Turkish Journal of Science & Technology
18(2), 449-459, 2023

Research Paper
https://doi.org/10.55525/tjst.1301903

Development of Unmanned Aerial Vehicle for Detecting the Forest Fires

Baris Mert KADIOGLU[1], Secil KARATAY[2*], Yucel CETINCEVIZ[3], Faruk ERKEN[4]
[1-4] Electrical Electronics Engineering, Faculty of Engineering and Architecture, Kastamonu University, Kastamonu, Turkey

[1] barismertkadioglu@gmail.com, [*2] skaratay@kastamonu.edu.tr, [3] ycetinceviz@kastamonu.edu.tr,
[4] ferken@kastamonu.edu.tr,

(Geliş/Received: 24/05/2023; Kabul/Accepted: 30/08/2023)

Abstract: In recent years, forest fires can be brought under control in line with the information obtained from Unmanned Aerial Vehicles (UAVs), which play an important role in determining the progression of fires, detecting heat points and determining intervention locations. In this study, if the UAV detects the fire by autonomously positioning in the area where the fire is located, the point where the fire reaches the most intense temperature is determined with the help of the thermal camera, and it is ensured that the fireball is dropped to the target with a 100% success rate. The requirements of the UAV, which will be produced in order to realize this task, such as fast, load-carrying and stable flight are also taken into consideration. In addition to being economical and long-lasting of the materials inside, it will be able to fly efficiently in most weather conditions (foggy, dark, etc.). In the construction of the UAV, a domestic Electronic Speed Controller (ESC) with a unique design is produced to meet the sufficient current. With this acquisition, ESC, which will meet the requirements by sending sufficient current to more than one Brushless DC (BLDC) motor, has been tested on our Radio Controlled (RC) aircraft and included in the project.

Key words: Unmanned Aerial Vehicle, Forest Fire, Electronic Speed Controller, Autonomous Flight.

Orman Yangınlarının Tespiti İçin İnsansız Hava Aracı Geliştirilmesi

Öz: Son yıllarda yangınların seyrinin belirlenmesinde, ısı noktalarının tespit edilmesinde ve müdahale yerlerinin belirlenmesinde önemli rol oynayan İnsansız Hava Araçları'ndan (İHA) elde edilen bilgiler doğrultusunda orman yangınları kontrol altına alınabilmektedir. Bu çalışmada İHA'nın, yangının bulunduğu bölgede otonom olarak konumlanarak yangını tespit etmesi durumunda, termal kamera yardımıyla yangının en yoğun sıcaklığa ulaştığı nokta belirlenmekte ve ateş topunun %100 başarı oranı ile hedefe düşürülmesi sağlanmaktadır. Bu görevi gerçekleştirmek üzere üretilecek olan İHA'nın hızlı, yük taşıma ve stabil uçuş gibi gereksinimleri de göz önünde bulundurulmuştur. İçerisindeki malzemelerin ekonomik ve uzun ömürlü olmasının yanı sıra çoğu hava koşulunda (sisli, karanlık vb.) verimli bir şekilde uçabilecektir. İHA yapımında yeterli akımı karşılamak için özgün tasarıma sahip yerli Elektronik Hız Kontrol Cihazı (ESC) üretilmiştir. Bu satın alma ile birlikte birden fazla Fırçasız DC (BLDC) motora yeterli akım göndererek gereksinimleri karşılayacak olan ESC, Radyo Kontrollü (RC) uçağımızda test edilmiş ve projeye dâhil edilmiştir.

Anahtar kelimeler: İnsansız Hava Aracı, Orman Yangını, Elektronik Hız Kontrol Cihazı, Otonom Uçuş.

1. Introduction

In today's world, as a result of the great development in the field of defense industry with Unmanned Aerial Vehicles (UAVs), UAVs can be integrated into other fields and can perform many operations without the need for manpower and without endangering human life [1, 2, 3]. Early detection of forest fires and at the same time the timeliness of the first response is of vital importance. One of the mission objectives of UAVs has been to notify the fire to the ground station by means of target detection and first response with the UAV fixed wing model, and to keep the fire under control, with the aim of preventing the increase in the destruction caused by the delay and inadequate response to forest fires, which have increased in recent years. By making extensive surveillance with UAVs, both the size of the fire can be determined faster and the correct locations can be intervened with the information obtained from these vehicles during extinguishing. Especially at night, monitoring the general course of fires, determining the heat points and determining the intervention places more clearly prevent the spread of flames to wider areas.

Preliminary studies on UAV technologies for remote sensing of forest fires started in the early 2000s. This period is characterized by the use of remotely controlled High Altitude and Long Endurance UAVs (HALE UAVs) utilized by research agencies as a complement to existing satellite tracking systems. HALE UAVs can fly for hours at high altitude and carry significantly heavy payloads, are expensive systems and do not provide

[*] Corresponding author: skaratay@kastamonu.edu.tr. ORCID Number of authors: [1] 0009-0001-5194-9158, [2] 0000-0002-1942-6728, [3] 0000-0001-6834-9442, [4] 0000-0003-2048-1203

more precise data than satellites [4]. In [5], a remote-controlled UAV equipped with a thermal scanner has been designed for forest fire mapping. Images in the study have been transmitted to the ground station via a satellite link and then geo-corrected to produce a fire map in real time. The system has been tested in a controlled burn zone using an ALTUS II UAV in 2001 and produced 5 geo-corrected images with a spatial resolution of 2.5 m during an hour of flight. The architecture of the fire system in this study is probably the first example of a complete wildfire monitoring system, serving as the foundation for more capable ones to come in the years to come.

In [6], a UAV has been designed that can follow a predefined flight plan that can be updated at any time from a ground control station. While performing the mission, the aircraft is able to capture high-resolution images transmitted in real time to the ground station via a satellite link. The raw images can then be forwarded to a Central Data Processing Center for additional processing, which archives all georeferenced images produced and allows end users to refer to the information. [7] suggests a system for cooperative fire detection using a fleet of diverse UAVs. The fire detection algorithm is based on cooperation between UAVs with IR cameras and other UAVs with visible cameras to increase the detection probability. The designed system has been tested in the field and very successful results have been obtained. [8] focuses on developing accurate and reliable forest fire recognition algorithms for UAVs. Experimental results in this study have shown that the structured Forest Fire Detection technique can achieve good execution with significantly increased reliability and accuracy in Forest Fire Detection applications. The purpose of [9] to provide useful knowledge on various UAV-based wildfire control systems and machine learning algorithms to predict and effectively deal with bushfires in inaccessible locations. In spite of the potential advantages of UAVs for bushfire management, it is decided in this study that there are accuracy issues, and solutions must be optimized for successful bushfire management. In [10], a metal oxide CO2 detector has been designed using a screen printing approach to detect the CO2 gas from the sensors to watch and make the appropriate controls in case of a fire in the areas and it has been observed that it may be used in conjunction with fire detectors to improve detection accuracy and shorten alarm duration with current fire detectors. In [11], a novel fire detection dataset has been used to propose a forest fire detection approach based on a Convolutional Neural Network (CNN) architecture. Experimental results in this study demonstrate that the approach can recognize forest fires within photos with a 97.63% accuracy, a 98.00% F1 Score, and an 80% Kappa after being trained on the dataset.

The effectiveness of an effective wildfire and smoke detection solution is suggested by [12], who proposes an architecture that combines the YOLO architecture with two weights with a voting ensemble CNN architecture to tackle two different computer vision tasks in a stage format. The classification model used in the study has an F1 score of 0.95, an accuracy of 0.99, and a sensitivity of 0.98e. By reaching a 0.85 mean average precision with a 0.5 threshold score for the smoke detection model and 0.76 mAP for the combined model, the evaluation of the detector model displays strong findings. Strong results are obtained from the evaluation of the detector model, which achieved a 0.85 mean average accuracy with a 0.5 threshold score for the smoke detection model and 0.76 mAP for the combined model. A 0.93 F1-score is also achieved by the smoke detection model. [13] includes a comprehensive explanation of the flame and smoke detection algorithms utilized by each optical remote sensing technology as well as a description of how these technologies are used in early fire warning systems. A number of models attempting to detect fire occurrences with high accuracy in difficult conditions are explored, and three types of systems—terrestrial, airborne, and space borne—are identified in this study. A thorough comparison of the three types of early fire detection systems, using a scale of 0 (low) to 5 (high) for performance (Accuracy), volume of research papers (Volume of works), future potential, minimum fire size that can be detected (Minimum fire size), monitoring area covered by the system (Coverage area), and response time. A summary of the literature on UAVs that use computer vision to detect fire is studied in [14]. In order to document the many types of UAVs, the hardware and software utilized, and the suggested datasets, the research has been done throughout the past ten years. The study revealed that multi-copters were the most popular kind of vehicle and that most applications involved combining an RGB camera with a thermal camera. [15] describes their control design process and indoor testing findings using a small fixed-wing autonomous glider that can perform a forceful high angle-of-attack landing maneuver. They begin by building an incredibly accurate model of the aircraft using unstable flight regimes and actual kinematic flight data collected in a motion-capture environment. A numerical nonlinear (approximate) optimum control approach is then utilized to construct a feedback control strategy for the elevator deflection using the study's model. Finally, they provide the results of their experiments showing how this basic glider may use pressure drag to perform a high-speed perching maneuver. Forest fires in Turkey are detected and intervened with TB2 produced by BAYKAR Technology in 2014. TB2, which can carry 150 kg of payload, has an important position in its field. Instant fire detection, transfer of images to the Fire Management Center in Ankara, Forestry Operations Directorates and Fire Extinguishing Systems is provided by image processing in TB2. In addition, archiving the images, using the tablet with the raven system, transmitting the instructions of the Fire Management Center to the field teams, monitoring the instant status of the fire fighting vehicles on the map of the General Directorate of Forestry and directing them to the fire area, analysis of meteorological data and instantaneous wind information in the fire area as a result of the progress of the fire can be provided with software that allows calculating the direction and intensity [16].

The purpose of this study is to intervene in increasing forest fires without endangering human life. For this reason, a fixed-wing UAV capable of carrying loads and reaching the fire zone as quickly as possible has been developed. The reason for not using a rotary-wing UAV is that the high temperature in the fire zone could damage a hovering drone, and also due to the lower payload capacity compared to a fixed-wing UAV. First and foremost, the boundaries of the fire will be determined using image processing to prevent the fire from spreading in order to stop the growth of the targeted fire. It is designed to autonomously perform its task by easily reaching the hard-to-reach areas of the fire.

The proposed system sends real-time images to the ground station both during reconnaissance flights and when it arrives at the area in response to a fire alarm. This facilitate knowledge of the size and status of the fire. Its innovative feature is its ability to intervene in the fire and its maneuverability. Thanks to the harmony between the mission mechanism and the flight computer, it has a high accuracy rate.

The UAV, which is initially considered for forest fires and whose design is completed, is capable of performing different types of load-dropping operations by changing the software and/or payload. Completing the mission with an efficient flight, the UAV immediately returns to the command area and becomes ready for a new flight by renewing its charge and loads. This fully national project, designed as a solution to the problem of delaying the detection of forest fires and having difficulties in extinguishing them, has a fixed-wing UAV design as it can carry heavy loads. The design and method of the produced UAV are given in Section 2, and the observations and findings are included in Section 3.

2. Material and Method

In this study, a durable, economical, domestic and national UAV is designed, which is fast, capable of carrying loads, can process the image and detect the fire thanks to its software, and can release the fireball without losing time with its easy activation feature thanks to the task mechanism designed to extinguish the fire. At the same time, it is aimed that the UAV has a large wing surface area and a high lift force, and with the sufficient ability of the control surfaces, it is aimed to provide the desired speed and maneuverability to the flight.

The airfoil structure used in the body strength and mechanical system of the UAV is chosen as NACA 6409, which will provide the required lifting force as a result of the analysis and calculations made. The drag reduction parameter is taken into account in the FoM (Figure of Merit) figure to select the configurations. An ideal chassis design is planned according to the weight measurements determined for electronic equipment by optimizing the chassis weight. With this factor, a body is designed in which electronic and mechanical systems can be placed easily. The UAV's weight with payload is 7800 grams, its length is 1100mm, its wingspan is 2000mm, and its body width is 80mm. According to the Reynolds (Re) number, NACA 6409 is chosen as the airfoil. The wing is made of EPP Foam and reinforced with carbon fiber pipes. The wing analysis of L, CD, CL ALPHA, CD ALPHA are shown in Figure 1. The dimension of the design of the UAV is demonstrated in Figure 2. The UAV is assembled based on the design in Figure 2.

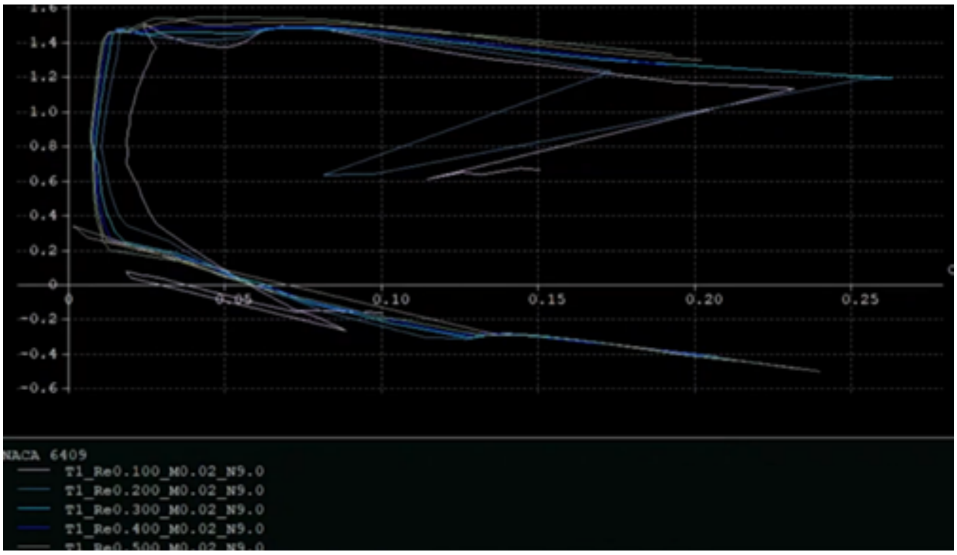

Figure 1. Aerodynamic analysis of CL and CD.

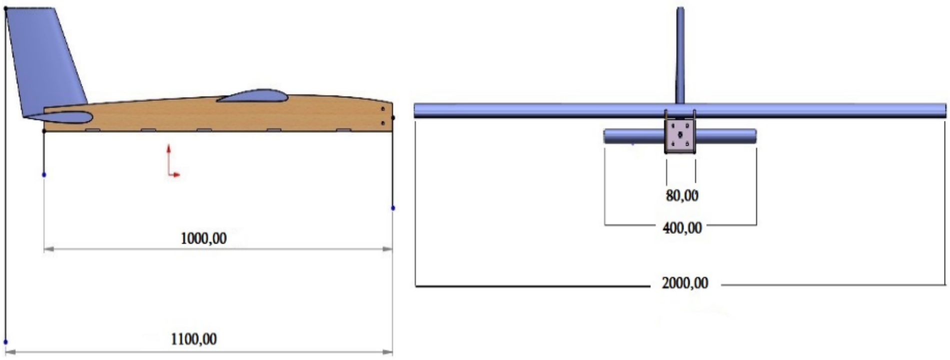

Figure 2. Dimensions of the designed UAV.

The image from the camera is divided into squares, and each of the frames takes certain values with reference to the color shades of white and black. Thus, when the camera captures the desired color and object, the algorithm detects this and activates the task mechanism as shown in Figure 3. With the vertical use of the design, it is aimed to reduce the area covered by the mission mechanism on the aircraft and to prevent the shift in the center of gravity during the release of the six balls, which is the duty of releasing the fireball, so that the flight control device is not affected for a stable flight. In the task mechanism, two crescent caps are controlled by a single servo motor. The first crescent cover has a small surface area and is ready to be pulled in front of the ball with a portion of it that can hold the ball inside the cylinder. If the servomotor is activated, it is pulled from the front of the ball and leaves the first ball. The second crescent cap has a larger surface area than the first crescent cap. In this way, the servomotor pulls the first crescent cap from the front of the ball; the second crescent will return to the starting position of the first crescent and prepare it for the second and final shot.

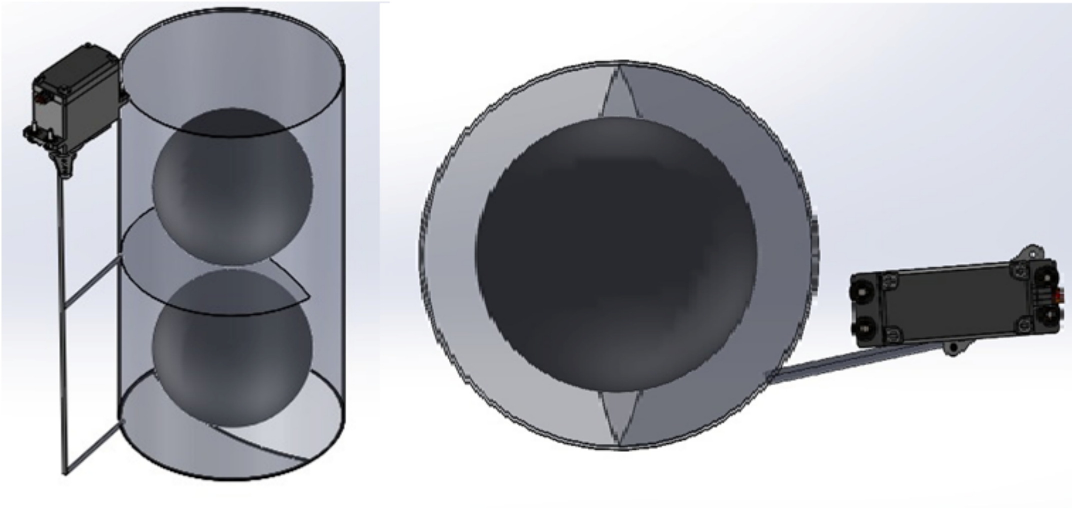

Figure 3. View of the side and top sections of the task mechanism.

X4125-440KV V3 2430W 5-6S brushless RC aircraft motor is used for the motor of the UAV. ESC value, Lipo battery (Lithium Polymer battery) value and propeller dimensions are determined as 100A, 6S 22000mAh 25C and 16x10 APC, respectively. Electronic components and circuit diagram, control card selected for flight control, sensors, RF receiver and transmitter systems, battery systems, power modules, fuse and current breaker, electronic equipment to be used in the mission mechanism system, radio control, ground station software and information about the systems in UAV are given in Table 1. The placement of the UAV on the fuselage and wings and the circuit diagram are given in Figure 4. Figure 4 shows how the direct current (DC) from the LiPo battery follows the servomotors such as S1, S2, S3, S4, S5.

Table 1. Electronic equipment and features of the designed UAV.

Electronic Components	Feature	Model
Motor	X4125 – 440kV Motor	SUNNYSKY X4125-440KV V3 2430W 5-6S Brushless Motor
ESC	Domestic ESC and 90A UBEC electronic speed controller	Designed 90A ESC
LiPo Battery	46.62mA that can provide 21 minutes of stay in the air, feeds the flight controller and image processing computer	Leopard Power 22000 mAh 22,2V 6S 25C
Flight Controller	Flight controller that provides more stable control and autonomous flight with its 32-bit processor for autonomous flights	Pixhawk 2.4.8
Servo Motor	180-degree metal gears to move the aircraft's control surfaces such as aileron, elevator and rudder and to control the mission mechanism.	Emax ES08D II 8.5G Digital Servo
Computer and Camera	High performance and high image resolution in image processing	Nvidia Jetson Nano Computer and Camera
Pitot Tube	Pitot Tube Sensor kit to measure the airspeed of the UAV and to see it at the ground station	Pixhawk PX4 Differential Airspeed Sensor Set
GPS	GPS module that shows the position of the UAV at the ground station with less deviations and enables it to move more sharply to the positions sent in autonomous missions	HERE 3
Ground Station Software and Systems	It has a more understandable interface that facilitates the use of the flight controller	Mission Planner
Telemeter	Transferring information such as the aircraft's motor temperature, battery status, altitude, bank angle to the ground computer	SiK Telemetry Radio V3 433MHz

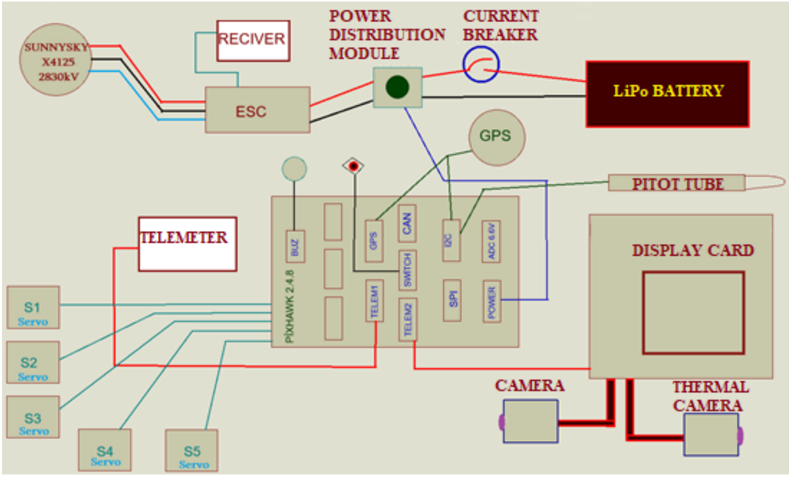

Figure 4. Electronic circuit diagram of the UAV.

As soon as the fire extinguisher is activated, it emits an audible sound (99 decibels) and warns people as an alarm. The approximate weight of the ball is 1.3 kg. It contains dry chemical powder obtained from 90 Mono Ammonium Phosphate or Native BOR powder. Simply throwing the ball into the fire or the area at risk of fire is sufficient. It gives accurate results within 3-5 seconds from the moment the ball comes into contact with Electric activation or fire. Since there is no need to approach the fire, it prevents the user from being harmed by fire or dense smoke. It does not harm the environment at the time of explosion.

In this study, the ESC circuit is designed and implemented to drive the motor. The current drawn by the X4125-440KV V3 2430W 5-6S Brushless RC aircraft motor mounted on the UAV is controlled by the designed ESC. STM32F105RCT microcontroller is used in motor driver (ESC) circuit for BLDC motor speed control, position control and torque control because it has more performance and lower power consumption. Hall Effect sensors are also used to determine the rotor position. A counter is created with the TIMER unit and this counter value signal period is recorded with an algorithm at each rising edge of the signal coming from the feedback element. Speed control and current control algorithms are also developed. "Anti-Windup" algorithm is developed in order to prevent integral clutter. It is aimed to avoid the undesirable effects of the integral term to control the motor speed or position using the "Anti-Windup" algorithm. In this way, it is possible to control the speed or position of the motor more stably and to achieve better performance with less overreactions. The analysis of the time dependent change in the full thrust state of the motor used with the 100 Ampere current passing ESC is given in Figure 5.

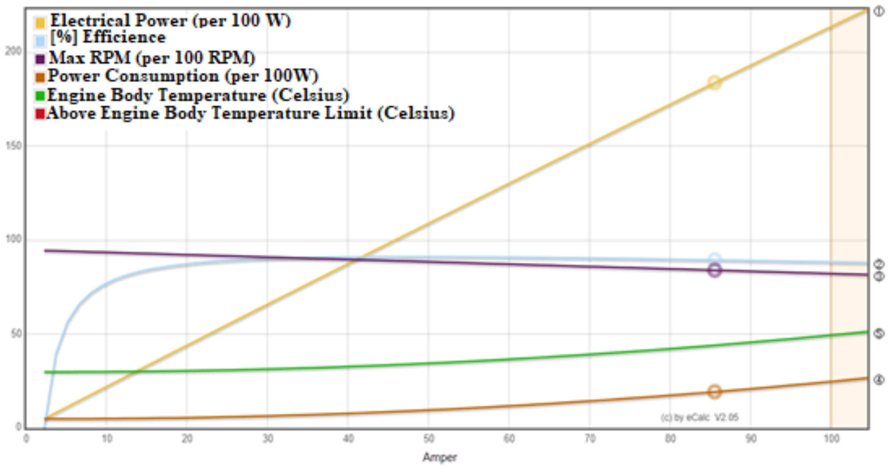

Figure 5. Characteristics of the motor at full thrust.

Electronic materials that have been analyzed together and obtained optimal values: ESC is 100A, LiPo (Lithium Polymer Battery) is 4S 22000mAh 120C and the propeller is 16x10 APC electric type propeller. These optimal values are obtained by examining the gradual partial load of the motor as presented in Table 2. The efficiency, electrical power, voltage, current and thrust (gram) values obtained from the produced ESC, used battery and propeller are as seen in Table 2.

Table 2. Gradual partial load of the motor.

Propeller	Impulse	Current	Voltage	Power	Efficience	Impulse	Impulse			Pitching Speed		Speed (level)		Engine Run
rpm	%	A	V	W	%	g	oz	g/W	oz/W	km/h	mph	km/h	mph	(85%)
1200	13	0.4	22.2	8.7	56.1	159	5.6	18.2	0.64	18	11	-	-	2841.8
1800	20	1.0	22.2	22.7	72.9	357	12.6	15.7	0.56	27	17	-	-	1094.1
2400	26	2.2	22.2	48.2	81.4	635	22.4	13.2	0.46	37	23	-	-	514.5
3000	33	4.0	22.2	89.3	85.7	992	35.0	11.1	0.39	46	28	-	-	277.3
3600	40	6.8	22.2	150.2	88.1	1428	50.4	9.5	0.34	55	34	-	-	164.7
4200	47	10.7	22.1	235.2	89.4	1944	68.6	8.3	0.29	64	40	-	-	105.0
4800	54	15.9	22.1	348.4	90.1	2539	89.6	7.3	0.26	73	45	-	-	70.7
5400	61	22.6	22.1	494.4	90.4	3214	113.4	6.5	0.23	82	51	61	38	49.7
6000	69	31.0	22.2	677.8	90.4	3968	140.0	5.9	0.21	91	57	92	57	36.2

Autonomous flight parameters are modeled in the ArduPilot algorithm and uploaded to Pixhawk 2.4.8. After completing the autonomous flight plan, PID settings, GPS calibration and ESC calibration in the Mission Planer interface, the UAV is enabled to take to the runway. Autonomous flight software is developed and communication is provided with Nvidia Jetson Nano. The operations to be performed in detecting any target are tested in the simulation environment and stabilized. The unique autonomous flight algorithm is revealed by meticulous attention to each test.

Fail Safe mode is set to full right rudder full right altitude. It is a mode that allows the unmanned aerial vehicle to land with the least risk in case of a possible connection jam and/or any emergency. The development phase has started after the design and production of the UAV. At this new stage, the features and performance of the UAV are tested in many aspects such as wind tunnel, autonomous flight stability, and target detection in the air. The problems that arise during the development of the algorithm are reviewed again. Stability in the route and flight of the UAV is improved in case of more than one target. The improvements made as a result of these tests and the issues that have changed and remained the same are given in observations and findings in Section 3.

3. Results and Discussion

The airfoil of the produced UAV has been first chosen as NACA-6408A, but the NACA-6409 airfoil is chosen considering analysis and carrier. In this way, the UAV autonomously demonstrates a stable flight without disturbing its stability. In the wing structure, the middle wing structure is abandoned and the upper wing structure is preferred in order to achieve a more stable flight and load carrying process.

Comparing the capability and price performance of the flight controller, it is decided that the Pixhawk Orange Cube is not needed. Adequate maneuverability is achieved in stable flight tests. Test flights are recorded and examined in detail. As a result of these examinations, it is observed that it is not far from a desired stable flight, but that it could be improved. Improvements such as weight reduction, landing gear change are applied. After ESC production is completed, measurements are obtained with an oscilloscope. When the desired results (RPM of the motors, feeding the flight controller and flight computer, having sufficient flight time using the battery effectively, maintaining the ESC temperature) are provided, the transition is made from the perforated copper plate to the copper plate. In the first place, the motor driver circuit was produced with Arduino UNO. The X2212 720kV motor was tested as a prototype. However, as a result of the R&D research, it is decided to use the STM32F105RCT microprocessor due to its high power consumption and lower performance than desired. The deformed life of both the battery and the UBEC (Ultimate Battery Eliminating Circuit) is extended with the UBEC in the ESC. Some objectives such as flight time (including landing and take-off), thrust weight ratio, and the ability of the ESC to work effectively with different types of motors have been determined as a result of the R&D work carried out during the design phase of the UAV. It can be observed that 92% of these targets have been achieved in Table 3 and 4.

Table 3. Motor and battery analysis results.

Battery		**Motor@Optimum Efficiency**		**Motor@Max**	
Load:	3.95 C	Current:	47.14 A	Current:	86.84 A
Voltage:	21.68 V	Voltage:	21.78 V	Voltage:	21.42 V
Rated Voltage:	22.20 V	Speed:	8873 rpm	Speed:	8365 rpm
Energy:	488.4 Wh	Electrical Power:	1026.5 W	Electrical Power:	1860.0 W
Total Capacity:	22000 mAh	Mechanical Power:	936.2 W	Mechanical Power:	1662.8 W
Used Capacity:	18700 mAh	Efficiency:	91.2%	Efficiency:	89.4.2%
Min Flight Time:	12.9 min				
Fixed Flight Time:	22.0 min				
Weight:	3252 g			**Wattmeter**	
	114.7 oz			Current:	86.84 A
				Voltage:	21.68 V
				Power:	1882.7 W

Table 4. Propeller, driver and speed analysis results.

Propeller		**Total Drive**		**Plane**	
Static Thrust:	7712 g 272 oz	Driver Weight:	4093 g 144.4 oz	Total Weight:	7000 g 246.9 oz
Speed:	8365 rpm	Power-Weight:	275 W/kg	Wing Load:	175 g/dm^2
Usable Thrust@0 km/h:	7712 g		125 W/lb		57.3 oz/ft^2
Usable Thrust@0 mph:	272 oz	Thrust–Weight:	1.10:1	Cubic Wing Load:	27.7
Pitching Speed:	128 km/h	Current@Max:	86.84 A	Estimated Adhesion Speed:	63 km/h
	80 mph	P(input)@Max:	1927.9 W		39 mph
Type Speed:	641 km/h	P(output)@Max:	1662.8 W	Horizontal Estimated Speed:	130 km/h
	398 mph	Efficiency @Max:	86.2%		39 mph
Thrust:	4.15 g/W	Torque:	1.90 Nm	Vertical Estimated Speed:	15 km/h
	0.15 oz/W		1.4 lbf.ft		9 mph
				Estimated Climb Speed:	13.4 m/s
					2631 ft/min

The maximum weight of the UAV that emerged within the scope of the study, namely BaSe, is compared with the useful loads it carried by examining the previously produced UAVs. The ratios of the payload to the maximum load of the previously produced UAVs and the Peace are comparatively given in Table 5.

Table 5. Ratio of payload to maximum payload in UAVs.

Model	Maximum Weight (g)	Useful Load (C)	Rate
TB2	650	150	0,2307
Akıncı	6000	1500	0,2500
mq9 Reaper	4760	1700	0,3571
BaSe	7750	2700	0,3483

The mission to be performed by the UAV is being tested on the Nvidia Jetson Nano. The first detection of fire is carried out by switching from BGR color space to HSV color space by including the red tone range of the point where the temperature is most intense in the thermal camera into the algorithm. The temperature and, accordingly, the red tone are evaluated according to the area it covers on the screen. Even if the desired color is obtained, when it is below a certain size, the masking process appears in the window and no other operation is performed. However, if it exceeds a certain size, it is determined by taking it into a square. For the normal camera, the top view of the flame and smoke is imported into Nvidia Jetson Nano using the color detection algorithm. This section is completed using ready-made code. After the test process on smoke and fire related videos is completed, the AZURE UAV team, which is prepared for the Teknofest competitions within Kastamonu University, is tested with the LUNA-37 aircraft on the inverter and integrated into BaSe. During the test, the first mission is successfully achieved by lifting two balls on a red tarpaulin. The segmentation of the red target is given in Figure 6.

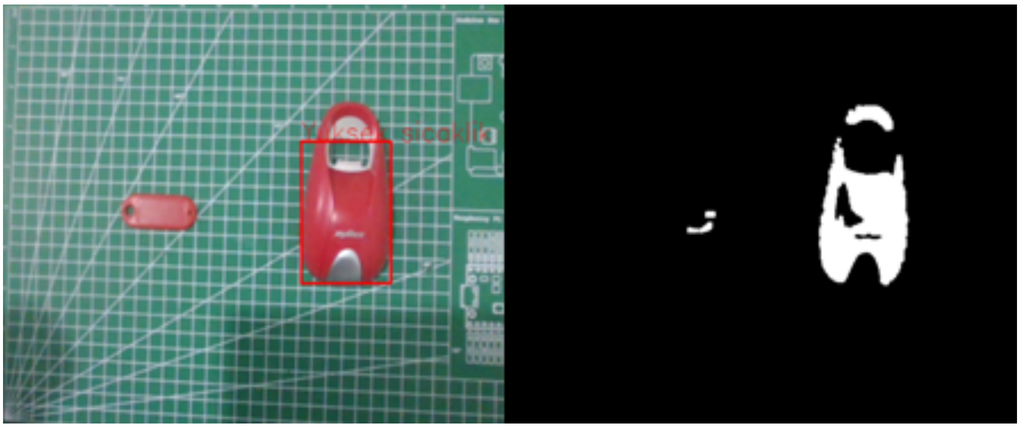

Figure 6. Segmentation of the target.

An ESC was developed using the STM32F401CCU6 microcontroller during the production phase. The desired efficiency is achieved and the operation is carried out with the X4125-440KV brushless motor integrated into the wings and the motor driver placed on the fuselage. Thus, multiple brushless motor control is realized with an ESC. The software part of the ESC is completed by performing the speed and position, trapezoidal commutation switching, development of the control module, and anti-windup algorithm, respectively. The soldering process is completed on the perforated copper plate and production is carried out as a result of the hardware configuration drawn in Proteus. The body is fixed in its proper position, considering that it is not affected by the magnetic field and the calculations of the center of gravity. The fact that the maximum current (I) that the ESC will receive from the LiPo battery chosen as the power source can be changed, enabled the motor driver to be used without the need for a change in case the battery and/or motor change. Thus, it is observed that BaSe can be used in many air, land and sea vehicles with its high compatibility.

4. Conclusion

In this study, an Unmanned Aerial Vehicle (UAV) is designed and produced by determining the purpose first. A fixed-wing model was preferred for rapid and effective response to forest fires. The fireball release process has been carried out with a rotary wing UAV in the literature. However, with this study, the fireball release process is performed for the first time with the fixed wing model. Considering that the high temperature of the fire with the rising of the heated air can negatively affect a rotary wing UAV and damage electronic components such as battery, ESC and motor, it has been planned and realized to minimize these effects with the fixed wing model. The fact that forest fires are more frequent in mountainous and hilly areas creates a disadvantage in the runway requirement of a fixed wing model aircraft. In order to minimize this disadvantage, a UAV that can take off in a short distance and stay in the air for a long time is produced in this study. In this way, it is observed that BaSe can stay in the air for a longer time and take off in a short distance by carrying a higher load compared to the rotary-wing UAV. In addition, a domestic motor driver is also produced in this study. With this motor driver, different motor types can be driven and two motors are connected and tested. In this way, one ESC is sufficient without the need for an extra ESC to be used. The unique value of the produced ESC is highlighted by a unique algorithm and PCB design drawn in Proteus.

Total cost of the UAV including ESC production (excluding fireballs and fireballs) is 26,300.00 TL. It is in a remarkable position in the price-performance balance with its economic cost in this area. BaSe can carry four fireballs weighing approximately 1.3 kg. With image processing methods, it can gradually drop the balls in question to the point where the fire temperature is most intense (the highest shade of red). In this way, convenience is provided in cases where it is difficult to reach the center of the fire by human power. Upon the communication of the computer with the flight controller, the location of the fire is determined by the normal camera and transmitted to Pixhawk 2.4.8. Position is determined autonomously and fireballs are released by passing over the fire. BaSe can perform the intervention by being suspended in the air and minimally affected by high temperature. As a result, BaSe's test missions, target detection, gun release, autonomous take-off and landing, and reporting of fire to the ground station are successfully accomplished. Therefore, it is observed that BaSe has become suitable for use in the area.

Acknowledgement

This work was supported to participate Teknofest in part by TÜBİTAK 2209-A with the research project number 1919B012222889 and by the scientific research project by Kastamonu University. The authors would like to thank TÜBİTAK and Kastamonu University Scientific Research Projects Coordination Unit for their outstanding contribution.

References

[1] Ucar UU, Isleyen SK. A New Solution Approach for UAV Routing Problem with Moving Target – Heterogeneous Fleet. J Polytechnic 2019; 22(4): 999 – 1016.

[2] Yilmaz T, Ayranci AA, Bacanli E, Ilhan H. UAV-Assisted NOMA-Based Network with Alamouti Space-Time Block Coding. J Polytechnic 2022; 25(3): 967 - 973.

[3] Ozcan O. Performance Evaluation of Bridges Under Scour by UAS Based Measurements. J Polytechnic 2019; 22(2): 385 - 391.

[4] Bailon-Ruiz R, Lacroix S. Wildfire remote sensing with UAVs: A review from the autonomy point of view. In IEEE 2020 International Conference on Unmanned Aircraft Systems (ICUAS); 01-04 September 2020; Athens, Greece. New York, NY, USA: IEEE. pp. 412-420.

[5] Ambrosia VG. Wegener SS, Sullivan DV, Buechel SW, Dunagan SE, Brass JA, Stoneburner J, S. Schoenun M. Demonstrating UAV-Acquired Real-Time Thermal Data over Fires. Photogramm Eng Remote Sens 2003; 69(4) 391-402.

[6] Lewyckyj N, Biesemans J, Everaerts J. OSIRIS: A European Project Using A High Altitude Platform For Forest Fire Monitoring. In: Safety and Security Engineering II. Rome: Wessex Institute of Technology Press, 2007. pp. 205-213.

[7] Merino L, Caballero F, Martinez-de Dios JR, Ollero A. Cooperative Fire Detection using Unmanned Aerial Vehicles. In: IEEE 2005 IEEE International Conference on Robotics and Automation; 18-22 April 2005; Barcelona, Spain. New York, NY, USA: IEEE. pp. 1884-1889.

[8] Sudhakar VVS, Kumar CS, Priya V, Ravi L, Subramaniyaswamy V. Unmanned Aerial Vehicle (UAV) based Forest Fire Detection and monitoring for reducing false alarms in forest-fires. Comput Commun 2020; 149:1-16.

[9] Partheepan S, Sanati F, Hassan J. Autonomous Unmanned Aerial Vehicles in Bushfire Management: Challenges and Opportunities. Drones 2023; 7(47): 1-34.

[10] Masat M, Saglam HK, Ertugrul M, Korul H. The use of unmanned aerial vehicles in the detection of forest fires with a gas detection technique. NanoEra 2021; 1(1): 14-18.

[11] Rahman AKZR, Sakif SMN, Sikder N, Masud M, Aljuaid H, Bairagi AK. Unmanned Aerial Vehicle Assisted Forest Fire Detection Using Deep Convolutional Neural Network. Intell. Autom Soft Comput 2022; 35(3): 3259-3277.

[12] Bahhar C, Ksibi A, Ayadi M, Jamjoom MM, Ullah Z, Soufiene BO, Sakli H. Wildfire and Smoke Detection Using Staged YOLO Model and Ensemble CNN. Electronics 2013; 12(1): 1-15.

[13] Barmpoutis P, Papaioannou P, Dimitropoulos K, Grammalidis N. A Review on Early Forest Fire Detection Systems Using Optical Remote Sensing. Sensors 2020; 20(22): 1-26.

[14] Moumgiakmas SS, Samatas GG, Papakostas GA. Computer Vision for Fire Detection on UAVs—From Software to Hardware. Future Internet 2021; 13(8): 1-17.

[15] Cory R, Tedrake R. Experiments in Fixed-Wing UAV Perching. In: AIAA Guidance, Navigation and Control Conference and Exhibit; 18-21 August 2008; Honolulu, Hawaii.

[16] B. Technology, "BAYKAR Technology," [Online]. Available: https://baykartech.com/tr/orman-yanginlariyla-mucadele. [Accessed 16 04 2023].