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Research Article

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User Opportunities of Unmanned Air Vehicles (UAV) for Forest Fires

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Abstract This study has been carried out in recent years to determine the benefits of unmanned aerial vehicles used in many subjects in fighting with forest fires. With the remote controlled air vehicles called drone in the research, it has been pointed out that the forest fires can be extinguished in a shorter time and with less cost, especially by monitoring during the fires. It will contribute to the implementation of the interventions that need to be accomplished without growing fire. The use of small unmanned drones would be more effective, economical and safe because of the limited number of helicopters and planes fighting against fires, high cost and, in some cases, security risks. Such practices have been used in many countries in the fight against forest fires for the past 10 years. The data obtained is important in the fight against forest fires and will give a new dimension to the fight with fires. In addition, a variety of equipment shortcomings have been identified as a result of the experience obtained at the end of the research, and these shortcomings will be completed and perfected in new studies on this subject.

Keywords Forest fire, unmanned air vehicles, IRIS$^+$, drone

Introduction

The contribution of visual observations in forest fire fighting has an undeniable importance. However, predictions made as an outcome of such observations may involve high error ratesdue to the natural reasons such as dispersal of smoke by the effect of wind, or human errors such as those in prediction of distance or location of fire region. Therefore, there has been an increasing demand for new technologies in forest fire fighting as in many other fields. Such novel technologies however may bring along certain problems including low levels of reliability and high costs.

One of the most suitable examples for these mentioned technologies is the use of unmanned air vehicles (UAVs).The first instances of UAVs are considered as 200 pilotless balloons used in 1849 by Austrians to bombard the city of Venice with time bombs [1]. Although they were initially used for military purposes, UAVs have been widely used for civil use in recent years. High operational expenses of air vehicles such as airplanes and helicopters as well as security related issues have rendered UAVs indispensable tools for various airborne applications. Such applications involve agricultural activities, aerial surveillance and monitoring, disaster management, various rescue activities, mapping and investigation of archaecological areas. Additionally, UAVs are expected to be used for all kinds of rescue, surveillance, maintenance and commercial applications in the near future [2-5].

In addition to the abovementioned uses, UAVs have been widely used in various forestry activities including forest fire fighting [6-19]. Successful outcomes of the use of UAVs in detection, positioning and monitoring of fires have rendered them an important means in fire fighting [15, 20].

The present research aims to give insight as to how unmanned air vehicles can be used in forest fire fighting operations in addition to their possible contribution during the process of monitoring the fire. Fire monitoring is possible only through real-time evaluation and measurement of highly important parameters related to the propagation of fire. Important parameters in fire fighting involve the direction, location, form, spreading speed of fire and the height of flames [21-22]. These information can be used during the planning stage of fire fighting upon integration with Geographical Information Systems (GIS). Such integration would be useful in prediction of the expansion potential of fire and determination of the optimal location for fire fighting.

Related Studies

Real time information on conventional forest fire fighting is obtained through interpretation of fire by professionals of fire fighting. Generation of such information can be possible through interpretation of direct field observations, evaluation of data received from fire towers. Or by combined use of both information types. Recently, systems equipped with air vehicles have been widely used for detailed evaluation of development of fire from an aerial vantage point, yet, most of the fire monitoring activities are still carried out by humans.

Satellite based systems are also proposed for fire detection San-Miguel-Ayanz et al. [23] and fire monitoring Gonzalo [24]. However time wise and positional resolution of such systems fail to meet the requirements for fire fighing and other forestry activities. As a different approach, fire analysis systems have been applied to evaluate forest fires in laboratory environments [25]. In addition to the aforementioned imaging methods, steady cameras are also used for monitoring forest fires [26].

Collective use of multiple unmanned air vehicles has been subject of several studies. On the other hand, studies carried out with a single vehicle are also available. Among these studies, Ollero et al. [27] and Casbeer et al. [11] investigated fire monitoring and fire propagation with a single drone having short endurance and low altitude capacity. Images of IRIS$^+$, a capable device for such activities, are given in Figure 1. In their study, Zhou et al. [16] accomplished orthorectification of the received images, yet, such applications can be accomplished within the scope of extensive projects. In the same study Zhou et al. [16] sought solutions for specific problems likely to arise in forestlands, and presented preliminary results based on the aerial images obtained by conventional air vehicles.

Figure 1: Images of IRIS$^+$ which can be used with gimbals, cameras and other sensors

Material and Method

The aim of the present research is to investigate the capabilities of unmanned air vehicles in fire monitoring and surveillance. For this purpose, flights tests are carried out with coordinated unmanned air vehicles with differing flying speeds.

Devices and Sensors

Unmanned air vehicles, intended for fire imaging and detection activities should meet the following specifications:

Operational specifications: Unmanned air vehicles should be capable of flying on predefined routes and hanging in the air.

Positioning: Unmanned air vehicles should have a self-positioning feature on referenced coordinate systems.

Carrying capacity: Unmanned air vehicles should be capable of carrying gimbals, cameras and other sensors used for detection-purposes.

The system used in this research was tested with IRIS$^+$, which has 20 minutes flight time without payload and 10 minutes flight time with addition of gimbal, camera and other sensors. Addition of an extra battery for extending the flight time was not found efficient as batteries have the highest weight among all components. Instead, taking images at specified intervals by use of additional chargers was found more suitable for monitoring activities. The instantaneous location of the vehicle in the geographical coordinate system could be found using a GPS receiver mounted on the unmanned air vehicle. In addition, GoPro cameras used for monitoring was capable of maintaining the horizontal position of vehicle under environmental effects such as winds by use of a gimbal. Receiving images by moving the camera at different angles was also possible by use of this equipment (Figure 1).

Decision-Making System

One of the main differences between manned and unmanned air vehicles is unmanned vehicles' capability to autonomously execute specific duties assigned for the device. One of the most important requirements for unmanned air vehicles is their capability to follow a predefined route. Additionally, fire monitoring activities constitute a crucial duty for UAVs which require both control and ground-air coordination of autonomous unmanned air vehicles during the course of flight. Decision making system is related to the evaluation process of data obtained from fire propagation system.

Propagation Identification System

The data obtained from unmanned air vehicles hold great importance for determination of the extent of fire propagation. The imaging process by unmanned air vehicle and the functioning of the evaluation system is illustrated in Figure 2. Images of fire received by an unmanned air vehicle are shown in Figure 3, and an example of propagation of fire is shown in Figure 4.

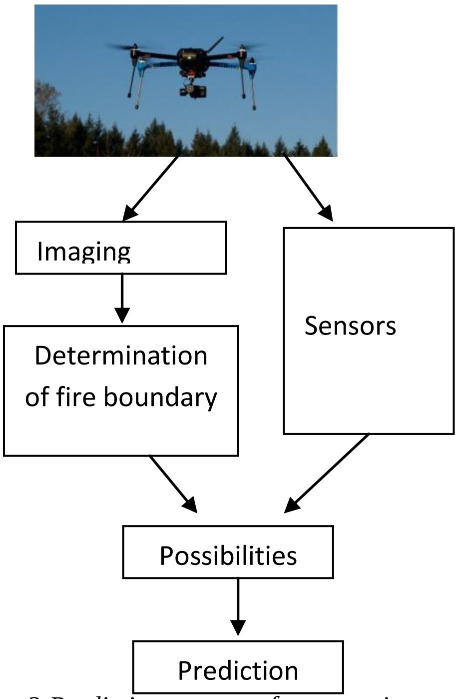

Figure 2:Prediction process of propagation.

The images received from unmanned air vehicles are taken in specific time intervals. As previously described, this is mainly due to the limited battery life, the time required to replace the battery and reposition the unmanned air vehicle in air, in addition to the effort to obtain the longest flight time with a single battery. Accordingly predictions for propagation of fire are made with the images taken in specified time intervals. Evaluations are made on the basis of predictions, since several external factors are effective on propagation of fire.

Figure3: Fire images received from UAVs [28].

In more extensive studies, the process illustrated in Figure 2 is performed by use of multiple unmanned air vehicles; in which predictions are made on the basis of images received from one vehicle and different data obtained from others, thus predicting the propagation of fire using prediction models. The complexity of the process can be ascribed to various factors including the slope of the area and meteorological factors such as moisture content of the vegetation, relative humidity and wind. EMBRY (Landscape fire succession model), used by Casbeer et al., [11] and Hargrove et al. [29] is an example for such models.

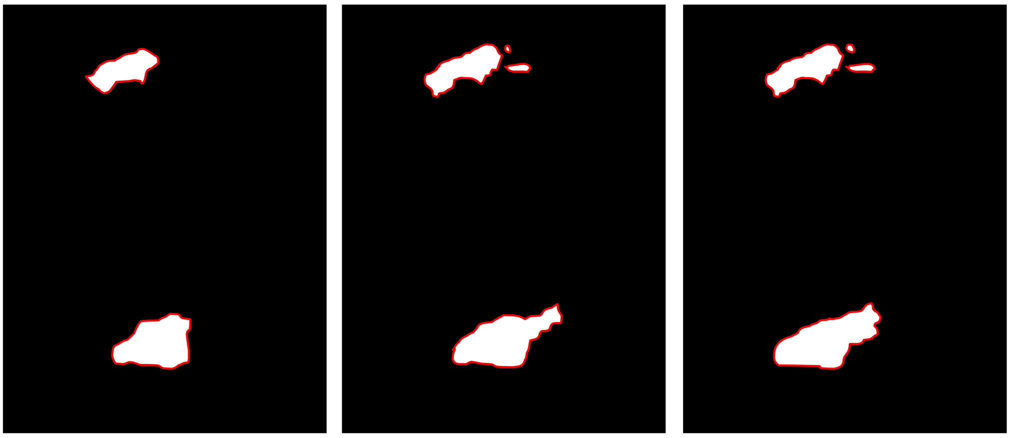

Figure 4: Image of fire propagation during sampling [30]

Results

In this study, the images of 3 different forest fires were taken by IRIS$^+$(unmanned air vehicle) within the scope of fire fighting activities (Figure 5). 65 images were taken during these fires and a maximum altitude of 75 m was reached during flights. Prior to the study, the target altitude was determined as 70-80 meters. This altitude was set as the limit height since the values exceeding 100 meterse require having helicopter pilot licence as prescribed by Civil Aviation Authority in Turkey. Also average flight time of the device was calculated as 12 minutes, as opposed to the values (16-22 minutes) specified in the catalogue, which can be attributed to the additional weight of the camera and sensors. Since nearly half of this period belongs to take-off – landing and arrival-return periods, images of six min. periods could be taken from the fire area. The overall flight speed of the vehicle was 2-3 m/s. Although the speed limit of the unmanned air vehicle is 6-7 m/s, this speed was applied to prevent the vehicle consuming most of the battery for maintaining its equilibrium as a result of the effect of wind. 72 minutes long visual data was obtained after the study.

In researches carried out with multiple unmanned air vehicles, the obtained visuals are transferred to a central station and here they are collectively evaluated to predict propagation. In the present research, the prediction was made on the sole basis of the changes in the images, since only one unmanned air vehicle was used. An image of of fire received from an unmanned air vehicle as well as the starting point and propagation direction of the fire are shown in Figure 6.

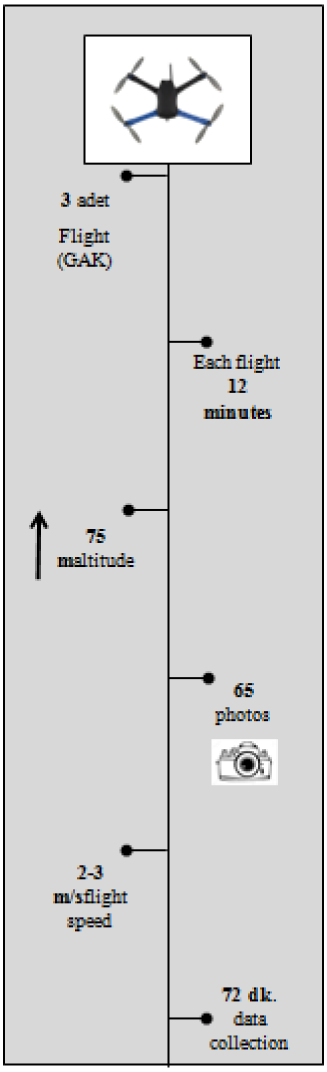

Figure 5: Statistics belonging to the unmanned air vehicle.

Discussion

The capabilities and applicability of unmanned air vehicles in monitoring and surveillance of forest fires was investigated in this research. Different images of fire were taken at specified intervals as a means to receive information about its propagation. In spite of the limited number of the received images, unmanned air vehicles proved to be significantly useful in fighting with forest fires, since the data obtained by these vehicles fill the void between the positional data received from satellites and the visual data obtained from fire towers. Also, unmanned air vehicles are capable of averting the negativities of other approaches such loss of sight by smoke or failing to cover the required observation area.

Figure 6: Two images of a forest fire (Straight line indicates the rear point of fire, and dashed line indicates the height of flames) [31]

Applicability of unmanned air vehicles in forest fire fighting is disputable in some aspects. One of these aspects is the scalability of the proposed approaches. Unmanned air vehicles with higher strength may be required for application of required techniques. Recently, unmanned air vehicles with such strength are used in military and security applications. New techniques should be developed to use such large vehicles in other fields. For instance, predator unmanned air vehicles developed by Ambrosia et. al. [15]was used within the scope of FIRE project as a platformto monitör forest fires. In some researches, more resistive vehicles may be required to fly more closely to fires. Another important issue is choosing among the following alternatives: use of a single and complex unmanned air vehicle, or the use of multipe air vehicles. The use of unmanned air vehicles in fire monitoring provide various supplementary images and provide them with detailed information on the local challenges within the fire area. Additionally, various sensors can be carried with unmanned air vehicles and development of more expensive vehicles capable of carrying all equipments will be required.

According to the results of various other projects in addition to the present research, the use of telescopic vehicles is considered to be more usefull for fire fighting staff in fulfillment of such duties. Also, autonomous motion function is additionally required in cases where required communication connections or bandwidth can not be supplied. Returning the vehicle to the take-off area with autonomous navigation system also gains important when the visual contact with the vehicle is lost. The use of autonomous navigation system gains further importance especially when multiple number of unmanned air vehicles are used.

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