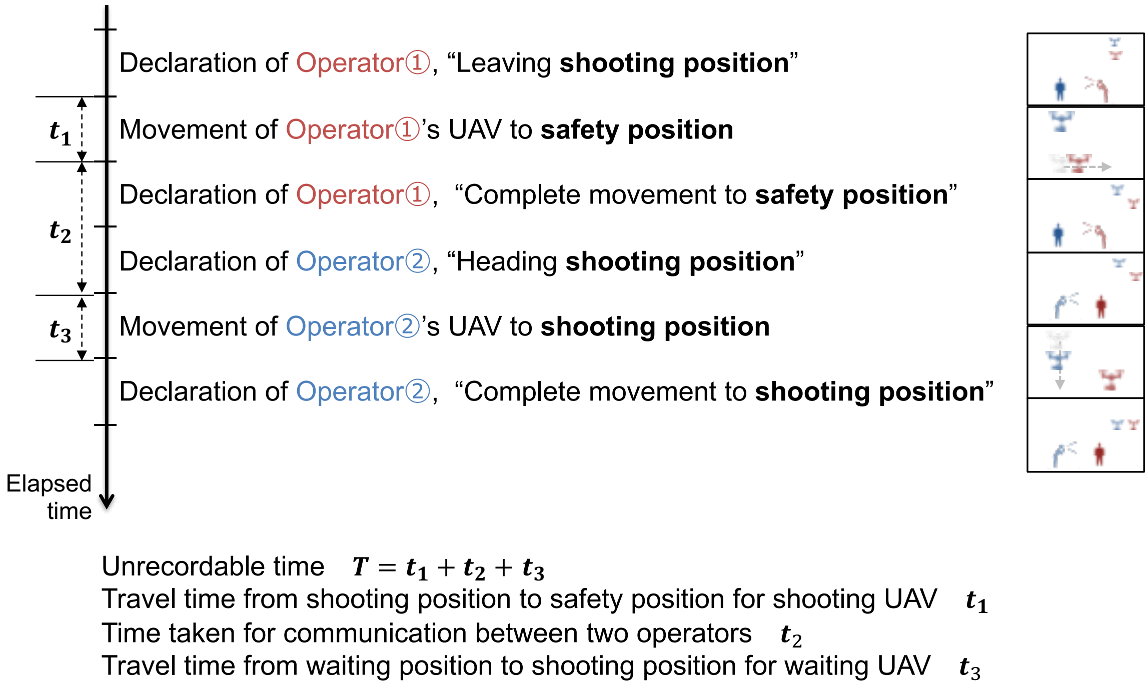

Fig. 2 – Procedure of down-in type continuous observation, and temporal parameters

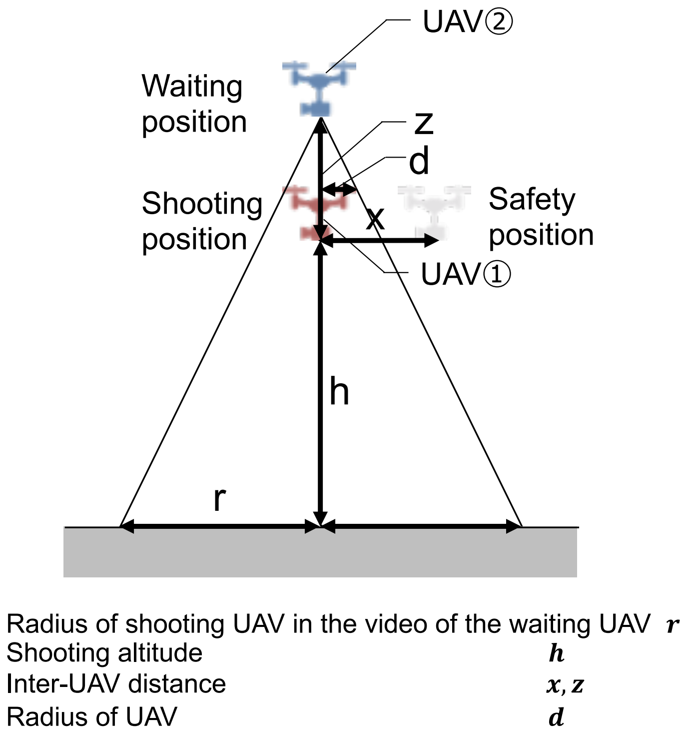

Fig. 3 – Spatial parameters for the down-in style continuous observation

3. RESULT

3.1 Unrecordable Time *T*

The relation between the unrecordable time *T* and the inter-UAV distance *x*, *z* was studied as: *x, z*(m)= 5, 10, 20, 30, as shown in Table 1. Test cases were conducted 5 times for each inter-UAV distance, and the total 20 test cases were conducted on 3 different days.

Table 1 – Test cases for the relation between the unrecordable time *T* and the inter-UAV distance *x*, *z*

Case	Shooting altitude	Inter-UAV distance
1	50m	30m
2	50m	20m
3	50m	10m
4	50m	5m

Fig. 4 shows the relation between the unrecordable time and the distance between the shooting and waiting positions by conducting test observations for the distances of 30, 20, 10, and 5 m; the unrecordable time for these distances were found to be 19, 16, 11, and 8 s, respectively. In tsunami evacuation drills conducted in Minamiawaji city, we could reduce the unrecordable time from 4 min 30 s with a single-UAV observation in 2017 to 13 s with a multi-UAV observation in 2018.

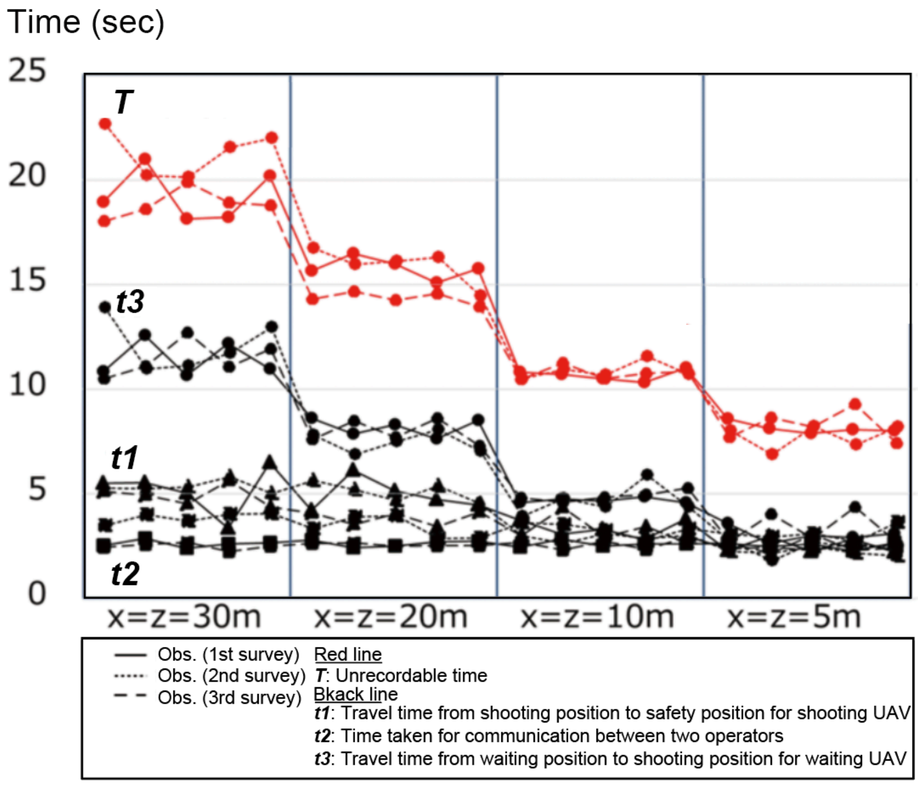

Fig. 4 –Relation between the unrecordable time *T* and the inter-UAV distance *x, z*

3.2 Radius of the Shooting UAV in the Footage of the Waiting UAV *r*

The relation between the radius of the shooting UAV in the footage of the waiting UAV *r*, the shooting altitude *h*, and the inter-UAV distance *x*, *z* was studied as: *x, z*(m)= 5, 10, 20, 30, and h(m)= 50, 75, 100, 125, 150, as shown in Table 2. Total 24 test observations were conducted on 2 different days.

Table 2 – Test cases for the relation among the radius of shooting UAV in the video of the waiting UAV *r*, the shooting altitude *h*, the inter-UAV distance *x*, *z*

Case	Shooting altitude	Inter-UAV distance
1～ 4	50m	30m, 20m, 10m, 5m
5～ 8	75m	30m, 20m, 10m, 5m
9～12	100m	30m, 20m, 10m, 5m
13～18	125m	30m, 20m, 10m, 5m
19～24	150m	30m, 20m, 10m, 5m

Fig. 5 shows the relation between the radius of the shooting UAV in the footage of the waiting UAV *r*, the shooting altitude *h*, and the inter-UAV distance *x, z*, comparing with the theoritical results calculated by the following equation (2).

$$r = \frac{z+h}{z} d \tag{2}$$

The differences between the observed values and theoretical values in case of the inter-UAV distance x=z=5m are larger than in case of the other inter-UAV distances. It was more windy on the first observation date than the second observation date. That effect became larger in case of the shoter inter-UAV distance.

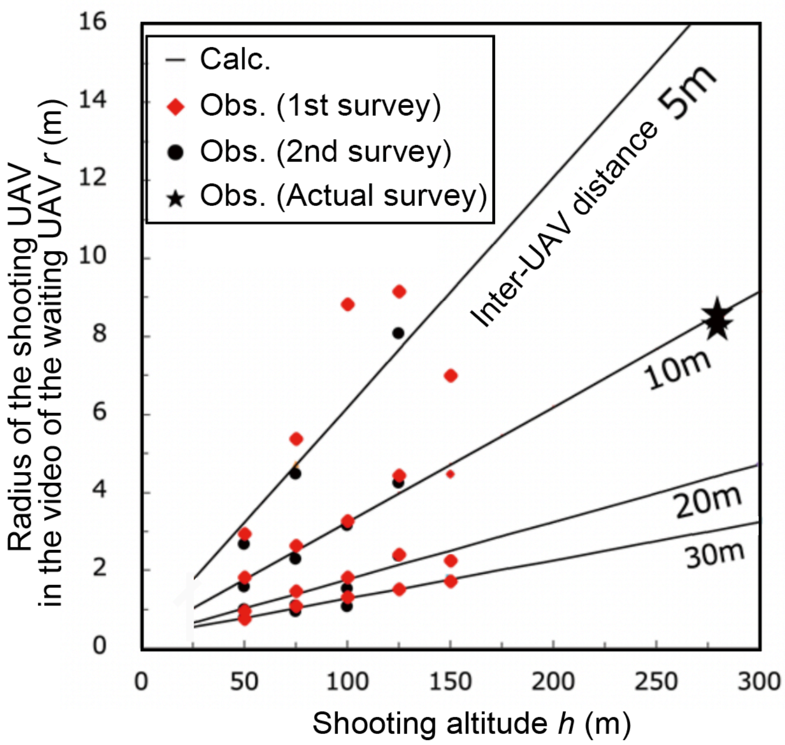

Fig. 5 –Relation between the radius of the shooting UAV in the footage of the waiting UAV *r*, the shooting altitude *h*, and the inter-UAV distance *x, z*

4. CONCLUSION

We established the relation between the unrecordable time and the distance between the shooting and waiting positions by conducting test observations for the distances of 30, 20, 10, and 5 m; the unrecordable time for these distances were found to be 19, 16, 11, and 8 s, respectively. This result is useful for an observer to determine the optimal distance for their observation. In tsunami evacuation drills conducted in Minamiawaji city, we could reduce the unrecordable time from 4 min 30 s with a single-UAV observation in 2017 to 13 s with a multi-UAV observation in 2018.

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