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UAV traffic in urban airspace: A simple measure of conflict

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ABSTRACT

The usage of Unmanned Aerial Vehicles (UAV) keeps increasing exponentially with enormous development in its technology and manufacturing. To cope with this increasing demand, there should be a traffic management system to control the demand of low-flying vehicles and the capacity of airspace in near future. In this study, we examine the effect of UAV demand to the urban airspace by measuring possible conflicts in a simulation environment.

INTRODUCTION

The public and commercial use of Unmanned Aerial Vehicles (UAV) has increased rapidly in recent years. Though this fast evolving technology has enormous potential in many fields from parcel delivery to film making, there should be procedures and structures to manage this new air traffic in a safe and efficient manner, just like land vehicles operating within a system consisting of road structures, signals, and regulations. In the U.S., FAA expects 2.5 million drones to be in use. by the end of 2016 and 7 million by 2020. To cope with this increasing demand NASA is developing a traffic management program called UTM for low-flying vehicles (Cavolowsky et. al., 2015). Other countries such as Korea, Japan, China, and the UK also are on their way to develop such management systems and regulations to ensure safety in the airspace (Kopardekar, 2016).

The objective of this study is to investigate how UAV demand will affect the urban airspace when there is no infrastructure system and traffic rule in place for UAVs. We simulate UAVs flying in airspace of Gangnam in South Korea. The demand and ODs are generated using gravity model based on population. For the simplicity, simulated UAVs are limited to fly on a straight line from origin to destination. We measured the number of conflicts depending on yearly demand of UAV usage per person.

MEASURING UAV TRAFFIC CONFLICT

Simulation logic

We adopt the gravity model to generate the OD demand from point to point. The gravity model is used in many field from social science to trades to predict demand between two units (Anderson et. al., 2003). The implemented model has a simple form:

$$d_{i,j} = \frac{G P_i^a P_j^a}{x_{i,j}^b} \tag{1}$$

, where $d_{i,j}$ is the demand (the number of flights) from i to j, P_i and P_j are the number of population at i and j, respectively, and x_{ij} is the distance between i and j. G, alpha and beta are constants. OD is generated based on 300m×300m grid where the centroid serves as the terminal point of each trip. There are 1,768 grids in the study area, which yields 1,768×1,768 OD pairs theoretically.

Each trip is generated using Poisson process, with flight ID, origin, destination and departure time information provided. UAVs are assumed to fly on a straight line, and static obstacles such as terrains and building are not considered at this stage. Speed is assumed 20 m/s. For each time step of 3 seconds, the position of each flight is updated to the flight table. Simulation is performed using MATlab.

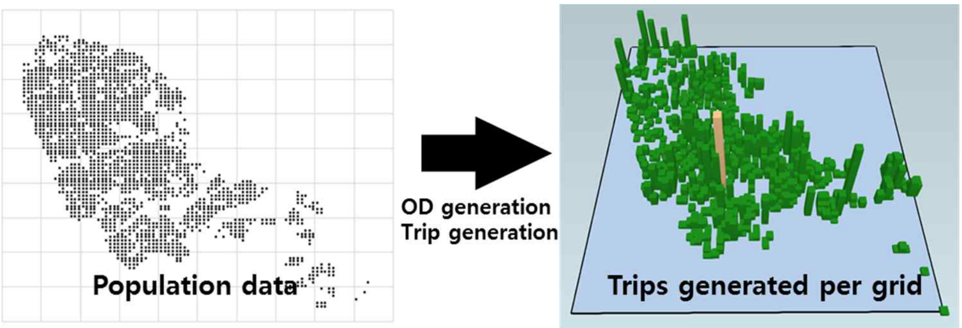

Fig. 1. OD and trip generation based on population data

Conflict calculation

We define that two flights are in a conflict situation if the distance between them is smaller than a conflict threshold. For each time step, we check whether each flight is in a conflict situation.

$$f_{i,j} = 1 \text{ if } |x_{i,j}(t)| \leq \text{Threshold}$$

We let:
N= $\sum_i \sum_j d_{i,j}$: total number of flights
$\sum_i \sum_j f_{i,j}$: total number of flights in conflict
$\sum_j f_{i,j}$: number of flights in conflict for flight i, i≠j
$C = \sum_i \sum_j f_{i,j} / N$: expected number of flights in conflict during T, i≠j
Threshold, h ={40m,80m,120m,160m,200m}
T = [0s, 3s, 6s, …, 3600s], t ∈ T

Results

Figure 2 shows the expected number of flights in conflicts depending on demand. There are 8 demand scenarios, ranging from 674 to 9656 flights during an hour. The expected number of flights in conflict is calculated for each demand scenario that is performed 100 times. In general, as demand increases, the expected number of flights in conflict increases with a hockey stock shape. For example, when conflict threshold is 40 meters, for N=1642 0.1% of flights experience one or more conflicts during T. This increases to 2.2% for N=9656. When h is 200 meters, meaning that we count two flights are in a conflict situation if the distance between them is below 200m, 0.7% of flights experience one or more conflicts for N=674. This number exponentially increases to 22.9% for N=9656.

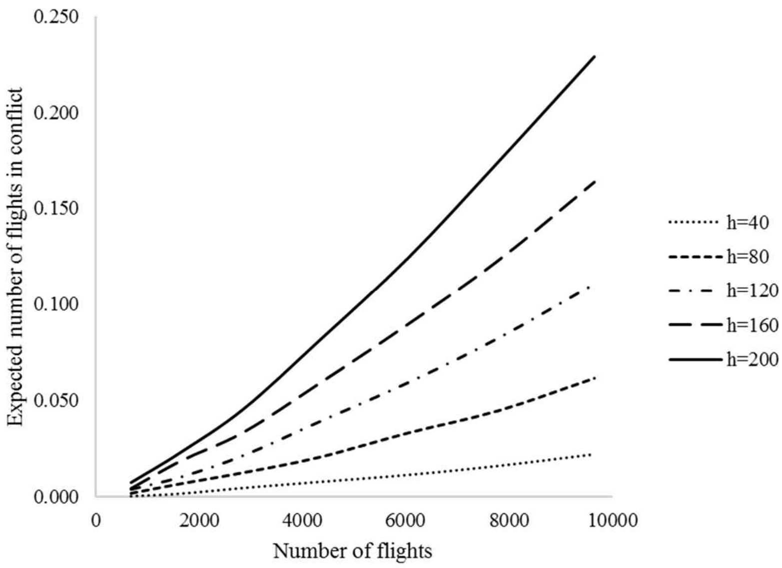

Fig. 2. Number of flights in conflicts depending on flight demand

Table 1 explains the number of conflicted flights that each flight encounters for demand N=4320. For instance, for h=40 there are 25 cases that a flight encounters one conflicted flight, 5 cases that a flight faces 2 conflicted flights, and 1 cases of facing 3 conflicted flights. Overall, the number of conflict size 2 cases is below 40% of that of conflict size 1 cases. In general, the higher the conflict threshold, the greater the number of conflicts for each conflict size. Especially, the number of flights for conflict size

1,2, and 3 increases more than 2.1 times from h=80 to h=120 cases. This indicates that there are many possible conflicts with distance from 80m to 120m generated in this particular simulation environment.

Table 1. number of flights per conflict size for N=4320

$\sum_i f_{i,j}$	Number of flights for each conflict size				
	h=40	h=80	h=120	h=160	h=200
1	25	33	70	84	85
2	5	5	15	35	26
3	1	3	9	6	17
4	0	1	2	6	8
5	0	0	1	2	10
6	0	0	0	0	1
7	0	0	0	0	4
8	0	0	0	0	0

CONCLUSIONS

The objective of this study is to investigate how UAV demand will affect the urban airspace when there is no infrastructure system and traffic rule in place for low-flying vehicles. It can be concluded that there needs such traffic control system with airspace structures and regulations to cope with increasing demand in urban airspace. Congested airspace due to the presence of UAV traffic could also be identified. In future study, we would introduce a simple route structure in airspace for UAVs and examine the effect of the airspace structure to safety and efficiency.

There are many limitations in this study. The static obstacles such as terrains and building are not taken into consideration yet. Various routing strategies can be developed if the 3D map information is integrated in the simulation environment. Also, the UAV is limited to fly in a straight line, which is the most efficient in terms of energy saving and routing complexity, but it fails to consider UAV operations such as photography, search and rescue, and infrastructure monitoring that UAV flights are kept in a certain boundary. This particular scenario may be appropriate for direct shipment cases such as UAV delivery.

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