The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 2019

Volume 7, Pages 199-203

IConTES 2019: International Conference on Technology, Engineering and Science

A Drone IFF and Tracking Algorithm with the Relay Drone and the Beacon System

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Abstract: A beacon system can easily be applied to recognize the registered drone information since the beacon can be worked as a sort of IoT device. But most of the beacon device can work in a short-range, the control center has lots of troubles to receive the beacon signal in it's out of range. In this study, we designed the drone IFF and tracking algorithm that can track the current position and the flight route of the target drone through the beacon information and the GPS positioning data from the approached relay drone in the beacon range of the target drone. The relay drone has the beacon receiver and GPS sensor and approaches to the target drone to receive the beacon signal. If the relay drone receives the beacon signal in a beacon range of the target drone, the relay drone checks the beacon information and its flight data and transmits it to the control center. To enhance the precision of the algorithm, the relay drone checks more than two different check positions at the critical distance from the inflight target drone. The drone IFF and tracking algorithm can calculate the current position and flight route of the target drone through the two or more GPS data and flight data at the check positions from the relay drone. Since the relay drone flies heading to the inflight target drone, the precision of the drone IFF and tracking algorithm could be fluctuated according to the critical distance and the number of check positions. The experimental results with the DJI Phantom 4 Pro showed the precision of the algorithm is proportional to the product of the critical distance and flight speed and has over 92% with two check positions.

Keywords: Relay drone, IFF, Beacon, Flight tracking algorithm

Introduction

Anyone wants to fly a drone in the sky without any control or regulation by law. But the drone is a kind of flight object that can harm someone by a fault or other unpredictable situation that should be carefully controlled in the air. Many states and regional governments have a sort of drone authorization rule and operate the surveillance systems to detect unauthorized aircraft. Many of these surveillance systems have an aircraft detection system that can distinguish our force from the enemy as known as IFF (Identification Friend or Foe) system. If there is some kind of IFF among the aircraft, air traffic control can become easy to identify the aircraft and order to move or fly somewhere under the schedule. In today's airports and military areas, the IFF system is the most essential and usual system that can enhance the air traffic surveillance system.

In the drone area, the beacon-based drone surveillance system also widely used as like on airports or air force bases. But the existing drone surveillance system has short-range compare to the commercial radar system target to the aircraft and limited to the narrow area control at all. A drone has a limited power source compares to an aircraft, it cannot carry a long-range beacon to reach to the control center from the air in a wide area. Since the control center can only cover the commercial low-power beacon range less than 150m, the drone surveillance system could not become an effective control system without a high-expensive radar system. If there is a kind of bridge or repeater between the control center and target drone, the drone surveillance range can be expanded. Like the target drone, we can use a commercial drone as a relay drone that can easily make a sort of bridge between the target drone and the control center. If we use a very long-range communication system between the relay drone and control center, we just approach the relay drone near the target drone to get the beacon information as like the IFF system.

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IFF Method for inflight drone

Basic Concept

The key idea of the drone IFF is a very simple method to identify the friend and foe by using a scout drone called "Relay drone" flies from the ground control center to the UAV or target drone. To identify an inflight target drone as a friend, the target drone has to carry a kind of beacon authorized by the control center. If there is an unidentified inflight drone, the control center sends a relay drone approach to the target drone. If the target drone has an authorized beacon, the relay drone can recognize it as a friend in the beacon active range. Otherwise, the target drone is recognized as a foe and handled by law or any other regulation. By using the relay drone, the control center can identify the flight authority of the target drone from the out of the beacon range, and even can track the inflight target drone by flight tracking algorithm.

Flight Tracking Algorithm

The flight-tracking algorithm also has a very simple method as known as triangulation. Fig. 1 shows a simple situation of the relay drone approached near the inflight drone. If the relay drone flight around the target inflight drone, it can check its aerial position and the azimuth to the target at two or more positions with different angles. From the aerial position data and angles, we can easily calculate the distance between the relay drone and the target drone that can identify the aerial position of the target drone.

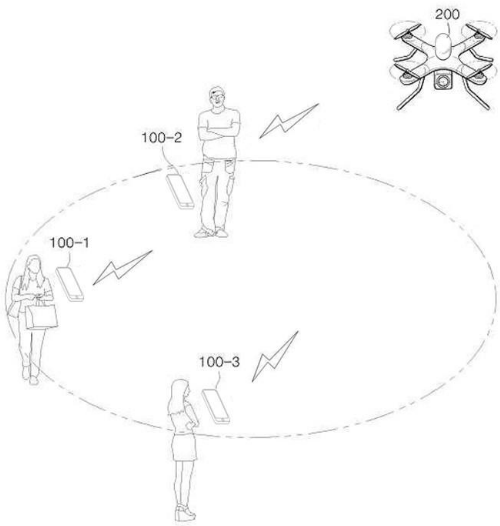

Figure 1 Basic concept of the IFF with beacon

In this work, we use the GPS data from the built-in GPS module of the relay drone as the aerial position data for triangulation. Since most of the drone system program libraries provide the GPS API and triangulation method in their development kit, we can easily estimate the distance from the relay drone on the specific position, and identify the aerial position of the target drone without any software modification of the target drone.

IFF and Tracking System Design

To identify the target drone, we attached a sort of long-range beacon module on the target drone and implemented the tracking app as shown in Fig. 2. Any of the commercial drones have no beacon module, the IFF beacon itself shows the target drone is an authorized drone for a specific control center. The tracking app can connect to the relay drone, and shows the recognized drones and its aerial position on the map. The relay drone searches the beacon signal that sends the beacon information of the target drone and its GPS data when identifies the authorized beacon signal from the target drone.

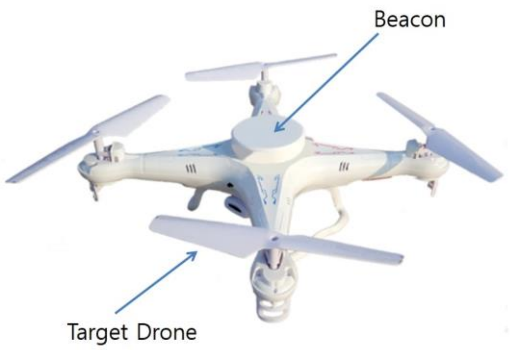

Figure 2 Beacon system design on the Phantom 4 Pro

Experimental Environments

Table 1. System environments

Environment	Item(s)	Specifications
Target Drone	Product	DJI Phantom 4 Pro
	Flight speed	P-mode:50km/s
	Weight	1,392 g
Smart device	Product	Samsung Galaxy Note 4
	OS version	Android Lollypop
Beacon	Product	BeaFon BLE C1
	Range(Max)	150 m
Total trials	Per checkpoints	8

To make sure of the proposed drone IFF and tracking algorithm, we made a series of experiments and check two major experimental results, *Critical Distance* and *Tracking Precision*. Although the drone tracking algorithm proposed in this work has a very simple method, its usability and efficiency have to by experiments under the inflight environment. Therefore, we tried 8 experiments with one relay drone and a target drone that has a beacon attached to the top of the drone. Table 1 shows all system environments in the experiments performed at the Hangang Drone Park in Seoul, Korea.

Critical Distance

The critical distance can be defined as an average distance from the relay drone to the recognized inflight target drone. If a relay drone approaches to a specific target drone that has a beacon, the relay drone can recognize the beacon signal. Since the relay drone always flies to the target drone straight, when the relay drone checks its GPS position at two or more check positions with different angle, we can estimate the distance to the target drone from the GPS data, flight angle and speed of the relay drone by the triangulation directly.

Tracking Precision

The tracking precision can be defined as a match percentile between the real aerial position and the estimated aerial position calculated by GPS data and direction of the relay drone when recognizing the target drone. The estimated aerial position of the target drone is calculated at the ground control center, not at the relay drone since the system program of the commercial drone is hardly modified by the user. If the estimated aerial position is closer to the real aerial position of the target drone, the tracking algorithm has high precision and reliability.

Experimental Results

In this work, one of the key results is the relation between the critical distance and the number of check positions for a specific target drone. To make the experiment clear, we tried multiple flights to get the critical distance from the relay drone to the target drone at constant flight speed. Table 2 shows the critical distances at

P-Mode flight speed (about 50km/sec) for a target drone with 2 check positions and 3 check positions. Although we had tried to maintain the other experimental condition despite the wind speed and temperature variation, the critical distance has a little deviation for every trial. The experimental results show that the relay drone can recognize the target drone's beacon signal almost at the same distance independent of the number of the check positions.

Table 2. Average critical distances at P-mode flight speed

Trials	*Ave.critical distance with 2 check positions*	*Ave. critical distance with 3 check positions*
1	126	123
2	105	111
3	97	101
4	111	106
5	121	112
6	108	103
7	101	102
8	107	108

Next, we check the tracking precision for a target drone at P-mode flight speed with 2 and 3 check positions. Fig. 3 shows that the tracking case with 3 check positions has higher precision than the case with 2 check positions. At the P-Mode flight speed, the tracking algorithm shows over 95% tracking precision for the target drone with 3 check positions. Even in the case of 2 check positions, the tracking algorithm has more than 92% of precision at the P-Mode flight speed. If the relay drone cannot recognize any authorized beacon signal from a UAV in the critical distance of a specific relay drone, the UAV could be recognized a sort of enemy's drone at the control center and the tracking algorithm can be worked as an effective IFF system without any expensive airplane or radar system within the drones flight range.

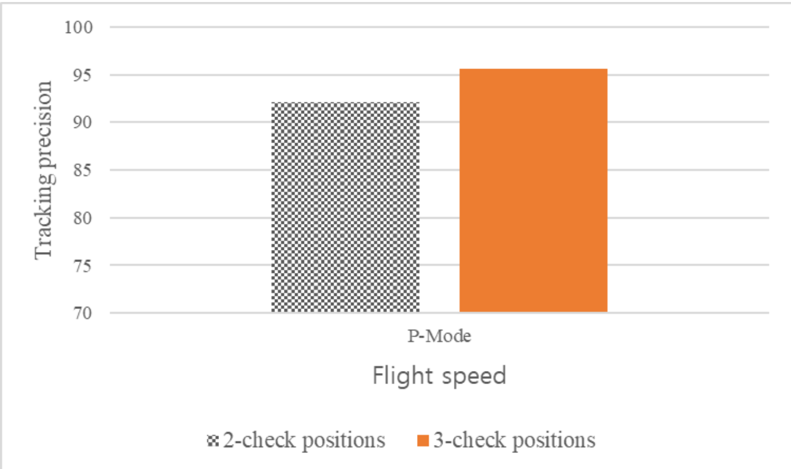

Figure 3 Tracking precision vs check positions

Conclusion

In this work, we designed and implemented an effective drone IFF and tracking algorithm with the relay drone and the beacon system. In this system, we use a relay drone to check a specific target drone is a friend or foe by using the beacon signal from the target drone. If there is a beacon signal from the target drone within the critical distance of the relay drone, we can recognize the fact that the target drone is a friend and vice versa. The critical distance can be worked as a kind of action range as like an IFF of the aircraft traffic control system. Since the critical distance could be varied according to the drone flight speed and various flight environment, we can select the appropriate method to authorized/unauthorized drone handling depends on the cost and environment. The experimental results show that the proposed drone IFF and tracking algorithm has over 92% and 95% of tracking precision at the P-Mode flight speed of the DJI Phantom 4 Pro with two and three check positions. These results enable the proposed algorithm to stretch to the commercial market or military area.

The proposed drone IFF and tracking algorithm can not only check the IFF but also check the aerial position by using the two or more GPS data of the relay drone with different target angles. Therefore, the tracking algorithm can be widely applied in the drone world, for example, regional drone traffic control, drone hunting or jamming to an illegal inflight drone, and so on. We are going to enhance the tracking algorithm works faster and simpler, and at further work, we aim to integrate the tracking algorithm into the dedicated relay drone system software along with the beacon system.

Acknowledgment

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MEST)(No. NRF-2017R1D1A1B03034804)

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