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RESEARCH ARTICLE

Design and Manufacturing of an Exploration Autonomous Unmanned Aerial Vehicle

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ABSTRACT

The importance of rotary-wing and fixed-wing Unmanned Aerial Vehicles (UAV), which have recently been used in various fields all over the world, is increasing day by day. Some of these vehicles are not only used for civilian life, but also in the military field. In this field, systems that undertake important tasks in the military field have been developed with very different technologies. These systems, which have developed rapidly in recent years, have become preferred because they facilitate the needs. The success of our country in the field of UAV has reached an important level and has set an example to the whole world. Among these systems, the UAV, which operate autonomously, have increased their importance because they provide great convenience to the user. For these systems, in this study, it has been tried to fulfill the autonomous reconnaissance task given to the UAV in places where there is no ground control center, where the remote control is not possible, or as a result of the disconnection with the UAV, and successful results have been obtained. In addition, in our study, the manual control system and the fully autonomous system were discussed and applied to the UAV system. It has been ensured that the UAV system can successfully take off as fully autonomous control, reach the target, reconnaissance, and land successfully at the take-off site. In addition, the sensor information and camera images on the UAV were instantly transferred to the ground control station and the reconnaissance mission was completed through the autonomous fly process.

Contents

1. Introduction

UAVs are vehicles that fly by being controlled by a ground control station, remote control, or fully autonomously on a platform or a designed system, which do not need to host any pilot. We can define them as aircraft that contain cameras, various control elements, sensors, as well as scanning devices, and other systems that transmit auxiliary information to the pilot. In this area, as the development of UAVs for civilian applications has increased, so has the interest in the research and design of such aircraft. In a general analysis, research has focused on the UAV fuselage, communication, and control systems [1]. Different studies in

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the literature have focused on alternative propulsion systems such as fuel cell technologies and distributed propulsion [2].

The word autonomy can be defined in general terms as the ability of the system to make decisions without the need for any user. In the literature, different autonomously controlled systems that can respond to system requirements have been developed last ten years [3, 4]. It has been found that UAVs are widely used in military operations where they are used, for example, for surveillance, to avoid threatening a pilot's life and significantly reduce the logistical impact of flight operations. In recent years, there has been a growing interest in recreational activities involving various types of UAVs, primarily conventional radio-controlled fixed-wing UAVs and helicopters and multi-rotor-based UAVs. Although a wide variety of UAV sizes exist, from UAVs called NanoUAVs (mass < 0.025 kg) (2500 kg < mass < 5000 kg) to "High Altitude Long Endurance" UAVs. In recent years, UAVs (UAVs) have been widely used in both military and civilian areas all over the world [5].

Simulating the UAVs with computer-aided programs before the production phase will reduce the errors to be encountered in production. Computational Fluid Dynamics (CFD) is also widely used as a tool to determine the performance of propeller designs [1, 6]. In the literature, it has been used to obtain performance data of a commercial propeller and compare it with experimental values, and a satisfactory agreement has been obtained between the results [6]. A similar study was performed where several low Reynolds propeller configurations were simulated using CFD and low approximation errors were obtained by comparing the results with experimental data [6]. However, the structural evaluation of propellers is often overlooked during the design phase, and very limited resources consider the structural reliability of UAV propellers a design limitation. In the literature, he described a design methodology for small electrically powered UAVs with a maximum takeoff weight of 35 kg, using a code based on the propeller design approach and structural considerations [1].

It is preferable to have a secure connection between the UAV and the ground station to communicate with a receiver. Traditionally, radio frequency (RF) communication has been used to accomplish this process. Increasing congestion of the electromagnetic spectrum and this optical communication blocking being less likely to occur in free space has led to free space optics (FSO) being an alternative to RF systems. It also provides a free operating license and provides solutions to various RF communication problems such as interference and crowded bandwidth while empowering the application. As a result of meeting the high data rate connection requirement for huge data generated by UAVs, the FSO communication link is a strong competitor in the development of a UAV [7]. The secure connection between UAVs and ground stations [8]. Both RF and millimeter wave techniques have lower capacity and higher cutoff probability than FSO communication where the light wave has a higher carrier frequency [9]. UAV Based FSO systems analysis was explored in depth in terms of channel modeling, performance analysis, and parameter optimization [10–12].

As a result, within the scope of this study, the design and modeling of autonomous controlled UAVs were examined by making a wide literature review. It is aimed to make a new design by analyzing the advantages and disadvantages of these designs compared to each other. By adding autonomous control to the optimum design, it is aimed to fulfill the reconnaissance mission and return to the station when the connection with the UAV is lost through duty time process.

2. Material and Method

UAVs vary depending on preferences for different needs. These are preferred according to the wing structure, the load it carries, and the way of flight. Carrying products according to the area of use, making exploration, carrying useful cargo in the military field, agricultural spraying, etc. are preferred in such fields. In this study, which we will carry out for exploration, the top wing supported model was chosen as the most suitable wing structure.

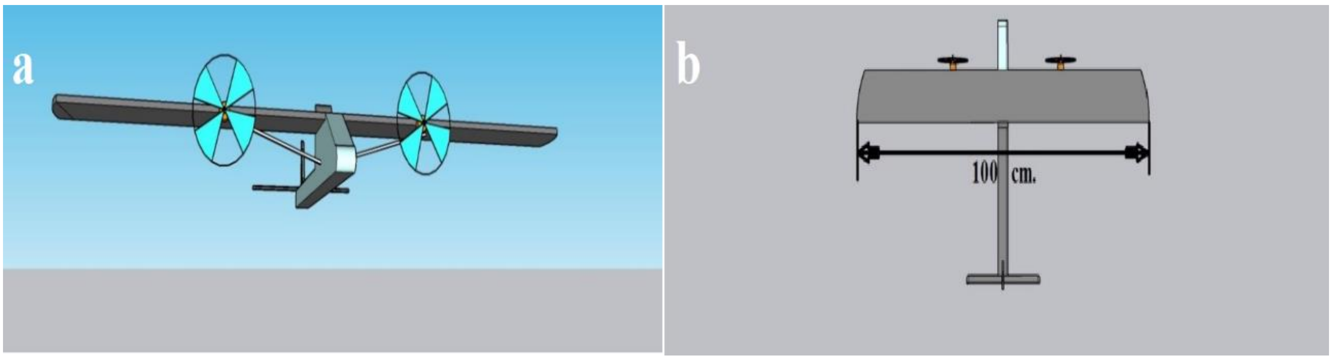

Figure 1 Wing model and wing of the UAV designed in this study in 3D

The traditional tail type was chosen as the tail type. According to the weight requirement of our model, it was preferred as a double engine. Within the scope of the study, 3 microprocessors were used to control our model. Two 1400 kV brushless motors were used. Two ESC Electronic Speed Controllers are used to feed the motors. Two 9x45 propellers were used. 2 servo motors are used for our model to tilt to the right and left and to maneuver more easily. In addition, 2 servo motors are used for the vertical tail and horizontal tail control in the tail. A 6-axis gyroscope was used to keep our model in balance. A 3-axis compass sensor is used to find the direction of our model. GPS module was used to obtain information such as coordinate information, speed, and altitude of our model. In addition, a temperature sensor was used to obtain the temperature information of our model. A voltage sensor is used to monitor the energy level of our model. 1 gimbal was used for our model to explore. A 1400 mAh Li-Po battery was used for the energy of our model. A transceiver is used for our model to send information to ground control. In addition, remote control and a receiver are also used for remote control. Figure 1 shows the wing model and wing of the UAV designed in this study in 3D. These design dimensions were analyzed and mathematically selected in the optimum region in terms of aerodynamics. The aerodynamic force and aerodynamic moment equations for the model airplane designed within the scope of this study are determined optimum region.

The traditional tail model was chosen for easy control and comfortable reconnaissance of our model aircraft in stable flights. This tail model is made of Styrofoam because it is water resistant and light. Figure 2 shows the tail structure of the designed model airplane and the components acting on the model airplane.

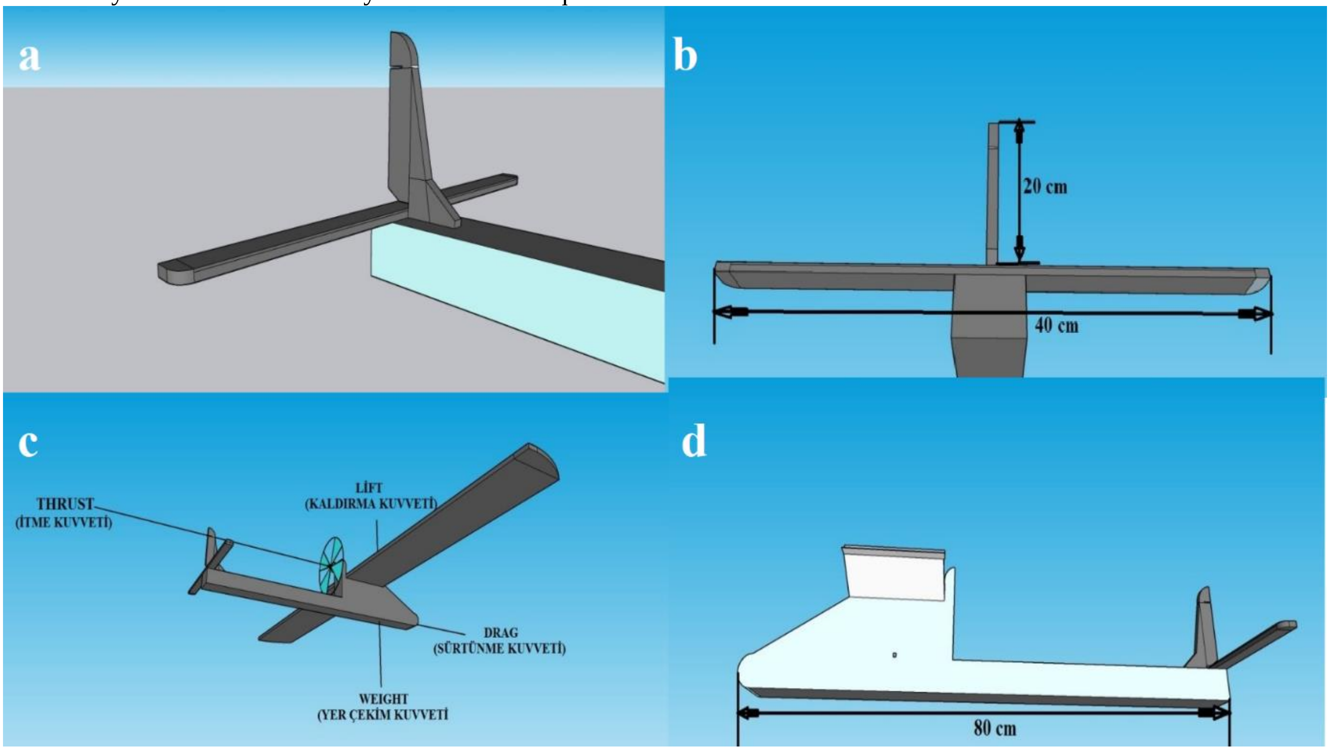

Figure 2 Tail structure of the designed model airplane and the components acting on the model airplane

DC electricity is applied to the brushless motor to drive each phase with a closed-loop controller. These motors, which rotate with DC electricity, are synchronous motors. Loop controllers are implemented by applying current pulses to the windings of the motor to adjust the speed and torque of the motor. The body, wing, and tail weights, together with all the circuit elements used in our model aircraft, weighed exactly 1100 grams. Looking at the technical specifications of the brushless motor given in the table above, it is seen that the thrust power of the 1400kV brushless motor is 3S, at 11.1 volts, and 910 gr when using a 90x50 propeller. Since our model aircraft weight is 110 grams and more different systems are planned to be added, 2 1400kV brushless motors have been selected. Since there are two brushless motors in the wings of our model aircraft, the first brushless motor rotates clockwise (CW) and the other rotates counterclockwise (CCW).

Within the scope of this study, the UAV is a fixed-wing aircraft designed for stable flights. If we define the wing, tail, and other parts of our aircraft, there are Rudder and Elevator in the tail part. There is Aileron on the wing part. Other parts include landing gear, vertical stabilizer, horizontal stabilizer, and propeller. The UAV exhibits some movement during flight with aileron controls, elevator controls, and rudder controls. If we define these movements, it exhibits a right or left orientation movement with the movement of the aileron. With the elevator, our vehicle moves up and down. When the rudder part is moved, the aircraft exhibits a right or left turn movement. If we define the movements of our aircraft in the air, it performs the rolling motion with the roll. Performs pitching motion with pitch. Thus, it performs a yaw motion. Servo motors rotate between 0 and 180 degrees according to the PWM signals sent by the microcontroller. In this study, our UAV needs right-to-left orientation for take-off and landing movement, and servo motors that rotate at certain angles for right-to-left rotation. That's why we chose the SG-90 servo engine model for our UAV. 6 SG90 servo motors are used, 2 of which are in the tail, 2 in the wings, and 2 in the gimbal. Servo-1 and Servo-2 motors move in two ways between 0-90 degrees and 90-180 degrees according to the incoming PWM signal according to the algorithm written to the microcontroller. These pull the fin down between 0-90 degrees. Stable fins at 0 degrees are positioned to be flat. If it is between 90-180 degrees, it pushes the fin upwards. In this way, it moves to the right and left. At the same time, according to the algorithm written for use with the gyroscope, it balances the roll motion of the aircraft and thus enables it to fly stably. In the tail part, we used a servo motor to make the elevator move up and down for our plane to take off and land. Here, the servo motors rotate 0-90 degrees, 0 degrees, and 90-180 degrees according to the PWM signal coming from the microcontroller. To take off, the elevator must move upwards. In other words, our aircraft takes off when our servo motor performs 90-180 rotations. If it is at 0 degrees, our plane moves in a stable straightway. For our plane to land, the elevator must move downwards. This happens when the servo motor rotates 0-90 degrees. In gimbals, servo motors are needed to take images by moving the camera 180 degrees left and right and 180 degrees up and down. Here, both servo motors rotate between 0-180 degrees according to the PWM information coming from the microcontroller. In this way, a 180-degree focus and directing the camera to the desired direction will be achieved. Figure 3 shows the blade design and the placement of the servo motors designed in this study.

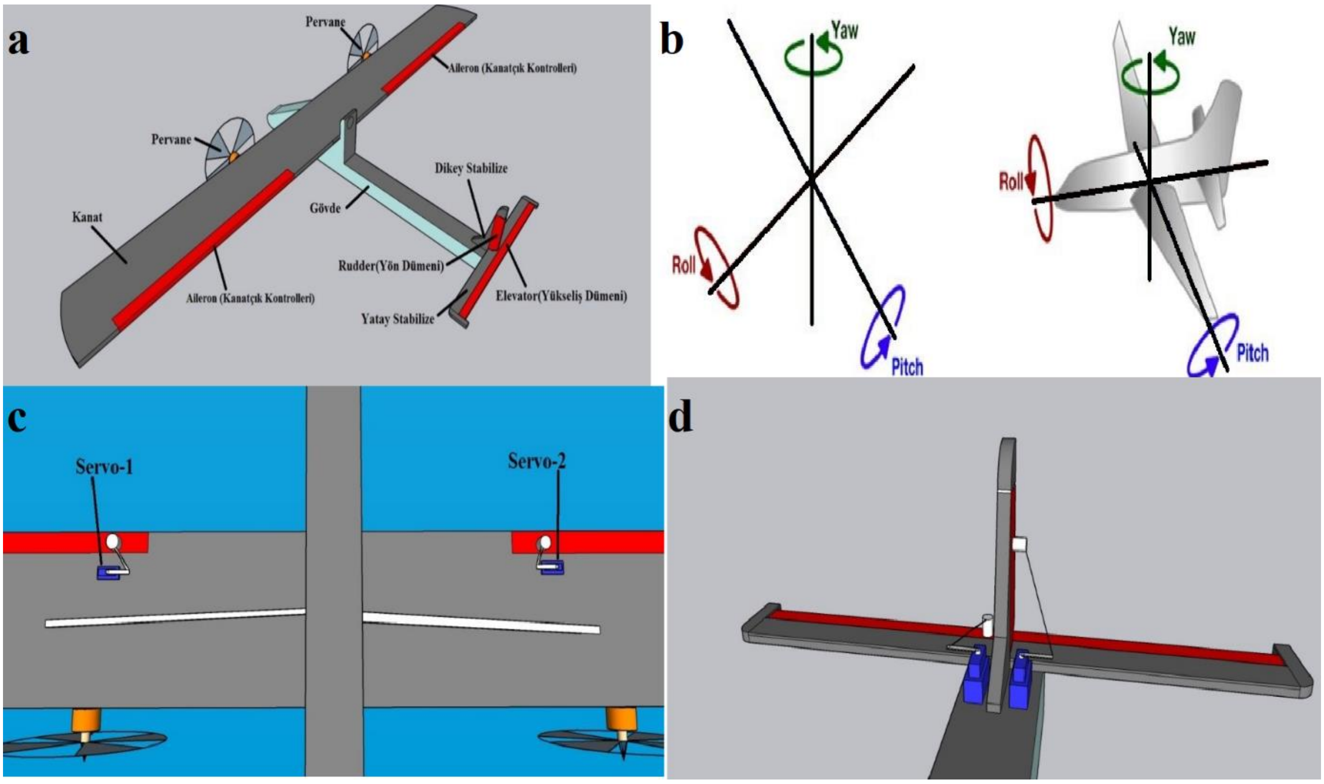

Figure 3 The blade design and the placement of the servo motors designed in this study

The working algorithm of our UAV is a fuzzy logic base. If we examine our algorithm scheme, first of all, the information on the sensors on our UAV is transferred to the ground control station. In light of this information, necessary information is entered from the ground control station to choose an autonomous or manual flight. In the case of manual selection, we have the control of take-off, stable flight, landing again after reconnaissance missions, and ending the mission by being controlled from the remote control or ground control station screen. If Autonomous is selected, we enter the coordinates to go to the destination. Then we enter the altitude information to rise. The location information of the aircraft from the sensors, the direction information of the aircraft according to the point where the aircraft is located, and the coordinate plane of the target coordinate according to the position of the aircraft are calculated according to the coordinate plane and the direction and angle of the plane to be taken according to this plane after our plane reaches a sufficient speed for our plane to take off, then it takes off. And after reaching a sufficient altitude, we proceed in the direction and angle of the flight and make a reconnaissance at the target point, then make calculations to come back to the point where it took off and return to land. In this process, we follow up from the ground control station.

3. Result and Discussion

Autonomous UAVs have different designs to be used for different purposes today. In addition, the designed UAV was subjected to various test processes and the results received were processed as feedback on the development of the system. An UAV with wings compatible with the task in the UAV designed within the scope of this study has been designed. In addition, aerodynamic calculations were made to make an UAV model. Figure 4 shows the model image of the completed UAV.

In the literature, different applications with autonomous control are carried out for solving various system problems [13]

In our study based on this study, we designed our wing structure according to the fixed wing torsion angle. In addition, we have designed the nose of our UAV as more pointed and horizontal as possible. Differently, it tried to reduce the friction of the wind by curving the wing tips. In the tail part, the classical tail model was chosen and the tail part was curved. In this way, it is ensured that the UAV can fly more effectively through assigned duty.

Figure 4 The model image of the completed UAV.

In the studies in the literature, it was stated that the cost of UAVs designed for reconnaissance, firefighting, and use in hazardous areas was high, and an attempt was made to design an autonomous UAV by reducing this cost and using cheaper sensors with a lower budget, and a trial fixed-wing UAV was designed. In this study, Ardupilot Mega (APM) was used and a GPS sensor, Gyroscope, Magnetometer, and other elements were used as external elements [14]. It has been seen that the use of APM does not provide an opportunity for different ideas, but studies can only be carried out for some applications. Therefore, the design and usability of the needs are of great importance. In our UAV study, the software of our electronic card was written and a study was carried out for our needs. In another study in the literature, an autopilot circuit was tried to be designed and a ground control station was built. In this circuit, GPS satellites were used for the autonomous UAV and a pressure sensor was used for altitude. Here again, a fixed-wing aircraft was designed for the test of the system and successful results were obtained. In literature authors, also used gyroscope sensors for the plane to fly in a balanced way [13]. In the same study in the literature, a ground control station interface was designed and implemented for the control of UAVs and to receive various information on the vehicle. Thanks to this interface written in C#, a design was made to help read the data informing the pilot such as the direction, altitude, position, and temperature of the aircraft [13]. In our UAV study, different from the one in the literature for the ground control station, LabWiev, a visual software, was used and a successful design was obtained. GPS information, speed information, Gyroscope information, Compass information, and Map information can be displayed on this design. Figure 5 schematically shows the UAV map simulation and Labwiew coding designed in this study.

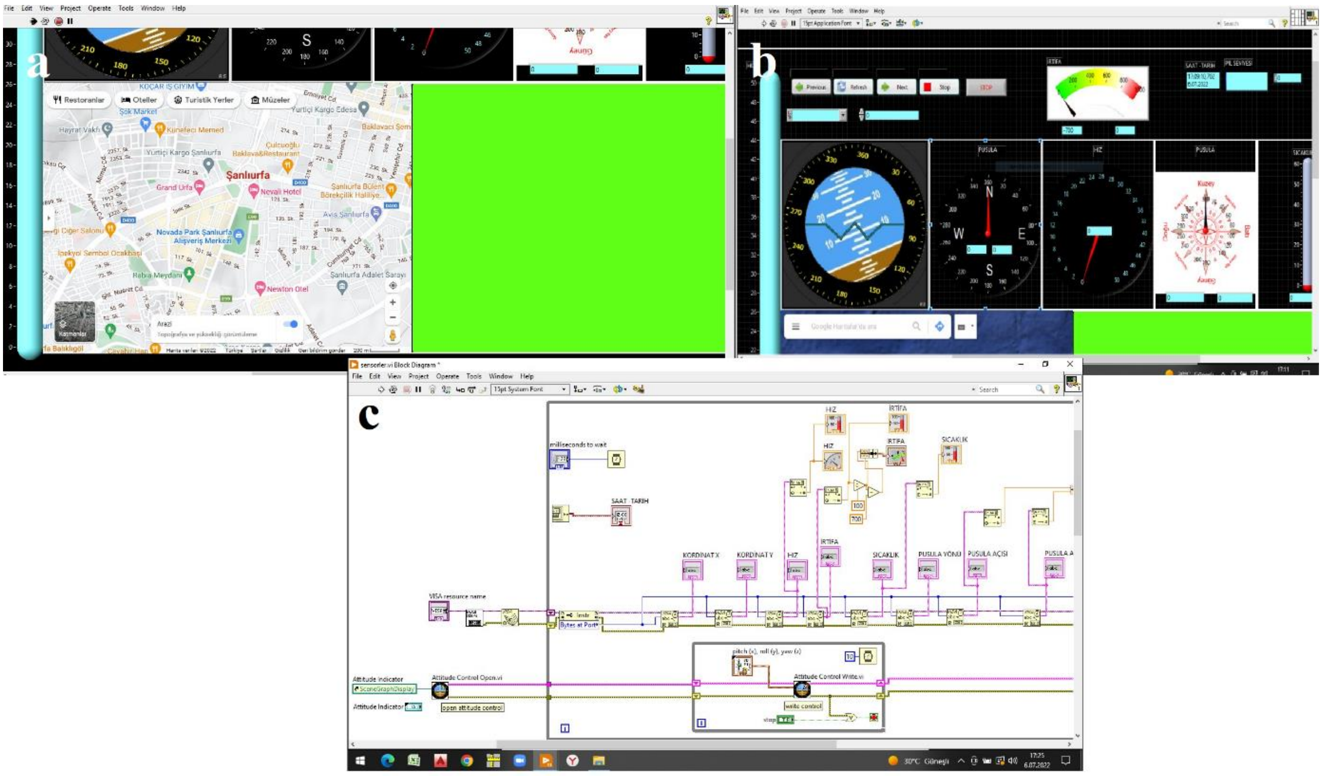

Figure 5 The schematically UAV map and LabVIEW simulation

LabVIEW is a visually designed platform that is used to create simple flow diagrams with small icons and cables, and to assemble small programs by designing your applications with visual objects. Since it is visual compared to written software languages, creating the algorithm can be done more easily. Its use has been developed since 1986 and has spread to many areas. Test measurement and control systems have gained an important place in the world market with data acquisition cards, modular instrumentation systems, and compact cards developed by LabVIEW. This software consists of two parts: Front Panel and Block Diagram. The front panel is the user interface. It helps the operator, who will use the application to be created with LabVIEW, to enter values into the system and see the outputs. The block diagram is where the main operations are done. While the user provides control on the front panel, virtual instruments work in the block diagram on the other hand. In addition, it can dominate real systems with the hardware developed by NI company. The block diagram corresponds to the coding section in visual programming languages, and the front panel corresponds to the forms in which the user interface is prepared. For this reason, the Labview program was chosen as a ground control station for a screen design that displays temperature, humidity, coordinate, speed, altitude, distance, compass sensor, gyroscope, voltage, and FPV camera information on our UAV.

4. Conclusion

The success of our country in the field of UAVs has reached an important level and has set an example to the whole world. Among these systems, the UAVs, which operate autonomously, have increased their importance because they provide great convenience to the user. For these systems, in this study, it has been tried to fulfill the autonomous reconnaissance task given to the UAVs in places where there is no ground control center, where the remote control is not possible, or as a result of the disconnection with the UAV, and successful results have been obtained. In addition, in our study, the manual control system and the fully autonomous system were discussed and applied to the UAV system. It has been ensured that the UAV system can successfully take off as fully autonomous control, reach the target, reconnaissance, and land successfully at the take-off site. In addition, the sensor information and camera images on the UAV were instantly transferred to the ground control station and the reconnaissance mission was completed through the autonomous fly process. Finally, aerodynamic analyzes of the design carried out within the scope of this study were carried out, contributing to the literature on reaching the optimum design. The next studies, it is aimed to increase the mission time of the UAV by using different materials and coatings.

Declaration of Conflict of Interest

Authors declare that they have no conflict of interest with any person, institution, or company.

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