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3 Dimensional Augmented Reality Flight for Drones

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Abstract

Drones are controlled by the remote pilot from the ground stations using the radio control or autonomously following the pre-programmed flight plans. In this paper, we develop a method and an optimal path search system for providing 3D augmented reality flight (ARF) images for safe and efficient flight control of drones. The developed system consisted of the drone, the ground station and user terminals, and the optimal path search server. We use the Dijkstra algorithm to find the optimal path considering the drone information, flight information, environmental information, and flight mission. We generate a 3D augmented reality flight (ARF) image overlaid with the path information as well as the drone information and the flight information on the flight image received from the drone. The ARF image for adjusting the drone is generated by overlaying route information, drone information, flight information, and the like on the image captured by the drone.

Keywords: *Unmanned Aerial Vehicle (UAV), Drone, navigation, First Person View (FPV), 3D ARF.*

1. Introduction

An Unmanned Aerial Vehicle (UAV) is one of the most popular and useful unmanned systems in recent years. Drones are more formally known as UAVs. Drones are originally built and mainly used for military purposes, but now the commercial drones market is growing very rapidly. Drones are used for the civil use in the form of quadcopters and octocopters. Drones are used in several fields such as surveillance, rescue, traffic monitoring, weather forecasting, filming and photography, videography, geographical mapping, agriculture services, sports broadcasting, and delivery service [1]-[3]. Amazon plans to use commercial drones to deliver goods [4]. Google's Project Wing tests a food delivery system for 30 minute delivery at Virginia Tech [5].

The distance that can be controlled by the RF system is very short as the drone must be controlled within the visible range. The visual flight distance that can be *seen* by the naked *eye* is as short as 600m. The revised law also allows drones to deliver packages long distance when users meet safety requirements, as part of efforts to support the fast-growing drone industry. Operators must ensure that they follow the following drone laws when flying in South Korea [6]: (1) cannot fly higher than 150 meters (492 feet), (2) cannot fly within 5.5km of airfields or in areas where aircraft are operating, (3) must fly during daylight hours and only fly in good weather conditions, (4) do not fly your drone beyond line of sight etc. The frequency bands used for drones [7] are ISM radio bands such as 900MHz, 2.4GHz, and 5.8GHz. One of these frequencies is used to control drone from ground system while the other frequency is used to beam or

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relay video FPV. 2.4 GHz are used for WiFi so that drones also use WiFi for remote controlling through or broadcast video to a computer, tablet, or smartphone. WiFi service range is limited to about 600 meters.

Drones are more often guided by remote controls by human pilots through radio waves or they fly autonomously *according* to the predefined path consisted of GPS trajectories [8]. We can also use flight control apps for drones that run on a *smartphone* or tablet. Gyroscope and accelerometer are used as sensors in drone for stabilization purpose. Advanced drones consist of camera, WiFi including high gain directional antenna, and LTE modem. The usage of smartphones can reduce the prices of microcontrollers, accelerometers and camera sensors. Development in flight control algorithms, machine vision, and onboard processing power will further enable these drones to take decisions themselves rather than relying on humans with less maneuvering expertise. Drones should also be equipped with an anti-collision system and a global positioning system transmitter that helps track their locations in case of crashes. In order to fly drones at night, flyers are required to buy insurance against possible accidents, place an "observer" and install an anti-collision light that can be visible up to 5kilometers away. Drones should also be equipped with an infrared camera and other first-person view devices.

FPV (First Person View) system [9] shows the first person view of the drone point of view, has been developed. The FPV system receives an image shot by a camera installed on the front of the drone and provides the image of the drone view through the screen of the receiver. FPV provides the same immersive and realistic feelings as flying in real drones in entertainment areas such as drone racing and games. FPV is used as an essential system for performing the long-range mission of industrial drones. The FPV system does not provide information such as altitude, position, speed, etc. necessary for flight, and it shows only the image transmitted from the camera of the unmanned aerial vehicle or adds simple numerical information to the image. The FPV system does not provide a path search function for autonomous driving. During the flight of the drone the aircraft can be collided and crashed due to lack of pilots' information.

The HUD allows the pilot to view the information on the instrument panel such as the speedometer, altimeter, and orientation indicator simultaneously while securing the field of view while the pilot is flying [10]-[12]. The HUD informs pilots of flight information, such as speed, altitude, direction and attitude, in figures, numbers and letters. Recently, HUD has been able to display not only figures and symbols, but also images taken with an infrared camera at night. HUD technology evolved into a Head Mounted Display (HMD) that displays information according to the direction the pilot is watching. HUD not only accelerates the response of pilots in an emergency, but also relieves fatigue by reducing flight burdens. The HUD used in manned aircraft has been developed to be mounted on automobiles in order to increase the safety and convenience of operation. In the automobile, the front window of the car in conjunction with the navi shows the state of the vehicle such as the speed and the position, and also shows a warning phrase indicating the danger such as the distance from the front car. The driver can check various information through the windshield window in real time, accident rate can be lowered by avoiding accidents that may occur due to the deviation of vision and by grasping all conditions of the vehicle.

In this paper, we develop a method and an optimal path search system for providing 3D augmented reality flight (ARF) images for safe and efficient flight control of drones.

2. Dimensional Augmented Reality Flight (ARF) for Drones

Drones are controlled by the *remote* pilot from the ground stations using the radio control or autonomously following the pre-programmed flight plans. In both methods, the optimal path planning system can be used for the unmanned aerial vehicle (UAV) in a 3D environment. The optimal path planning system is to find the optimal route in tough environment. The optimal path search system for the unmanned aerial vehicle (UAV) consists of the drone, the ground station and user terminals, the optimal path search server, and communication networks as shown in Fig 1.

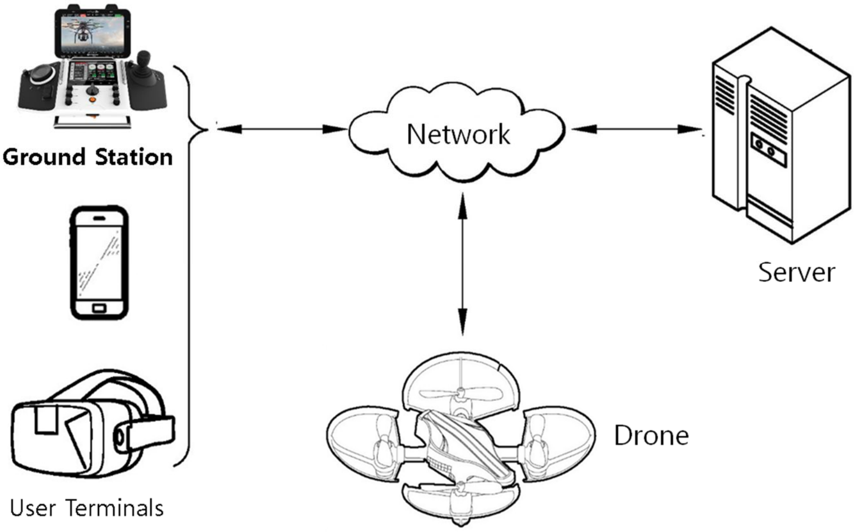


Figure 1. Optimal Path Planning System for Drones

Drones, which are *controlled remotely or* fly *autonomously*, use GPS modules to aid flight and camera modules to obtain aerial video. Extensive human efforts are needed for the first method, the pilot may not be able to determine the optimal path and guarantee the safety of the flight path. For the second method, the flight path is pre-programmed and cannot be changed during missions. If some unknown obstacles suddenly appear along the path, the drone would not be able to respond to the obstacles. Optimal path planning is one of the most crucial factors in autonomous control. The incorporation of GPS receivers in advanced drones allows a drone to autonomously fly to preprogrammed waypoint navigation. Drones include 3-axis gyroscopes for *measuring angular velocity* around 3 axes of yaw, pitch, and roll, 3-axis acceleration sensors for measuring the orientation of a drone relative to *Earth's* surface, and 3-axis geomagnetic sensors. In addition, drones include barometric pressure sensors for measuring the translational motion state. The drone receives the flight information including the optimal route from the optimal route search server or the drone user terminal and fleets based on the flight information. Handheld-based wireless communication devices such as a smartphone, a tablet PC, a virtual reality (VR) device, and a HMD are used as drone user terminals.

Figure 2 shows a head-up display (HUD) of a manned aircraft. The conventional aviation HUD shows information such as the aircraft position, flight direction, and speed of elevation of the pitch, roll, and yaw that pilots should concentrate most on the center of the screen. Navigation information such as air routes and waypoints not related to aircraft attitude control are not displayed in the HUD but displayed to the pilot in different screens. In the conventional aviation HUD used for manned airplanes, information can be clustered and divided into two screens as manned airplanes can gain visibility.

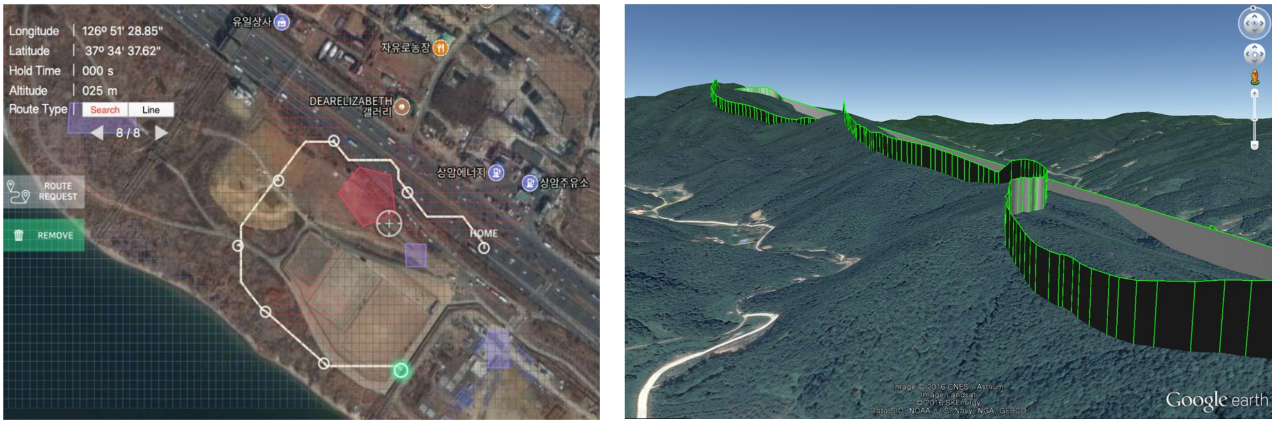
(a) Classic Aviation HUD **(b) Advanced Aviation HUD** **(c) Navigation Display**

Figure 2. Conventional Aircraft HUD

The user terminal transmits the destination coordinate and drone information to the optimal route search server and requests the optimal flight route. The optimal path search server determines the optimal flight path from the origin to the destination using the terrain height information, the height of the ground facilities, and the geo-fence information. The flight information received from the user terminal includes the origin and destination coordinates and drone information. The flight information includes the flight route, the flying distance, the remaining flying distance, the pitch, the roll, the yaw, the flight speed, the coordinates, the remaining battery, the flight altitude, the communication sensitivity, flight image, ground magnetic field direction, and the number of GPS satellites. The drone information includes the maximum flight altitude of the unmanned aerial vehicle, time to fly, battery capacity, weight, and mission information. Environmental information includes wind direction, wind velocity, field of view, cloud height, magnetic field strength, and geo-fence information on the digital elevation model (DEM). The environmental information such as numerical map, contour line data, and building ledger is collected from public data. Geo-fence information related to safety flights includes ground facility information, non-flying areas, restricted flight areas, military operation areas, and flight areas.

Path planning is one of the most important technologies for autonomous flight of UAV. The optimal path search server receives the flight image and the flight information from the unmanned aerial vehicle in flight, and generates a 3D ARF image including the optimal path, the drone information, and the flight information as shown in Fig. 3. The path is a sequence of waypoints, each of which is a point on the Cartesian plane. The drone visits the waypoints in the order specified by the sequence as shown in Fig. 3(a). The optimal path search server first searches the optimal path by taking into account the aeronautical information of the unmanned aerial vehicle, the terrain altitude information and the height of the ground facilities in the possible area using the geo-fence information as shown in Fig. 3(b). Generally, searching for the optimal route at a height of 100m or more can reduce the risk of colliding with an obstacle by the unmanned aerial vehicle because there are obstacles such as power transmission towers, buildings, and mountains in low altitude areas of 50m or less.

The optimal path search system can legally search the optimal path at maximum flight altitude of unmanned aerial vehicle. However, the higher the altitude, the more battery consumption, so the optimal path search server also considers battery capacity. If the magnetic field strength is more than the set value, the communication between the optimal path search server and the control terminal is likely to be cut off, so that the flight to the optimal path may not be possible. The optimal route search server uses the drone information to determine whether it is possible to fly to the optimum route that has been searched. The optimal path is searched for by using the Dijkstra algorithm, considering the priority of each environment information or different weights. The optimal route search server transmits the flight information including the optimal route to the control terminal or the unmanned aerial vehicle so that the drone can fly to the optimum route. The user terminal can control the drone using 3D ARF as shown in Fig. 4.


Longitude | 126º 51' 28.85"
Latitude | 37º 34' 37.62"
Hold Time | 000 s
Altitude | 025 m
Route Type | Search Line

(a) Drone waypoints (b) Drone geo-fence

Figure 3. Drone waypoints and geo-fence information.

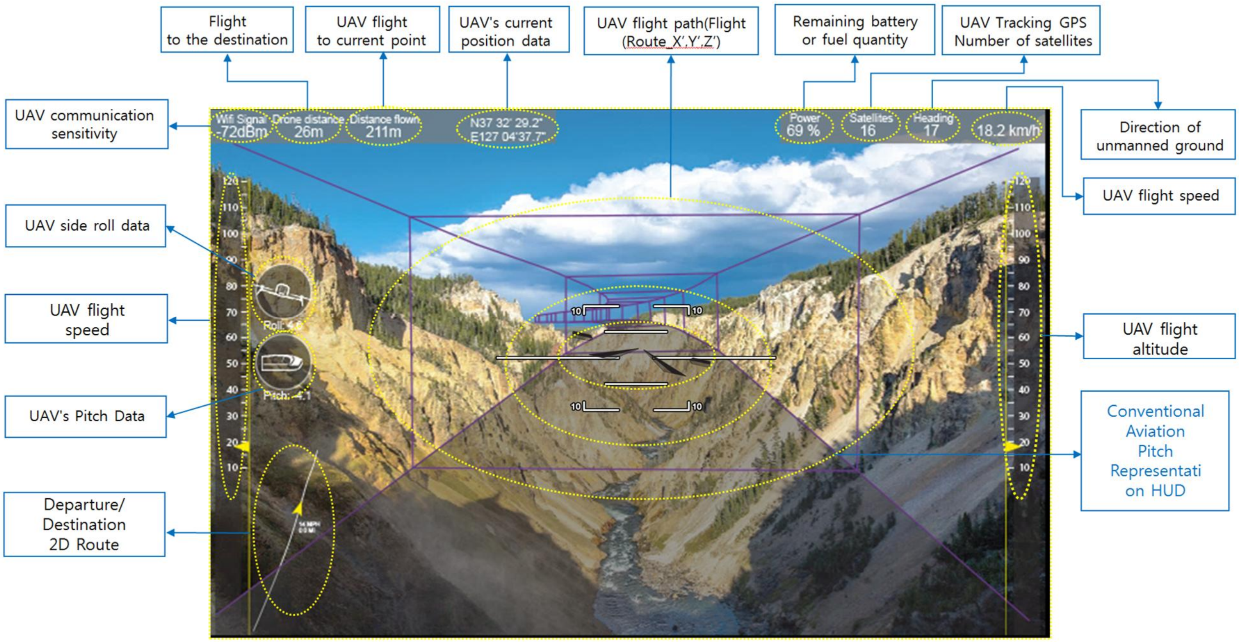


Figure 4. Advanced HUD for Unmanned Aerial Vehicle (UAV).

3. Conclusions and Discussions

Drones are more often guided by remote controls by human pilots through radio waves or they fly autonomously *according* to the predefined path consisted of GPS trajectories. Path planning is one of the most important technologies for autonomous flight of the drone. The HUD allows the pilot to view the information on the instrument panel such as the aircraft position, flight direction, and speed of elevation of the pitch, roll, and yaw that pilots should concentrate most on the center of the screen. In this paper, we develop a method and an optimal path search system for providing 3D augmented reality flight (ARF) images for safe and efficient flight control of drones. The optimal flight path search system uses the Dijkstra algorithm to determine flight mission, drone information, and environmental information. When the optimal flight path is determined, the 3D augmented reality flight (ARF) image is generated by overlaid on the flight image received from the drone. The 3D augmented reality flight image includes drone information and flight information. We can safely control the drone while avoiding collisions using the developed 3D ARF image that is transmitted to the user terminal or the drone.

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