SIMULATION STUDY FOR VFR AIRCRAFT AND SMALL UNMANNED AIRCRAFT SYSTEMS (SUAS) MIXED OPERATIONS IN LOW LEVEL AIRSPACE

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Abstract

The utility of small unmanned aircraft systems (sUAS), known as drones, is increasing rapidly around the world. In Japan, the use of drones in industry has been encouraged and an aviation law was developed in 2015 to ensure the safety of manned aircraft. To study of safety level in low-altitude airspace, our research team has been developing techniques to simulate the movement of multiple sUAS and small aircraft, especially helicopters. First, this paper introduces the concept of the simulator we are developing. Next, a case-study analysis using air ambulance-position and radar data is presented to for understanding low-level-flight characteristics using visual flight rules (VFR). The case study's results are analyzed to show that air ambulances tend to move the shortest course from point to point because they need to transport personnel as rapidly as possible. The superimposition of air ambulance-position and radar data on the map showed that flight altitude and terrain greatly affect the radar-coverage area.

In the near future, the necessity for an information –sharing mechanism not only among sUAS themselves but also between sUAS and manned aircraft will increase. Elucidation of problems in this field such as error possibilities of data is important.

1 Introduction

A vehicle that flies without a human pilot on board is called an unmanned aerial vehicle; subsequently, the term unmanned aircraft system (UAS) has also been used in recent years to emphasize along with just a single vehicle, a "system" is involved, which includes ground devices, command, control, and communications. And the unmanned aircraft (UA) is being used as vehicle itself. UA includes a broad spectrum of aircraft, from small UA (sUA, drones), unmanned free balloons, and model aircraft to highly complex remotely piloted aircraft [1]. Due to their utility, the demand for small UAS (sUAS) is increasing in various fields, including aerial photography, measurement, and surveying all over the world. Most such sUA fly at low level, mostly in uncontrolled airspace (Class G) [2]. The increase in sUA flights in Class G airspace is creating more proximity events, not only among sUA flights themselves, but also between sUA and manned aircraft. However, schemes for managing vehicle that fly at low level airspace have not developed yet. Uncoordinated flight without sharing of information such as planned flight or in-flight date and time, flight course, flight altitude etc. among sUAS or with other airspace users results in a risk of midair collisions. To mitigate such risks, work on a UAS traffic management (UTM) framework to achieve safe, secure and efficient sUAS operations is ongoing around the world [3-5].

In Japan, an aviation law developed in December 2015 defined unmanned aircraft and arranged the rules of flight [6]. Accordance to Japanese aviation law, sUAS operators must fly their UAs within their visual line of sight during the day less than 150 m, avoiding airports or densely populated areas, leading to little influence on people and property. In case where flight is necessary that does not satisfy the above requirements, permission or approval of the Japan Civil Aviation Bureau (JCAB) is required.

Class G airspace is an uncontrolled airspace wherein air traffic control (ATC) service is not provided and separation intervals between aircraft are not guaranteed. In this airspace, aircraft operate under visual flight rules (VFRs) when performing their various missions. Thus, airspace conflicts between sUA operation and VFRs may occur, and there is concern that these vehicles may come too close to one another. Several approached are considered to evaluate the safety of airspace, indices are proposed and methods are being studied to measure the safety of this airspace [7, 8]. One factor affecting the safety of the airspace is operation of a vehicle flying there. So, regarding sUA, categorization of UAs according to operational risk is becoming popular [9], and discussion on this subject will continue around the world.

To maintain safety in this airspace even as demand for the sUAS operations increases, it is important to initially analyze the airspace. Next, by simulating various airspace operation situations on a computer, it becomes possible to design provisions and schemes for future high-demand sUAS operations

This paper provides our approach for simulating low-level airspace as a mixed environment of sUAS and VFR flights, and to conduct preliminary analysis of VFR flight using radar processing data.

2 Simulation of Low-level Airspace

To clarify issues related with simultaneous operation of multiple sUAS and VFRs, especially for helicopters, and to propose solutions to these problems, we designed a simulation of a sUAS and VFR flight environment.

Figure 1 shows the concept of the simulator we are developing. The simulator comprises two main elements: a dynamic simulator and electromagnetic field simulator. The dynamic simulator calculates both VFR and sUA flight trajectories using dynamic aircraft performance models. Electromagnetic field simulator simulates radio communications. Simulation is executed based on each operational scenario by setting a simulation environment.

A partial exercise regarding the simulator that we are developing has executed [10].

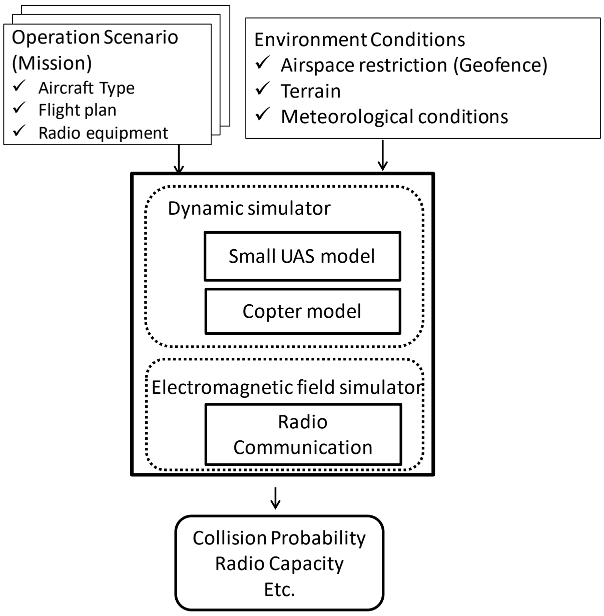


Fig. 1 Simulation concept of low altitude airspace

sUA trajectory have been simulated using the dynamic model. For the electromagnetic field simulator, we have used a free space propagation model for electromagnetic field for a preliminary examination [10]. To improve the accuracy of the simulation, more realistic models will be considered, such as Okumura-Hata model, to express electromagnetic wave propagation with a consideration of terrain.

3 VFR Flights

3.1 Flight Rules

In general, there are two flight rules for aircraft: the instrument flight rule (IFR) and VFR. Most airliners flying between airports as passenger/cargo flights operate according to IFR. IFR flights always follow the instructions of ATC and safety is ensured after a consideration of other flights, the terrain, and other factors. On the other hand, VFR aircraft fly based on the pilot's own judgment in sufficient visibility weather.

3.2 VFR missions

Various missions, such as sightseeing, photography, rescue, etc., are performed by light

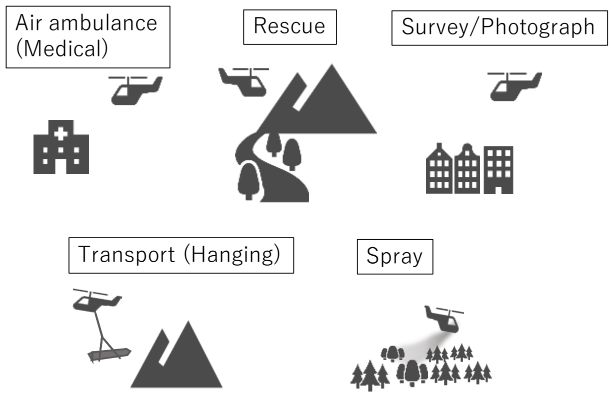


Fig. 2 Various missions by VFR flights

aircraft (small planes). Most of such flights operate under VFRs because they are well suited for that purpose. Figure 2 shows the various missions conducted by VFR flights, which are executed at relatively low altitudes that classify as Class G airspace.

The air medical service, which moves patients to hospitals by helicopters (air ambulance), is one useful application of light aircraft flight. The takeoff and landing locations of air ambulances can be set flexibly at locations other than airports as required. Thus, transportation of patients from accident scenes or land-inaccessible locations is possible within a short time. To realize safe and efficient flight management of air ambulances, an air ambulance dynamic management system has been developed as a portable system in aircraft, and it has been introduced to most air ambulances in Japan. To search VFR flight characteristics, air ambulance trajectory data from the air ambulance dynamic management system are used in this study.

4 Data Analysis of VFR Flights

4.1 Air-ambulance Data

"Foster-CoPilot," a portable system in aircraft, has been developed by Weathernews Inc. to enable unified management of air ambulance flight for greater safety and efficiency. The GPS-position information of the in-flight air ambulance is transmitted to the ground station via the Iridium satellite by this system. One example of the utility of the system is overlaying with weather information: the pilot can be informed by on-ground flight managers about the latest weather on their route. The system is also expected to be utilized by search-and-rescue helicopters to share data in disaster situations [11]. Air ambulance position data collected by Foster-CoPilot was provided for research purpose in cooperation with Weathernews Inc. and Nakanihon Air Service, who are the operators of air ambulances. The data contains the GPS position (latitude, longitude, and altitude) and positioning time collected every few minutes.

4.2 Radar-processing Data

To obtain the characteristics of VFR flight, radar-tracking data were also provided by JCAB. Radar-tracking data include aircraft position data obtained from the airport surveillance radar (ASR) of the Chubu Airport Office, which covers the area in which air ambulances of the Nakanihon Air Service fly.

Generally, radar-based ATC is used to identify flights on radar using the assigned secondary surveillance radar codes transmitted from the aircraft transponders. In the case of IFR flights, a unique code is assigned to the aircraft before it becomes airborne to identify it over the whole flight process. In the other hand, most VFR flights set a common code for VFR (in the case of Japan, "1200" or "1400"). Upon contact with an ATC unit to obtain radar-ATC services as necessary, a unique code will be assigned for radar identification. Radar data contains the code information associated with position information, but distinguishing all VFR flights is difficult based on this code information.

4.3 Case Study analysis

Two case-study analyses were performed. The first was to find the flight characteristics of an air ambulance to plot the air ambulance position data of Foster-CoPilot on the map. And the second was to superimpose air ambulance position data and radar tracking data to ascertain how the ambulance data was captured by the radar.

Figure 3 shows a plot of air ambulance position and radar data on the map in the same time zone on the same day. Flight altitude information from both datasets is expressed in a color scale. Figure 4 shows the flight altitude above mean sea level and the ground speed of the air ambulance flight data with elapsed flight time. The air ambulance moved from points A-C in Figure 3, flying down at each point and up again and moving to the next point along the shortest-relative-distance (direct) course. In this case, the vehicle moves between points at an altitude of 3,000-3,500 ft with a ground speed of about 120 knots. For an air ambulance, it is necessary to transport personnel as rapidly as possible; thus, there is a tendency to move the shortest course between points (one of which is a hospital) at high speed. The statistical values of flight altitude and flight speed obtained from this result will be reflected in the simulation calculation that we are developing as described in Chapter 2.

The radar plot data shown in Figure 3 indicate flights with VFR codes. So, it was not being identified the flight. Nevertheless, based on the time, position, and height trend, it is presumed that the radar captured part of the air ambulance flight. The site of the airport's radar is in the upper right of Figure 3. Despite the fact that the distance from the radar site is almost the same, not all locations for which there is air ambulance data were captured on radar. Flight altitude and terrain have a significant effect upon radar coverage.

For air ambulances, takeoff and landing mainly use heliports or corresponding spaces instead of an airport. Figure 5 shows the Chubu airport radar site (black asterisk) and the heliports used by air ambulances (red squares). The color scale expresses the atmospheric pressure of the surface at a time on one day. Atmospheric pressure data were obtained from the grid point values of the Japan Meteorological Agency's meso-numerical model. Radar data altitude values are obtained from the QNH altimeter settings at the airport (where the Q code indicates that atmospheric pressure was adjusted to the mean altitude of the airport). On the other hand, helicopters flying from a heliport set their QNH altimeter settings by reference to the mean altitude of the heliport. In the case shown in Figure 5, the air pressure difference between the airport and the heliport is 0.4 hPa. The altitude displayed in the radar data may have an error of

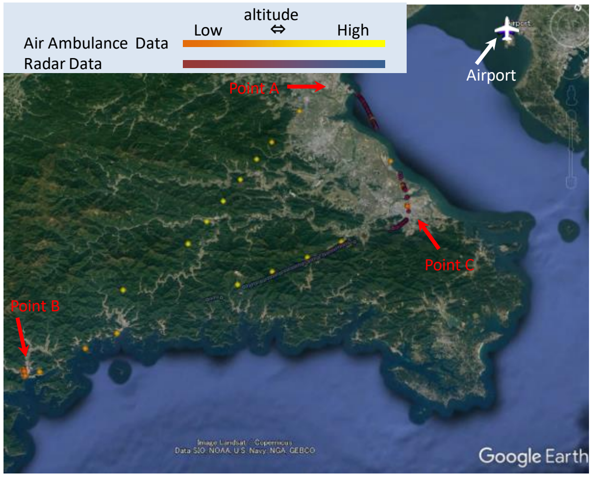


Fig. 3 Superimposition map of air ambulance position data and radar data

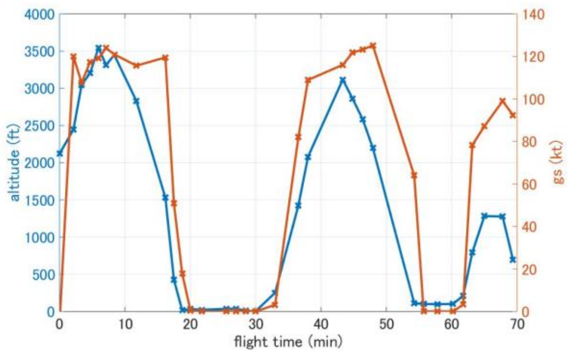
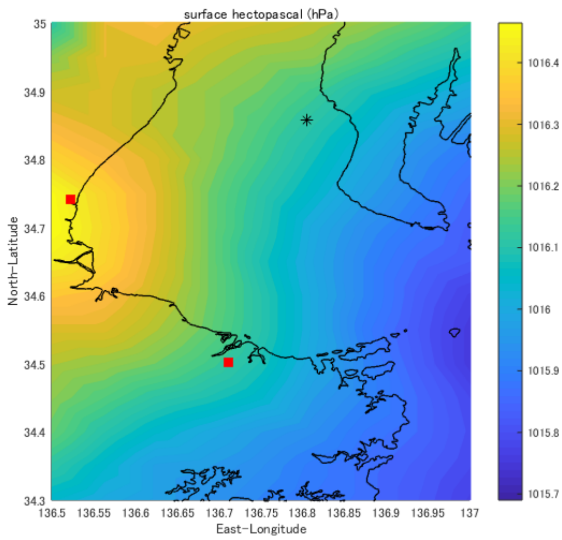


Fig. 4 Flight altitude and ground speed of a flight



* radar site, ▪ heliport

Fig. 5 Atmospheric pressure of the surface about 3 m from the difference in the altimeter setting. This represents a key consideration when utilizing radar data to capture aircraft that do not receive control services.

5 Conclusions

As the use of sUAS is likely to increase in the near future, the necessity of a mechanism for information sharing among sUAS and between sUAS and manned aircraft to maintain safety in low-altitude airspace will increase. To clarify issues and propose solutions regarding mixed operation of multiple sUAS and VFR aircraft (especially helicopters), our research team has constructed a simulation of their flight environment. First, the flight characteristics of air ambulances were analyzed using air ambulance position data. The results of a case study showed that air ambulances have a tendency to move the shortest course between the heliport of a hospital and the landing/takeoff site at an altitude of 3,000-3,500 ft above mean sea level with a ground speed of about 120 knots. The statistical values of flight altitude and flight speed obtained from this analytical result will be reflected in a simulation calculation that we are developing.

As one means of information sharing, we consider sharing location information from different sources. Radar tracking data is one possibility for data sharing. However, VFR aircraft flying at low altitude often do not receive ATC services, and may not always be captured by radar. This paper indicated that altitude errors may be contained in radar data, even if the VFR flight is captured.

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