

UAV based navigation system for forest fires monitoring

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Abstract — In recent years, large amount of forest has been destroyed by fires, bringing terrible consequences for the environment and society. It is important that firefighters possess an increased situational awareness about the fire spread, in order to act appropriately to prevent the fire to an uncontrollable size. Recent advances in UAV technology shows promising applications for UAVs to detecting and monitoring forest fires. Therefore, one of the most important issues is UAV's flight navigation system. In this study, we suggest a structural diagram of the UAV navigation system, which is based on radio control from a ground control panel using geolocation system. This approach provides effective application of UAV, both in automatic and manual modes by means of onboard navigation and control equipment. The results shows that the use of UAVs is an effective way of combating a fire situation in addition to existing methods and technologies for solving operational problems of fire detection.

Keywords — *aerial fire monitoring, forest fire, UAV, navigation system.*

I. INTRODUCTION

In recent years there have been a significant number of wildfires that have devastated millions of hectares of forest. In addition to destroying local flora and fauna, these fires also destroy infrastructure and, unfortunately, sometimes result in human casualties among fire brigades and civilians who may be accidentally surrounded by fire. Thus, early detection and real-time fire surveillance are two key factors that allow firefighters to act appropriately to keep fires from reaching unmanageable proportions. There is a need for a less costly and more efficient way to accomplish the forestry tasks previously performed by aviation. In this regard, of particular interest are unmanned aerial vehicles of various technical equipment and flight ranges.

Unmanned aerial vehicles (UAVs) are becoming even more important for environmental monitoring, on the one hand, providing data from remote and inaccessible areas, and on the other, reducing the cost of conducting necessary research using traditional field methods, while increasing operational efficiency. Photo and video recordings obtained with the help of unmanned aerial vehicles, both with conventional and special cameras, give a complete picture of forest massifs and their condition, including information on the species and heights of trees and their exact location in accordance with the coordinates of the GPS and Glonass navigation systems, which, of course, is necessary for effective and sustainable forest management.

UAVs with computer-based remote sensing systems are an increasingly becoming an attractive and realistic option. The use of UAVs in the fire systems solves a number of problems associated with the lack of staff, the inaccessibility of areas, the need to minimize the impact of human presence, when

carrying out forestry work to determine the operational and current data on the fire.

The use of UAVs at the moment is limited to special cases when solving production tasks, mainly in an experimental manner. Relevant is the development of theoretical foundations and practical techniques for organizing the effective use of UAVs for detecting forest fires with the definition of flight paths, parameters of information and command lines of communication. In addition, it is important to have spare power units or a device for recharging them in the field, as well as the required number of the most demanded spare elements of the UAV [1].

The modern level of technology has greatly expanded the capabilities of UAVs as an autonomous system of various structural forms of design and purpose. Thanks to the use of various cameras and prompt automated processing of the obtained information, such vehicles can be used to monitor the state of forests, roads, the effectiveness of forest management activities [4]. The use of computer vision technology in the remote monitoring system using UAVs will automatically detect fires in real time and warn about them. The processing of data received from the UAV makes it possible to determine the places of fire occurrence, as well as to quickly and correctly determine the coordinates of the place of fire occurrence and mark them on the terrain map. This article discusses the use of navigation control system of UAVs, which allow to perform flights for monitoring and detection of forest fires.

II. SYSTEM DESIGN

A. System description

One of the most important issues in the use of UAVs for forest fire control and suppression of forest fires is the development of flight paths and flight control systems. At the same time, the built-in navigation equipment of the UAV and automatic course and vertical stabilization devices on the basis of direction gyroscope and position sensors allow to keep the body in a stable state and thus provide acceptable accuracy in determining the coordinates and direction of the forest fire on the terrain map [3]. Various methods are proposed for the precise georeferencing of UAV images, implemented by additional use of GPS navigators as part of the receiver, increasing the overlap of images [2].

Each forest fire must be monitored from the air from the moment of its detection until its complete elimination in order to take prompt action. In order to detect hidden fires, forest fires are circled 4-5 times a day. Range of fire location depends on height of observation, weather and smoke level. For the solution of this problem it is optimal to use UAVs with the flight range from 2 km to 10 km and with the flight time of 20...60 min, that corresponds to the ground patrolling.

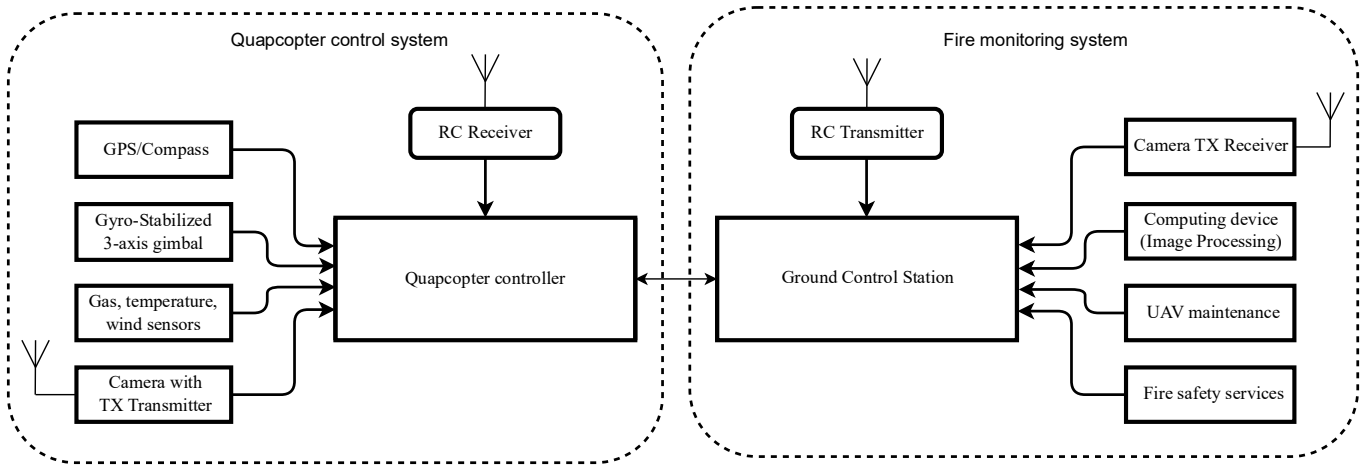


Fig. 1: Basic architecture UAV-aided navigation system communications

The UAV navigation system under development is based on radio control from the ground console by the operator and the use of a satellite navigation system, which determines navigation parameters with high accuracy. The proposed system is designed for real-time monitoring, which collect data from sensors and cameras using the UAV. The schematic of UAV based navigation system is shown in Figure 1.

B. Ground Control Station

The Ground Control Station (GCS) acts as the central control point during UAV flights and provides the necessary capabilities to plan and execute safety-related tasks. The GCS performs functions such as flight mission planning, processing of received data (video images), modules for mobile and satellite control, and displays to track all progress. The GCS also generates alarm commands based on safety system warnings.

During flight, the UAV is controlled manually in radio control mode and automatically through onboard navigation and control equipment, which includes [8]:

- satellite navigation receiver, which provides reception of navigation information from GLONASS and GPS systems;
- an airborne communication system operating in a certain frequency range for transmitting UAV commands, streaming video and photo images;
- sensor system for determining spatial orientation by course and vertical, stabilization and motion parameters of the UAV;
- air signals system ensuring measurement of altitude and flight speed.

The onboard navigation system must ensure that the UAV [8]:

- flight along a set route (the route assignment is made with the coordinates and altitude of the route turning points);
- change the route setting or return to the start point and fly around the specified point on command from the ground control point;
- automatic takeoff, flight and landing at the operator's command at the ground control point.

To achieve these goals, the UAV-based forest fire monitoring and detection system includes the following: 1) various frames and sensors, including global positioning system (GPS) receivers, inertial measurement units (IMUs), and digital cameras; 2) specific algorithms for monitoring, detection, diagnosis, and prediction; 3) GNC guidance, navigation, and control systems for both single and multiple

UAVs; and 4) multiple UAV localization and control systems for optimal cover of fire areas [6].

C. UAV

Currently on the market there are a plenty of UAVs of different classes, with completely different technical characteristics [9]. Let us formulate the basic requirements with the goal we are considering: the device must have an electric drive, good flight characteristics, a quality video camera and at the same time the lowest possible price. When choosing a UAV, we mainly took into account such aspects as the possibility of transporting sensors that allow monitoring a fire, together with a computer. In our case we propose to use quadcopters, because their advantages are compactness, the ability to take off and land under fairly limited conditions, the capability to change the flight speed up to zero (hover mode) for detail images [5]. The position of the UAV in latitude, longitude and altitude is determined by the controller based on the global positioning system (GPS) signal. The controller also provides the three Euler, pitch, roll, and yaw angles needed to determine the position of the UAV.

D. Sensors

Collecting sensors data is cheap and effective way of monitoring forest fires in a secure. Nowadays, a wide variety of sensors are available, and many of them are reliable enough to help authorities respond quicker and make decisions. Temperature sensor can be useful to keep the drone in a safe zone, and this means that if the temperature is superior to a threshold, the drone should not keep the path. Besides that, it gives important information to the firefighters.

Gas sensors (also known as gas detectors) detects and identify different types of gasses. The measurements can be useful to detect the fire, for example, measuring abnormal concentration carbon dioxide.

Wind sensors with anemometer measures the wind speed, and it presents useful information for firefighters, since wind speed affects forest fires in a significant way.

Also, there are several required embedded drone sensors. The combination of accelerometer and gyroscope sensors is very useful to estimate the speed of the drone. Barometer is necessary to estimate and keep the drone altitude.

E. Creating UAV flight mission

The flight path is set using the Mission Planner software for autonomous UAV flight. For our applications, the Mission Planner software is excellent (Figure 2). This program is an

open-source control center for the autopilot of different types of UAVs. With this program, various configurations and fine-tuning of the UAV can be selected for optimal performance; also, individual flight missions can be planned, tracked, stored, and downloaded to the autopilot with conventional point-and-click waypoint entry on Google maps or other online services[10].



Fig. 2: Mission Planner flight plan

There are several recommended measures when performing a flight operation. The starting point should be chosen as high as possible relative to the intended route with a minimum distance from the objects under investigation to increase the useful operating time and achieve maximum results. It is necessary to determine the direction of the route relative to the ground control station and make sure there are no obstacles in this direction to ensure direct radio visibility. The landing site is selected near the starting point, taking into account the possibility of visual control of the UAV landing by the operator.

III. ALGORITHM OF MONITORING OPERATION

A. Data collecting

In the first monitoring phase, the UAV takes off and begins surveillance of the target area, transmitting high-resolution images in real time to the ground station. The control points of the UAV flight are indicated on the satellite image along with coordinates in which the status of the drone is displayed. The UAV begins surveying by following the route and begins scanning the area, transmitting video images to the station. The detected event is recorded and the information is transmitted in real time to the base station. This stage also provides infrared and thermal data to simulate fire behavior and environmental parameters. The UAVs also pick up smoke and gases and transmit the information to the ground station.

B. Monitoring

The monitoring phase is responsible for collecting environmental parameters, scanning the target area, detecting the fire, and responding after detection. The UAV operation is programmed from the ground station and continues to explore for scanning until an event is detected in the allotted time. For this purpose, the UAV establishes several communication channels between the satellite and the ground station.

C. Data analysis and image processing at ground station

Control of the UAV is in the ground station, and information is transmitted to the ground station for real-time analysis for decision making. The ground station is directly connected to the UAV and the satellite system. The video

image data from the UAV is processed by a computing device (personal computer), applying image processing algorithms to detect the fire. They include:

- Image preprocessing techniques are used to improve the accuracy of data processing by changing its brightness and contrast, removing noise and sharpening the image, etc.
- Motion detection techniques such as background subtraction are used to detect fire and smoke motion in the video by analyzing the differences in the images of the video frames.
- Color detection based on RGB and HSI color models are widely used at the first step to extract fire-like pixels. This reduces the search space for further processing with more computationally expensive detection algorithms.

In case a fire is detected by the input image, a firefighting team from the ground station makes a plan to extinguish the fire [6].

D. The operation of the proposed architecture

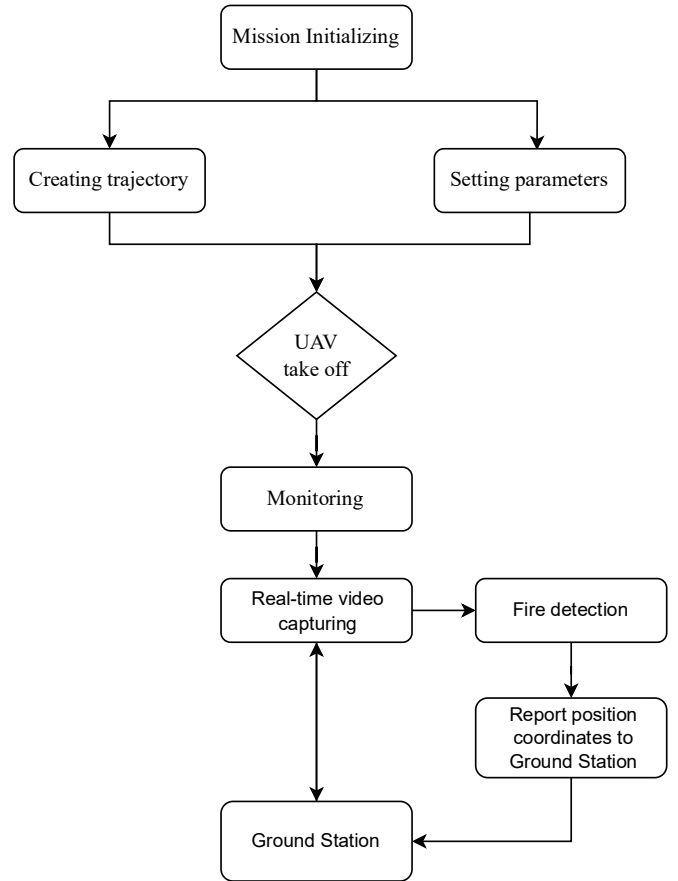


Fig. 3: Algorithm of operation of the UAV fire detection system

The operation of the proposed event detection system is shown in Figure 3. In the initial stages, the ground station sends mission development requests by setting parameters and UAV flight paths to monitor the target area. The monitoring map of the area generates UAV flight paths according to the mission, and then this information is transmitted with updated parameters to the ground station. As soon as the connection is established and the conditions for the UAV flight are satisfied, the UAV takes off and begins to take high-resolution images. During flight, the UAV begins scanning the marked area, transmitting data to the ground station in real time via the communication channels between the UAV and the ground

station as well as with the satellite. The resulting information is transmitted to the ground station for real-time processing. In the last stages, the data collected from the UAV is analyzed at the ground station, which continuously monitors the data for fire detection, and whenever a detection occurs, the UAV will transmit coordinates to the ground station to confirm the information. Based on this data, a decision on further operations will be made. When a fire is detected, the geolocation must be accurately known to the firefighting crews in order to act quickly and effectively in the extinguishing process. The geolocation of the fire can be calculated by knowing the coordinates and position of the UAV, as well as the distance between the UAV and the fire itself.

IV. CONCLUSION

UAVs are increasingly used in practice as a tool for monitoring and early detection of fires. In this article we have presented UAV based monitoring system for fire detecting. The proposed structure of the system provides the requirements to the accuracy and safety of UAV flights. It is safe to say that the use of UAVs can significantly reduce the cost of detecting forest fires. Therefore, there is a need for additional research and development of integrated solutions for monitoring, detection and control of forest fires. Among the future works of this research is the technical implementation of the proposed method and the conduct of field tests to optimize the system. Thus, we can expect further developments in this area in the future.

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