Research Article

Energy, Environment and Storage (2021) 02-01:15-19

Energy, Environment and Storage

Journal Homepage: www.enenstrg.com

Country Border Line Control of Autonomous Rotary Wing Aircraft that Can Detect and Track Moving Objects

Tuğrul Oktay[1], Enes Özen[2*]

[1] *Erciyes Univ., Faculty of Aeronautics and Astronautics, Dept. of Aeronautical Eng.,Kayseri, Turkey, ORCID: 0000-0003-4860-2230*

[2*] *Hasan Kalyoncu University, Vocational School, UAV Technology and Operation, Gaziantep, Turkey, ORCID: 0000-0001-7816-2374*

ABSTRACT. Autonomous systems are widely used in missions that require continuity and high attention. The most important of these is the control of borders, which is a national security problem. It is done with PTZ (Pan Tilt Zoom) cameras located in the watch towers of the country's land borders, moving objects (human, vehicle, etc.) can be detected and this data is analyzed and converted into information in the relevant unit. In countries with very large land borders, installing such watchtowers would result in very high costs. Instead, this can be achieved with low-cost, low-altitude rotary wing aircraft. In this study, a system that can perform target detection and tracking is implemented thanks to the rotary wing aircraft that can perform this task and the imaging system it has on it.

Keywords: Rotary Wing Aircraft, Image processing, Target Detection and Tracking, Unmanned Aerial Vehicle System

Article History: Received:28.09.2021; Revised: 11.11.2021; Accepted:15.11.2021; Availableonline: 22.11.2021
Doi: https://doi.org/10.52924/ZURR2598

1. INTRODUCTION

By sensing the signals sent from the ground control station, the unmanned aerial vehicle enables it to guide and cruise in the air by changing the control surfaces in fixed-wing aircraft and rotor rotation speeds in rotary-wing aircraft. Another method is to load the previously specified task on the aircraft to the flight computer and navigate by generating signals to the relevant actuators by using the data it receives from the sensors it has on it [1]. Unmanned aerial vehicles are used for tasks such as search, rescue and surveillance in order not to put the human element at risk, in environments that require continuity, where terrorist elements are intense and chemical wastes are present, thanks to the useful loads they carry. An aircraft is an unmanned aerial vehicle system with its ground control station and its payload [2]. Unmanned aerial vehicles are used to increase agricultural productivity thanks to their cruising speed and ability to move independently from the ground. By placing the image processing feature on aircraft, real-time data analysis and transfer are realized, and studies are carried out to increase agricultural spraying and productivity [3]. High-altitude and long-range unmanned aerial vehicles used to provide border security are costly [4].

In this study, the unmanned aerial vehicle system developed for border security needs a more affordable budget, which makes the project advantageous. More than one aircraft in a given region can be commanded from a single ground control station. In this way, it is desired that more than one rotary wing, low-cost aircraft alternately scan and control the region, which will perform the task of the aircraft, which can cruise at high altitudes and observe the wider region. Thanks to the sensors it has on the aircraft, it will be able to instantly transmit battery information, flight time and location information to the ground unit, and will return to its base for the resupply process in order to be able to operate again. Thanks to the set containing more than one aircraft, it will be able to perform uninterrupted zone control.

*Corresponding author: enes.ozen@hku.edu.tr

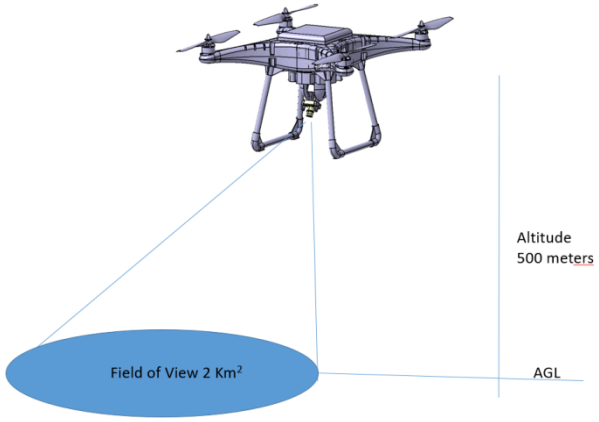

Fig. 1. Unmanned Aerial Vehicle Imaging System

2. MATERIALS AND METHODS

Unmanned aerial vehicles are classified according to their weight. Aircrafts weighing between 500-4000 gr are classified as UAV 0 category. Aircraft weighing between 4 and 25 kg are classified in the UAV 1 category. Aircrafts weighing between 25 and 150 kg are classified in the UAV 2 category. Aircraft with a weight of 150 kg or more are classified in the UAV 3 category [5]. In this study, the necessary programs for the control and analysis of movements with a quadrotor unmanned aerial vehicle, gimbal and ground control station were used. Quadrotor aircraft has advantages over other configurations in terms of ease of manufacture and maintenance.

Unmanned aerial vehicles can provide remote observation and intervention in cases where nuclear wastes are accessible so that people are not harmed in risky situations, to examine the situation of the fire during a fire and to perform the response more effectively. The increase in the world population increases the need for food. Efficiency needs to be increased in order to meet this need. For this, the costly spraying process should be done at a sufficient level, both the spraying costs can be reduced and the damage to the plants can be prevented. The most appropriate form of application can be achieved by adding the image processing capability to ensure that the drugs are applied to the most suitable parts, and it can be applied much faster than the manpower to apply. To achieve these, unmanned aerial vehicles are used. Rotary wing aircraft are suitable for this work. Thanks to its ability to hang in the air during spraying and imaging, a more effective task can be performed in the task area. In this study, the detection and tracking of moving objects from 500 meters altitude is carried out. Thanks to the electro-optical camera and thermal camera on the aircraft, target detection is performed at low altitude, day or night. The movement in the image is selected instantaneously and this data is transmitted to the aircraft's guidance unit. The data processed here is processed by the controller and transmitted to the actuators and rotors, and the aircraft can create and follow a flight path to follow these objects. The control system diagram that enables these processes to take place is shown in figure 2.

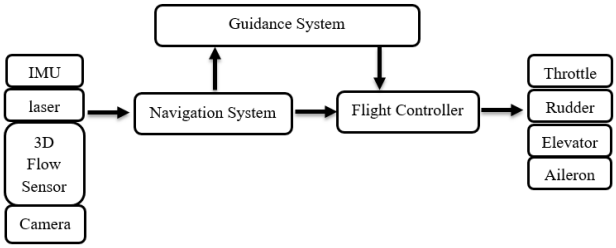

Fig. 2. Guidance, Navigation and Control Systems

The guidance system provides the orientation of the aircraft. It moves the airspace by creating the flight route and waypoints. While doing this, it also uses the data it receives from navigation and sensors [6]. In this way, flight safety is ensured and errors that may occur during navigation and tracking are reduced. It can move without the need for any direction command from the ground control station. At the same time, the imaging system modulates the image data to radio waves and transmits it to the antenna, thanks to the image transmission unit (Transmitter) on the aircraft. By means of the receiver unit on the ground, the operator on the ground can instantly follow this image from the ground and a warning can be sent to the relevant units.

2.1 Rotary Wing Aircraft Design

The principle of generating lift of rotary-wing aircraft, unlike fixed-wing aircraft, is achieved by positioning the rotors in a vertical position and rotating the propeller in a horizontal position. Multirotor aircraft, in order to zero the torque around the z-axis, as in helicopters, allows more than one rotor to rotate in different directions instead of the tail rotor, and the drag force and the torques created to balance each other and steer to their route. A controller is needed to control unstable rotary wing aircraft [7]. The reference signal enters the controller, the desired route is calculated and the rotational speeds of the rotors are determined. Since the rotation speeds of the rotors are controlled by the computer, the rotor configuration information must be introduced to the system and mounted accordingly. There are 2 types of configurations in quadrotor aircraft. These are given in Fig. 3 and 4.

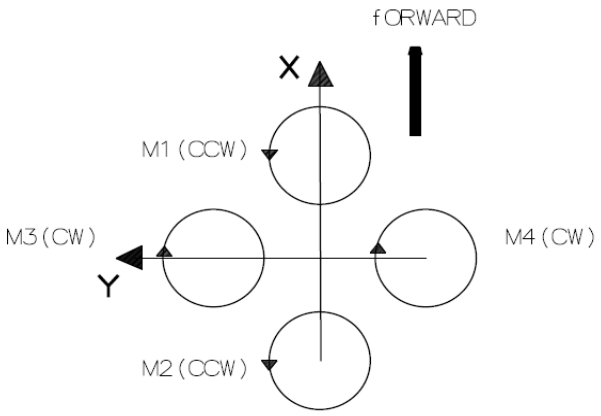

Fig.3. Quadcopter + Configuration

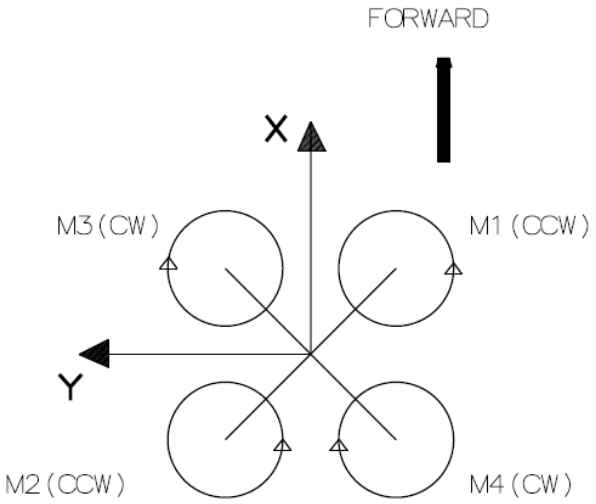

Fig. 4. Quadcopter X Configuration

Quadrotor aircraft consists of control board, ESC, engine and propellers. It is important that the propeller, motor and ESCs are chosen as equivalent, that the forces generated are the same, and that the responses to the signals are the same. In X configuration quadrotor aircraft, increasing the rotation speed of the rotors on the right causes the aircraft to lean to the left, that is, to perform a rolling motion. The faster rotation of the rear rotors according to the selected head position causes the air arc to move forward, that is, to make a pitching motion. It achieves this with a combination of rotation and linear motion around the axes according to the axis set placed in the center of gravity of the aircraft [8][12].

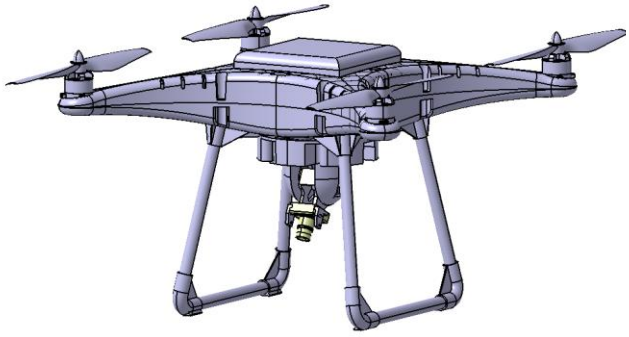

Fig.5. Isometric View of Quadcopter

Table 1 Quadcopter General Features

Wide	400 mm
Length	400 mm
Weight	3 kg
Flight Speed	75 km/h
Altitude	1500 feet
Flight Time	30 minutes
Payload	Sony 30X Electro-optic
Cost	20.000,00 TL

Unmanned aerial vehicles are equipped with payloads according to their purpose. In this study, target detection and tracking will be performed, so it is a payload camera system. Camera system; It consists of camera, image transmitter, antenna and 3 axis gimbal carrying them. gimbal; Independent of the aircraft, the camera performs pan-tilt-yaw movements around the axes of the axis set placed at the center of gravity. In this way, the aircraft can perform target tracking while suspended in the air within certain limits. In order to do this, a controller that can control the BLDCs on the axes is needed. Thanks to Alexmos and IMUs, which are very popular controllers in this regard, the aircraft can lock onto the target even while it is moving, and transmit this information to the flight controller.

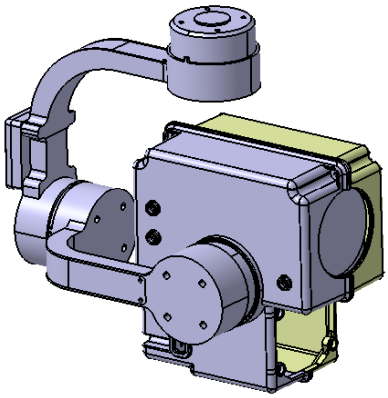

Fig. 6. 3 Axis Gimbal of Quadcopter

2.2 Image processing

Image processing is a set of operations that allow us to extract meaningful expressions from the image we have. These operations are performed by means of mathematical operations to be performed on the pixels that make up the image. After the image is obtained, an algorithm is designed according to the task to be done, and the image passes through these stages and fulfills the desired task. Any object can be detected and tracked on the image by using the necessary methods and algorithms according to the object to be detected. For example, in many countries abroad, the detection of criminals is carried out by this method. Any person can be detected through the images taken from the existing camera setups. Apart from this, it is also used in the traffic area. It can count the vehicles in the traffic and the speed of the vehicles can be measured. In this way, situations such as traffic density or excessive speed can be detected and necessary notifications can be made to the center. The quadcopter creates control commands to the aircraft with the help of the microcomputer and software, and the guidance system uses these commands to create a new route [10].

The stages of the signals that will be processed by the image obtained from the imaging system on the quadrotor and sent to the rotors by the controller are given in fig. 7.

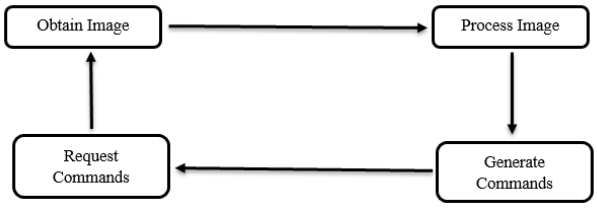

Fig.7. Image Processing Control System

The real-time images obtained are processed and compared with other sensors and previous data, as given in the flow in Figure 2, target detection and tracking is performed. Thanks to the data received from the navigation and sensors, the problems caused by image processing can be tolerated. In this way, the flight route to be created by the guidance system will prevent accidents.

Image processing method; It is defined as the application of digitally changing a picture taken with computer and software support. While image processing applications were initially used for military and security purposes, today they also serve sustainable and sensitive agriculture [10]. Three basic steps are important for the realization of image processing. The first of these is the conversion of the obtained image to digital format. The second step is to convert the obtained image to the desired format and edit it. The third and last step is to obtain results from the image by performing the necessary analysis. In order for an image to be processed digitally, first of all, data libraries must be created and transferred to the digital environment without any problems. After the existing data libraries have been created, it is time to process the selected images. Three different processing techniques are used for these.

The first of these is the histogram process, which is referred to as the white-gray balance. The aim here is to determine the shape in the image by using the white-gray balance in the digital image. In the second method, image filtering is used. In image filtering, it is aimed to use and process the desired part of the digital image by dividing it into grids. Thirdly, it is the definition of the digital image by using the RGB(red green blue) values based on the basic color model.

After choosing the right processing method, the selection of an ideal processing program (such as Matlab, phyton) and the processing of the data are carried out. The data obtained after processing needs to be interpreted and used. The data obtained with the technological developments are not only checked later, but can also be used with instant evaluations (real time) [11].

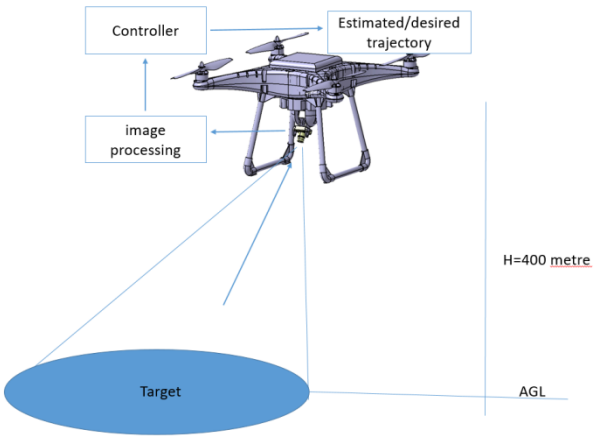

Fig.8. Vision-based tracking approach.

3. CONCLUSION

In this study, it is aimed to examine the studies on image recognition technology to design and implement the autonomous control system of the rotary wing aircraft and to prepare the academic ground for the aircraft developed for security to be used at the borders. The data obtained from the researches can be sent to the aircraft with the integrated camera system and image processing computer on the aircraft, and the ability to follow the target tracking can be gained thanks to the instant data received from other sensors and GPS. In this way, the long border line can be controlled without interruption by using more than one rotary wing aircraft.

In the next study, the necessary algorithm for the designed aircraft will be simulated in the MATLAB environment, and target detection, tracking and uninterrupted control of a certain region will be realized with the software obtained. Any object can be detected and tracked on the image by using the necessary methods and algorithms according to the object to be detected. For example, in many countries abroad, the detection of criminals is carried out by this method [13]. Any person can be detected through the images taken from the existing camera setups. Apart from this, it is also used in the traffic area. It can count the vehicles in the traffic and the speed of the vehicles can be measured. In this way, situations such as traffic density or excessive speed can be detected and necessary notifications can be made to the center.

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