Toward Cooperative Aircraft Swarm Control

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1. Introduction

Aircraft flight control system is designed to meet stability and control requirements while placing top priority on aircraft flight safety. Aircraft operation ultimately depends, however, on pilots and air traffic controllers (ATC). The increased number and complexity in a lot of aircrafts in the same airspace thus becomes a major issue.

Mitsubishi Heavy Industries, Ltd., (MHI) is studying cooperative aircraft swarm control in which aircraft form a mutual information network to share the obtained information and to carry out control based on the obtained information. In other words, instead of individual aircraft control, numbers of aircraft are treated as a group under combined control.

The sections that follow introduce automatic formation flight demonstration system using two small flight-demonstration aircraft and results of a flight demonstration test.

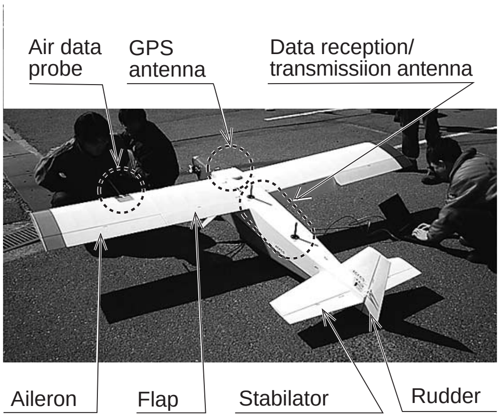

Fig. 1 Small flight-demonstration aircraft

2. Flight demonstration system using small flight-demonstration aircraft

The flight demonstration system is based on commercially available wireless control system in the market. The system consists of two small flight-demonstration aircraft with flight controllers etc. and a ground station. The ground station has a personal computer for monitoring and controlling flights and a data receiver/transmitter for data communication.

Each small flight-demonstration aircraft shares information on mutual flight status of the other through the ground station.

2.1 Small flight-demonstration aircraft

The small flight-demonstration aircraft selects either of two wireless-control mode by switching operation. One is Radio Control mode not using a flight controller, and the other is FBW mode using a flight controller.

Aircraft are approximately 2 500 mm long, 2 700 mm span, weigh 14 kg, and have a wing area of 1.2 m^2 (**Fig. 1**).

2.2 Flight control system

The flight control system equipped on the aircraft consists of a flight control computer, attitude heading reference system (AHRS), air data probe, GPS receiver, surface angle sensor, data communication unit, and a power source to realize the flight control of the aircraft.

3. Flight control law

The flight control computer uses the flight control laws below (**Fig. 2**).

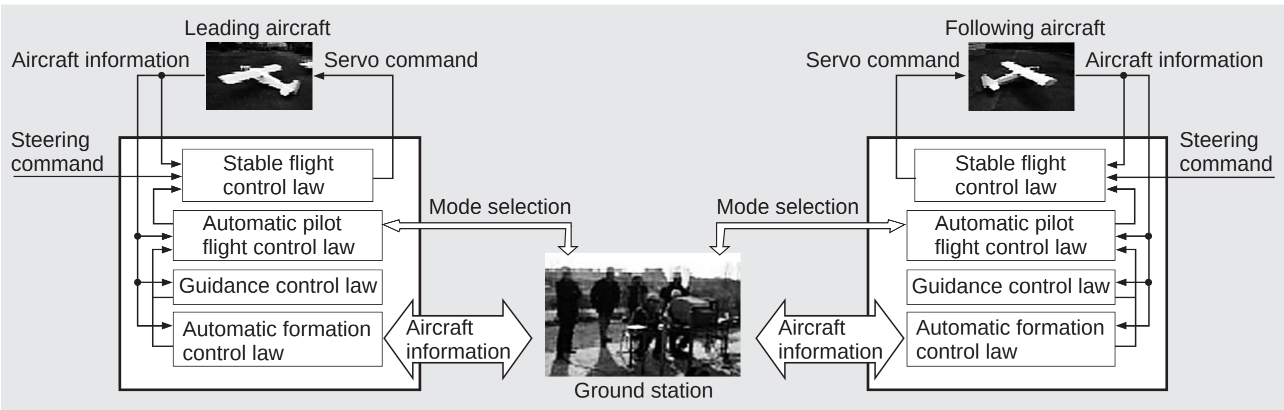

Fig. 2 Flight control law configuration

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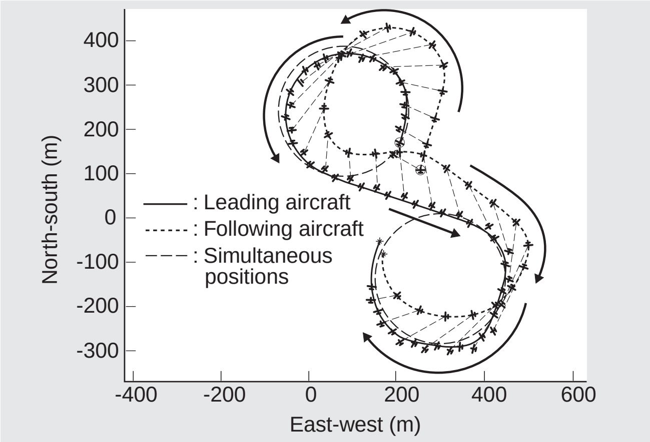

Fig. 3 Flight tracks of two aircraft during automatic formation flight

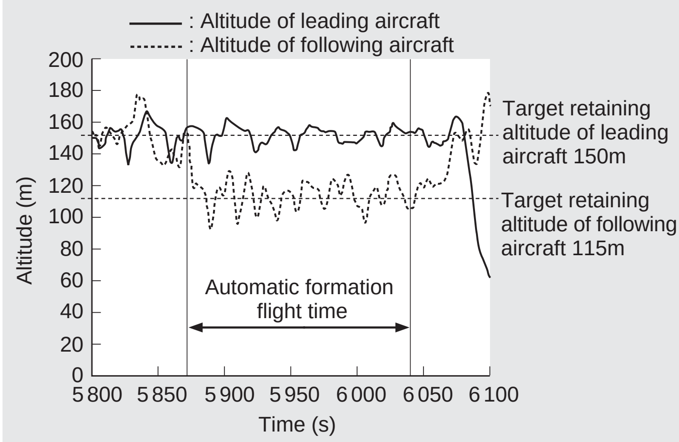

Fig. 4 Attitudes of two aircraft during automatic formation flight

3.1 Stabilize flight control law

When the FBW mode is selected through a command from the ground, stabilize flight control law on the flight control computer transmits command signals for the horizontal tail, aileron, and rudder. The command signals, which are based on information from sensors, are transmitted to maintain response characteristics and aircraft stability regardless of flight conditions.

3.2 Autopilot flight control law

Autopilot flight control law can be engaged after selecting the flight by FBW mode. Autopilot flight control law has a function of attitude hold, altitude hold and speed hold. The engage/disengage of each function is controlled by the ground station.

Altitude data from GPS may differ greatly from the actual data because of the scramble signals, number of satellites captured, etc. To prevent this, we developed a hybrid altitude calculating algorithm to prevent sharp changes in altitude data (information) upgraded from GPS and acceleration data from AHRS.

3.3 Guidance control law

Guidance control law involving automatic flight with a preplanned route and speed was set at automatic formation testing to facilitate flight test evaluation by fixing the track of the leading aircraft.

3.4 Automatic formation control law

Automatic formation control law involves maintaining the distance (position) between leading and following aircraft set in advance. The aircraft compares data for its own position, altitude, and speed with those of other aircraft from the ground station before transmitting commands to autopilot and stabilize flight control laws to maintain the preset distance.

4. Flight demonstration test results

An automatic formation flight test was conducted on December 24, 2003, using two small flight-demonstration aircrafts. With snow from the previous day still on the ground, the leading aircraft took off, engaging guidance control law after confirming the safety of FBW mode.

The leading aircraft flew in a figure 8 while automatically maintaining an altitude of 150 m and an air speed of 30 m/s. The following aircraft took off next the same way and, after confirming FBW mode, engaged automatic formation control, automatically flying 30 m behind, 35 m below, and 0 m parallel to the leading aircraft.

The two small flight-demonstration aircraft flew automatically, with the following aircraft receiving information from the leading aircraft automatically in tracking flight. The flight tracks are shown in **Figs. 3 and 4**.

5. Conclusion

An automatic formation flight test was conducted using two small flight-demonstration aircraft in cooperative aircraft swarm control. The automatic formation flight experiment was conducted on a small scale in the United States using manned aircraft, but our experiment using unmanned aerial vehicles (UAV) is quite rare. We plan to proceed targeting improved function and performance.

Improving aircraft-to-aircraft information network reliability is vital to commercializing research. An important issue is how to enable information to be communicated even if the network is interrupted as in the case of a ground internet network.

Cooperative aircraft swarm control would dramatically increase the number of flights by manned aircraft followed by UAVs. Transport could be made more efficient through accident prevention such as near-miss by applying collision prevention and providing greater freedom in setting air routes.

In the near future, cooperative aircraft swarm control technology is expected to ensure safer, more efficient operation of aircraft. Linking information among ground, air, and sea traffic is expected to improve overall safety in vehicle operation.

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