Regular paper

Journal of the KIECS. pp. 127-132, vol. 13, no. 1, Feb. 28 2018, t. 87, pISSN 1975-8170 | eISSN 2288-2189
http://dx.doi.org/10.13067/JKIECS.2018.13.1.127

FANET을 이용한 다중 무인비행체의 충돌회피 방안

양현호

Multiple Unmanned Aerial Vehicle(UAV) Collision Avoidance Scheme Using Flying Ad Hoc Network(FANET)

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요 약

무인비행체와 관련된 기술의 주요 이슈 중 하나는 충돌 회피이다. 특히, 다중 무인비행체 간의 충돌 회피는 무인비행체의 응용분야를 다수의 무인비행체가 제한된 공간에서 운영되는 민간 분야로 확장하기 위하여 매우 중요한 기술이다. 본 논문에서는 FANET(: Flying Ad Hoc Network)에 기반을 둔 충돌 회피 방안을 소개한다. 제안된 방식은 무선 데이터통신에서 사용되는 충돌회피 방식과 유사한 방법을 채택한다. 이 방식을 통하여 무인비행체들은 통상적인 사용자 정보를 주고받을 뿐만 아니라 충돌 회피를 위한 비행 정보도 공유한다.

ABSTRACT

One of the key issues in the Unmanned Aerial Vehicle (: UAV) technology is the collision avoidance. Specifically, the collision avoidance among multiple UAVs is critical to expand UAV applications to civil sector where large number of UAVs could be operated in the limited space. In this paper, we introduce a collision avoidance scheme based on Flying Ad Hoc Network (: FANET). The proposed scheme adopts collision avoidance mechanism used in wireless data communication networks. Using this scheme UAVs can not only communicate conventional user information, but also share flight information to avoid collision.

키워드

Unmanned Aerial Vehicle, UAV, Flying Ad Hoc Network, FANET, Collision Avoidance
무인 비행체, 충돌 회피

Ⅰ. INTRODUCTION

UAVs are economical and easy to operate because they are flying without a person, so they can be used more easily in various fields than manned aircraft. In particular, the use of several low-performance UAVs can further improve efficiency and economy. As a result, the technology development related to the flight of the UAV has attracted attention recently.

One of the most important issues related to UAV is the extension of flight times and the prevention of collisions. Among these, collision avoidance is a matter that needs to be solved in order to stabilize the flight of the UAV itself as well as other UAV in the vicinity.

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• 접 수 일 : 2017. 11. 24
• 수정완료일 : 2018. 01. 04
• 게재확정일 : 2018. 02. 15
• Received : Nov. 24, 2017, Revised : Jan. 04, 2018, Accepted : Feb. 15, 2018
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In order to prevent the collision of UAVs, the usual method is to use the ground control system similar to the conventional manned aircraft. This method is to avoid the collision by detecting the possibility of collision by sharing the information about the position information and the flight direction detected by the moving UAV, with the ground control system and other UAV around.

Information necessary for collision avoidance of UAV is obtained through image sensor or GPS receiver mounted on UAV. However, since the flight information obtained from these devices is managed individually for each UAV, the information may be duplicated or may differ from each other in the case of UAV flight. These problems are controlled by the ground control system, but in the environment where a large number of UAV are flying at the same time, the control capability of the ground control system will reach its limit.

The above problem can be solved in part if the UAV can be controlled in a decentralized manner through exchange of information on UAV. In this paper, we discuss flight information exchange method using FANET (: Flying Ad Hoc Network) among UAVs performing cluster flight. This method is expected to be used as a distributed flight control system avoiding collision of UAVs flying in a cluster. This method is expected to be used as a distributed flight control system avoiding collision of UAV flying in a cluster.

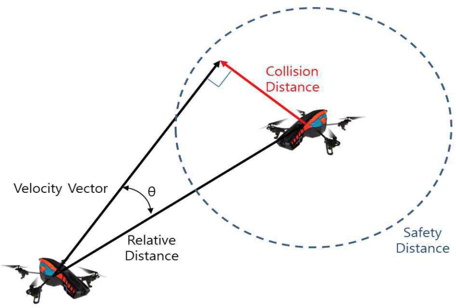

Fig. 1 Collision Distance Calculation Using Relative Position and Relative Velocity.[1]

The contents of this paper are as follows. Section 2 discusses related research, Section 3 describes the proposed method, and Section 4 describes the discussions and conclusions.

II. RELATED WORKS

2.1 Collision Avoidance of Multi-UAV Using Motion Capture

A collision avoidance scheme for smooth maneuvering of a large number of indoor UAVs has been proposed in [1],[2]. In this study, a motion capture system was installed to observe the UAV in the indoor clusters, and extracted the position vector and the relative speed vector of the UAV. From these two pieces of information, the collision distance is calculated as shown in Fig. 1 and the collision is avoided by operating the controller in the direction of increasing the collision distance. This study is an attempt to avoid collision of UAVs with cluster flight, but it is attempted under indoor and limited conditions and is not suitable for distributed autonomous flight environment because it is controlled through ground control system.

2.2 Collision avoidance through flight information exchange

An ad hoc network using GPS receiver, acceleration sensor and UAV equipped with WiFi transceiver has been introduced in [3]. In order to avoid collision, they designate a path to avoid collision by sharing information such as speed,

Table 1. Examples of neighbor table [4]

Drone id	Location (*lat* , *lon* , *alt*)	TTL(*sec*)
192.168.3.3	35.888057° , 128.612980° , 14.8m	2.34
192.168.3.5	35.887875°, 128.613227° , 15.4m	2.51

angle, position and size of each UAVs flying through this network. Though this study proposed a collision avoidance scheme for mobile obstacles, it requires additional consideration for the configuration and maintenance of the network.

2.3 Restoration of FANET

The authors of [4] proposed a method of restoring communication when it is disconnected in FANET, a wireless network used for information exchange and flight control of multiple UAVs flying.

For this, if the neighbor table is managed as shown in Table 1 and the neighbor's time-to-live (TTL) expires, the network is restored by returning to the location of the neighbor whose TTL has expired. Since this method uses location information received from GPS, it is applicable only when GPS reception is possible.

2.4 Location tracking using RSSI

The authors of [5],[6] proposed an RSSI-based location tracking scheme for WiFi networks, with irregular signal strength in indoor environments, where GPS reception is difficult. In this study, the position of a moving object is tracked by the method of the next position estimation. This method is proposed assuming existence of fixed AP in the environment and is not suitable for adaptation to a flight environment without fixed APs.

Ⅲ. SYSTEM MODEL AND METHODS

Conventional methods for avoiding and preventing collision of UAVs should commonly requires devices such as an acceleration sensor, a GPS receiver or a camera on each UAV in order to grasp the flight situation of the UAV.

In a cluster flight, a large number of UAVs fly with a relatively narrow distance and maintain a constant size. Therefore, collision may occur more easily than in single flight if the distance between each UAV is not maintained stably. Thus, in the case of UAVs flying in a cluster, it is sufficient to keep the distance of each UAV in order to maintain safe flight formation of the cluster, in stable flight condition. In addition, there is a need for a method of preventing collision in the case of an environment where GPS reception is difficult. Further more, when a conventional position management schemes using a GPS or similar system, there is a restriction on the location that the good GPS signal reception should be guaranteed in that position. If the UAV is in is included in the error range included in the received signal, There is also the potential for position control errors due to the GPS signal error. Therefore, in order to avoid the collision of UAV during cluster flight, a special position control method is needed including the following factors.

- communication method for exchanging flight information such as speed, distance, direction and size of UAV
- direct method to measure UAV positions e.g. using RSSI
- neighbor node table management scheme for neighboring UAVs
- algorithm to control UAV to avoid collision according to the change of position, direction and speed of UAV

3.1 FANET

FANET can be used to share flight information, such as flight speed, distance, direction, etc., between multiple UAVs or between specific UAVs and ground stations. Fig. 2. shows an example of such a FANET [7]. When FANET is used, advantages such as overcoming the communication distance limitation, securing a reliable communication path between the plural UAVs, and

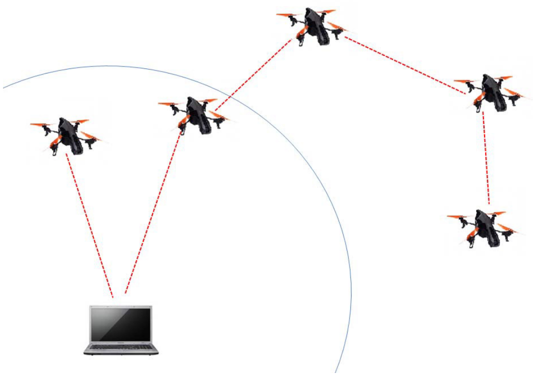

Fig. 2 A FANET scenario to extend the scalability of multi-UAV systems.[7]

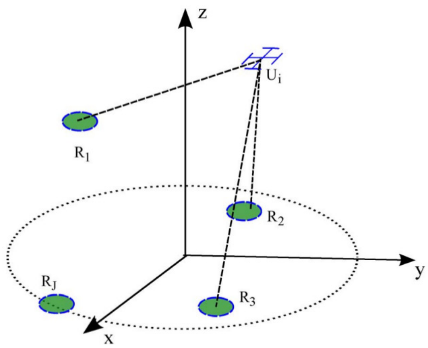

Fig. 3 Model of UAV position estimation [10]

managing the position of plural UAVs can be obtained.

In this paper, it is noted that, as described in the following section, it is possible to perform the position management of the UAV and the collision avoiding function using the FANET without introducing additional devices.

3.2 UAV location management using RSSI

The UAV position can be measured as shown in [8], [9], using the RSSI of the radio channel used for communication between UAVs in FANET.

In these methods, we can calculate the distance between the transmitter and the receiver using RSSI value of the radio signal used in a conventional short-range wireless communication system such as IEEE 802.15.4. Specifically, the distance d could be calculated using equation (2) which is derived from the Friis formula of equation (1).

$$L = 20\log\left(\frac{4\pi d}{\lambda}\right)[dB] \quad (1)$$

$$d = \frac{\lambda}{4\pi}\times 10^{\frac{L}{20}} = \frac{c}{4\pi f}\times 10^{\frac{L}{20}} \quad (2)$$

Fig. 3. shows how to determine the exact location of a UAV by triangulation[10]. This way of managing the location has the advantage that the absolute or relative position of the UAV can be found only by the communication device without the introduction of the additional device.

3.3 Routing Algorithm

In the proposed method, the flight information of UAVs are shared between adjacent UAVs using FANET, and in special cases, they are transmitted to fixed sink nodes on the ground.

This requires additional consideration of the routing protocol used in FANET. Table 2. compares several routing protocols available in FANET according to their characteristic criteria[11].

The routing protocol required in this proposed scheme should have a small delay time to enable flight information transmission in real time.

In addition, it should be able to maintain the route even when the topology is changed from time to time, and it should be easy to secure an alternative route when the route is disconnected.

Considering these conditions, it is necessary to use a routing protocol similar to Reactive Protocol in Table 2.

3.4 collision avoidance algorithm

The collision avoidance algorithm proposed in this paper is generally similar to the handshaking method used for collision avoidance in ad hoc wireless networks. The difference from handshaking

Table 2. Comparison of routing algorithms in fanets.[11]

Criteria \ Different Protocol Types	Static Protocols	Proactive Protocols	Reactive Protocols	Hybrid Protocols	Position/Geographic Based Protocols	Hierarchical Protocols
Main Idea	Static routing table	Table driven protocols	On demand protocol	Combination of proactive and reactive protocols	Position-based protocol	Protocol maintained through hierarchy
Complexity	Low	Medium	Average	Average	High	High
Route	Static	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic
Topology size	Small network	Small network	Large network	Both small and large network	Large network	Large network
Memory size	High	High	Low	Medium	High	Low
Fault tolerant	Absent	Present	Present	Mostly present	Present	Present
Bandwidth Utilization	Maximum	Minimum	Maximum	Medium	Minimum	Maximum
Convergence Time	Fast	Slow	Mostly fast	Average	Average	Average
Signalling Overhead	Absent	Present	Present	Present	Present	Present
Communication Latency	Low	Low	High	High	Low	High
Mission Failure Rate	High	Low	Low	Very low	Very low	Very low
Popularity	Less	Medium	Medium	High	Less	High
Application	Fixed mission	Dynamic mission	Dynamic mission	Dynamic mission	Dynamic mission	Dynamic mission

in a wireless ad hoc network is as follows;

- It is not the main purpose of securing the channel for information transmission, but the main purpose is to secure space for collision avoidance between UAVs.
- Use the RSSI value of the radio signal received from the surrounding UAV instead of the RTS-CTS packet exchange used for handshaking.
- Instead of exchanging RTS-CTS packets at link establishment time, transmit Beacon packets periodically and continuously.

IV. DISCUSSION AND CONCLUSIONS

It is possible to recognize the flight information of the UAV simply without using additional sensors, and it is expected that the flight information of the neighboring UAVs in the cluster can be easily acquired and shared. In addition, it is possible to share real-time UAV flight information among UAVs in close proximity in a cluster. Also, it can reduce the power consumption of UAVs by simplifying information acquisition and processing procedures for the UAV cluster.

The application field of UAV is continuously expanding. Especially, it is expected that the number of UAVs operating as a cluster will increase. In this paper, the technical considerations necessary for the collision avoidance method which is specialized for the increasing cluster flight of UAVs are discussed.

The results of this study can be applied to the development of a collision avoidance scheme that can be used to keep the safe flight of large number of UAVs. This method can also be used to prevent collision of UAVs in the environments where it is difficult to receive GPS signals

감사의 글

이 논문은 2016학년도 군산대학교 대학자체 학술 공모과제 연구비 지원에 의하여 연구되었음

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