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Research Article

Evaluation of the performance of an unmanned aerial vehicle with artificial intelligence support and Mavlink protocol designed for response to social incidents response

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ABSTRACT

The unmanned aerial vehicle name is TOMHA, which was developed to be used in the response of social incidents, aims to support the operational activities of security forces in response to social incidents, to expand their domination areas, to detect incidents that may disturb social peace in advance and to provide rapid intervention with the new unmanned aerial vehicle technologies developed. The scope of the TOMHA system designed was kept comprehensive compared to other unmanned aerial vehicles and the scope includes intervention to social events, ordering in local administrations, defense, reconnaissance and attack activities in military operations, inspections arranged for public interest, AFAD and service areas, forest fires detection and intervention, and public order operations. This TOMHA is being developed using the Pixhawk flight control card and the jetson nano artificial intelligence card. In addition to these cards, it has the feature of manual or artificial intelligence supported autonomous flight thanks to GPS, telemetry, FPV transceiver module, camera systems and national software to be used. It is controlled through the controller using RC communication channel for manual use. TOMHA has a flight time of 13.6 minutes, a thrust of 4.45G and a speed of 78 km and a mileage of 4993 meters in optimum conditions. The findings obtained by the tests performed with the designed TOMHA prototype show similar results with the literature. Thanks to the national design, TOMHA stands out when it encounters other unmanned aerial vehicles. It is seen that the response of the system to the sudden changes caused by the maneuver movements in the simulation environment is very fast and it follows the changes.

1. Introduction

The use of unmanned aerial vehicles in various areas has achieved a great increase today. Due to its ease of use and service to more than one area, TOMHA, an aerial vehicle to respond to social events has been developed. While performing a literature review for TOMHA unmanned aerial vehicle, it was observed that Yolo V5 is generally preferred for artificial intelligence in other unmanned aerial vehicle technologies [1-3]. However, the trials and experiences obtained in the TOMHA development process have shown that SSD MobilNet V2 gives more stable and faster results. Another result obtained during the literature review is based on the straight label definitions. However, since the project is an aerial vehicle, it has made it compulsory to use various mathematical operations and algorithms rather than flat label definitions to obtain images with a certain slope and to detect thereof. In many studies conducted for autonomous flight, especially Jetson Nano was preferred [4], and these preferences played an effective role in the preference of Jetson Nano in the TOMHA process. However, the fact that Jetson Nano was not introduced as an auxiliary computer in the fabrication of Pixhawk made the connection and news reporting of Jetson Nano and Pixhawk very difficult.

Studies are also conducted in the field of hexacopter design and mathematical modelling [5-6]. For example, Akbulut et al. designed a four-propeller unmanned aerial vehicle. The drone structure was completed by designing components to meet the

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movement and usage demands [7]. In another study, flight performances of six-rotor and eight-rotor unmanned aerial vehicles were compared under different interference effects. It was concluded that the thrust forces of six-rotor and eight-rotor drones are high [8]. Wu et al. examined the mathematical modeling of hexacopters and conducted carbon fiber material studies to increase the damage resistance of hexacopters [9].

In some studies, manual drone flight was addresses [10-11]. Considering the Covid-19 pandemic process, Ramesh et al. conducted a study aiming to spray 2 lt of disinfectant in the tank from the body of the designed hexacopter drone to the ground [12]. In addition to manual drone flight, studies are also carried out in the field of autonomous drone flight [13]. In the unmanned combat aerial vehicle developed by Taş, Pixhawk flight control card, brushless engine, esc, gps module, telemetry module and NVIDIA Jetson Nano equipment were used to make a successful flight. Enemy UAV detection was also performed using various Python libraries such as YOLO, OpenCV, TensorFlow and Keras. At the same time, NVIDIA Jetson Nano and Pixhawk managed to move the motors instantly depending on the situation by communicating the flight control card via the MAVLink protocol [14]. Lorenz Meier et al. designed a drone that integrates a Pixhawk flight control card which enables autonomous driving using a built-in computer. One of the advantages of these projects is that Pixhawk flight control card can be programmed more easily than other control cards, provides integration with most components and parts, and has a suitable software network for autonomous driving [15].

TOMHA which was studies in this study besides having a manual use, has the ability to fly autonomously with artificial intelligence support; and with the help of its special design head, its ability to release the ammunition into the community in a way that will not harm the demonstrators, is the original value of TOMHA both in terms of design refinement and human values. Unlike the classical methods, it will be able to provide the security forces the ability to intervene in the operational activities with the support of artificial intelligence. This study consists of 4 parts: Introduction, Material and Method, Research-Results and Conclusions.

2. Material and Method

TOMHA is a supported unmanned aerial vehicle project supported by artificial intelligence in order to facilitate the operational activities of security forces. The selection of the materials to be used in the TOMHA project was carried out by taking into account the literature review and the desired abilities. The selected materials were grouped in 8 main units. These units are:

- Skeleton Unit
- Flight control unit
- Flight Unit
- Communication unit
- Power Unit
- TOMHA Controller
- Operations Unit
- Tool and Equipment Unit

Studies were carried out with the materials in these units in terms of system design and connections and calculations were carried out.

In the study, first of all the installation of the S550 body and landing gear of the vehicle was completed. Pixhawk was first installed on the installed body. MissionPlanner is clearly welded without mounting on the Pixhawk body various calibration settings have been made with the software. After the calibration settings, several initial tests were applied on the Mission Planner. Passing these tests, the Pixhawk is ready for mounting on the body. The Pixhawk Shock Absorber Antivibration Damper Set was fixed to the body and the installation was completed before placing the Pixhawk ready for body assembly. Impact tests of the Pixhawk placed in the anti-vibration bearing were carried out physically and after visual inspection, other steps were carried out. After the assembly of the body and Pixhawk, brushless motors and ESCs will be installed respectively. After the installation of the motors and the ESC, the Lipo battery connections were carried out and the engine connections were tested through the Mission Planner program. After the confirmation of the engine connections and the directions of rotation of the engine, the installation of the other equipment has been started respectively. RC control connections were made after the engine connections were made through the Mission Planner in appropriate test environments. After the connections were completed, the control key assignments and the expected reactions of the motors show were tested in healthy and appropriate test environments. The installation of the GPS and Telemetry modules was commenced by completing the engine on-off successfully, engine speed increase and decrease tests were performed by the help of RC control. Immediately after the GPS and telemetry connections were completed, the test process was carried out to obtain instantaneous GPS and telemetry data through the Mission Planner program. After observing that we received these data completely, "Fail Safe" tests were started. Fail Safe is the situation in which the UAV comes to the mission starting point by using the GPS module by itself, when the control of the UAVs is lost by the pilot. The appropriate test environment was created and the motors were powered and the test was started under RC control. It was checked whether data was received in a healthy way through the Mission Planner program. After this process, the installation of the system that provides live image transfer was carried out. FPV transmitter and RunCam2 camera were mounted on the drone and their connections were carried out properly. The FPV receiver was operated and paired with the FPV transmitter. It was observed that the image was taken instantly and completed at this stage. Basically, the completed TOMHA was subjected to the first controlled short-range flight test. In this test, healthy reception of GPS and telemetry data, inspection of RC control key combinations, test of drone maneuverability, continuous transmission of live FPV image, flight stabilization, etc. tests were performed. After the successful completion of this test, the assembly phase of the payload ignition and gripper system were started. The developed useful load ignition system was tested under healthy test conditions. Upon successful completion of their tests, the development of a gripper system commenced. The functionality has been taken into consideration in the design of the gripper system to be made. After the completion of the gripper system, the tests are completed in the outdoor environment. RC control and Pixhawk connections have been completed for control of the gripper system with success. After RC control connections of the useful load ignition system were completed, assembly procedures were carried out on TOMHA. The first test to be carried out with a useful load was applied after this stage. After completing all hardware for manual operation, TOMHA was operated by remote control throughout the entire test. With the remote control, all functional conditions expected from TOMHA were realized and the design and test process for the manual use of TOMHA was completed. In the next process, studies were carried out to perform all functions that can be used and applied with remote control in an autonomous system supported by artificial intelligence. In other words, the TOMHA project was completed with the remote control and then artificial intelligence support was provided. The YOLOV5 dataset was first customized for the needs of TOMHA for artificial intelligence-assisted autonomous use. Tests of the customized dataset were performed externally. The YOLOV5 dataset, whose tests were successfully completed, was installed on the Jetson Nano artificial intelligence computer. Immediately after installation on the Jetson Nano, processing of images taken via the LI-IMX219-MIPI-FF-nano CSI CAMERA was tested. Upon successful completion of object detection, Jetson Nano and Pixhawk started the communication phase. After the successful detection of objects with artificial intelligence, communication studies were initiated with Pixhawk through the MAVLink protocol in order to control the TOMHA by the jetson nano after the object detection. With the MAVLink protocol, autonomous landing, departure, autonomous discovery, autonomous object detection and autonomous return features have been added with the software written on the jetson nano. In short, with the MAVLink protocol, the jetson nano can take over the flight control and control the engines instead of the Pixhawk. In this way, all desired autonomous activities can be carried out. Figure 1 shows the general view of TOMHA, which was installed with all these features.

Figure 1. General view of the TOMHA designed

TOMHA has the ability to automatically switch from manual use to autonomous flight by the help of the software. In addition, it can be carried out in hundred percent autonomous flights. For the TOMHA project, 2 different camera systems were preferred. The reason for this is that the CSI camera is used for artificial intelligence operations and the RunCam2 camera is used for live image transmission.

3. Research and Results

Performance analyses of the product that emerged in the TOMHA project were carried out. Comparative visuals will be used to show the accurate and correct selection of the engine, ESC, propeller and battery. This section includes the data obtained with the equipment used, different equipment performance value comparisons, use of 4 motors instead of 6 motors, 5000 mAh, use with 20c battery, use of 20a ESC, use of motors below 1400KV (1200, 1000, 930), use of propellers other than APC 8*4.5.

First of all, the values of the materials used in the TOMHA project were entered into the ECalc system. As a result of these values, various graphs and analyses were carried out. As seen in Figure 2, with the materials used, TOMHA reached a thrust of 4.45 G for 13.6 minutes of flight time.

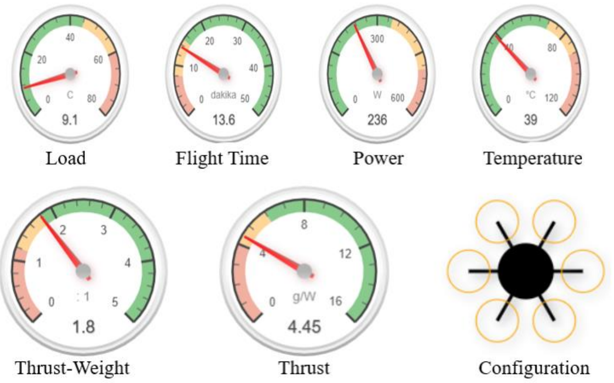

Figure 2. Values obtained with the materials used

As seen in Table 1, the battery used in the TOMHA project is 50 C. The fact that the motors normally have a current demand of 9.14 C is an indication that the selection is quite appropriate. The motors operating at optimum efficiency draw a current of 21 A as 13.10 A max at normal standstill. It is obvious that the selection of the 40a ESC is also quite appropriate. The change in g felt after the moment of departure relaxes the motors and the current drawn per motor is 8.42A. The motors used can accelerate logarithmically with 64% linear and 52%. In the TOMHA project, it is 228.7 Watts per weight.

Table 1. Electrical calculations of peripherals

Battery		Motor (flight)	
Electrical Load	9.14 C	Current	8.42 A
Voltage	11.34 V	Voltage	11.55 V
Energy	155.4 Wh	Speed	9066 d/min
Total Capacity	14000 mAh	Electrical Power	97.3 W
Used Capacity	11900 mAh	Mechanical Power	80.3 W
Min. Flight Time	5.6 min.	Efficiency	82.5 %
Fix. Flight Time	11.7 min.	Acceleration	64 %
Flight Time	13.6 min	Power-Weight	228.7 W/kg
Weight	1101 gr	Temperature	31 °C

In general, TOMHA can use 1481.7 W of energy within 14 minutes with 80% efficiency. It has the ability to climb up to 8.4 m per second. TOMHA can reach 78 km per hour and travel 4993 m with optimum conditions.

When the data shared in Figure 3 above are examined;

- 14 minutes flight time
- 8571 meters flight range (excluding drifting)
- The best range is 5714 meters and 70 km per hour
- The electrical power increases in direct proportion to the amperage
- The maximum number of revolutions has been reached around 21 A
- It is understood that the efficiency reaches saturation after a certain point.

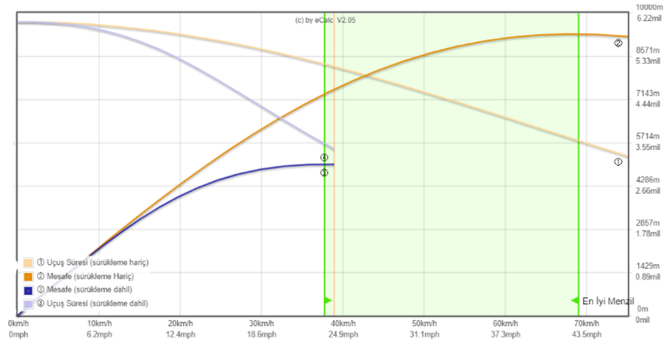

Figure 3. TOMHA flight time graph

The values given by the materials used in the TOMHA project and the performance values of different materials are compared figure 4.

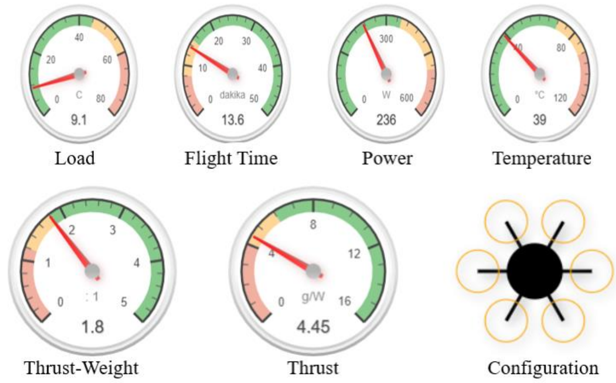

Figure 4. Four Motor utilization performance values

As shown in Figure 4, flight time, thrust weight, thrust, decrease in electrical power and estimated temperature value remained constant. The reason for this is to make analysis for the same battery.

When the graph shown in Figure 5 is examined, it is observed that the maximum range fell from around 8.5 km to around 4.5 km. The average speed of 70 km/h fell to 22.5 km/h optimally. While any rotor loss during flight with 6 motors does not affect the flight, in 4 motor flights, the flight is seriously affected. The condition of rotor failure is quite a bad situation.

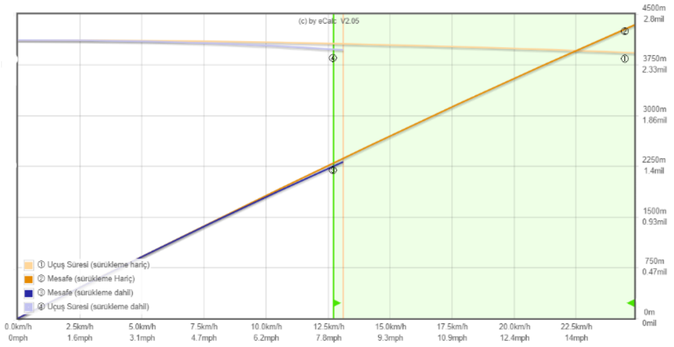

Figure 5. Four Flight time performance with motor use

Considering the graph given in Figure 6, with the decrease of the battery C value and capacity, the current that the motors will draw instantaneously from the battery has increased. flight time and electrical power decreased. The reason for the decrease in the estimated temperature is due to the battery's inability to deliver high current.

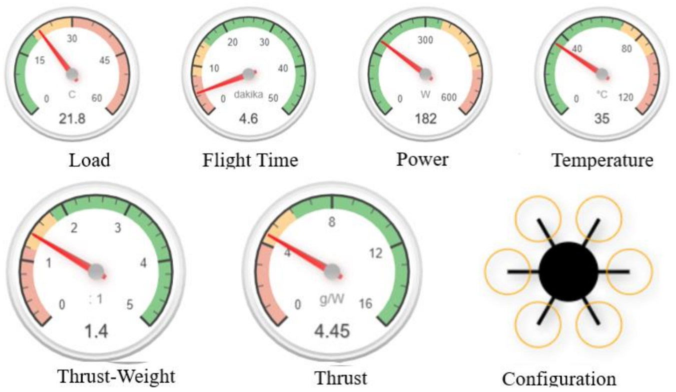

Figure 6. Utilization performance with 5000 mAh, 25 C battery

When the table shown in Table 2 is examined, it is concluded that 20a ESCs will not be suitable for the project, and that the ESCs will burn because the motors will already draw more than 20a current. The 20a ESC is not suitable.

Table 2. Performance chart with 20a ESC

Battery		Motor (flight)	
Electrical Load	9.01 C	Current	8.46 A
Voltage	11.35 V	Voltage	11.51 V
Energy	155.4 Wh	Speed	9066 d/min
Total Capacity	14000 mAh	Electrical Power	97.3 W
Used Capacity	11900 mAh	Mechanical Power	80.3 W
Min. Flight Time	5.7 min.	Efficiency	82.5 %
Fix. Flight Time	11.6 min.	Acceleration	64 %
Flight Time	13.5 min	Power-Weight	229.6 W/kg
Weight	1101 gr	Temperature	31 °C

When the graph given in Figure 7 is examined, it is seen that the flight time and thrust values are 0. The reason for this is the inadequacy of the engine thrust. In other words, it was documented that the 1400 kV engine preference is a very appropriate preference.

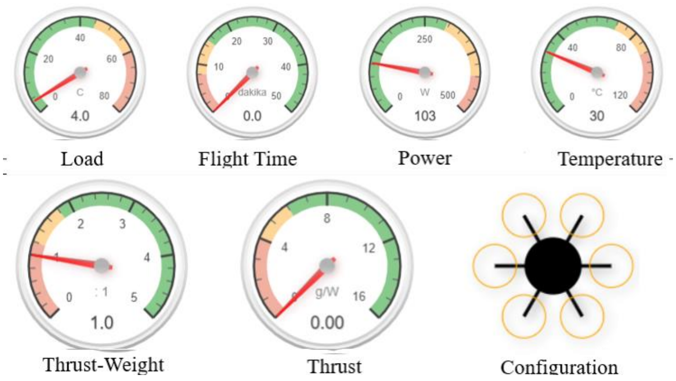

Figure 7. Use of engines below 1400 kV

When the graph given in Figure 8 is examined, it can be said that the current drawn per engine is very high, the electrical power is very high, the temperature value is very high, the flight time and the impulse are zero.

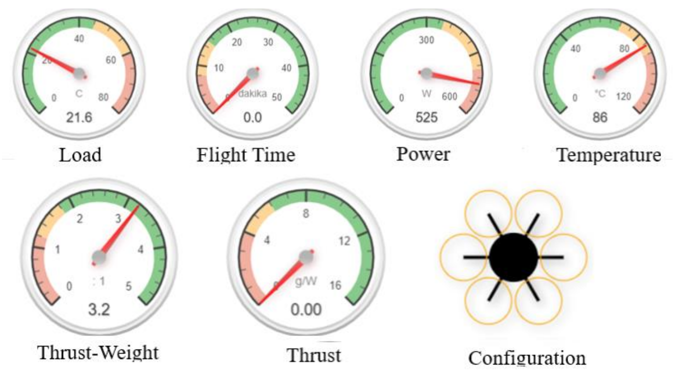

Figure 8. Non-APC 8*4.5 propeller utilization performance

4. Conclusions

The results obtained in general with performance tests with the prototype TOMHA designed are given below:

- Assignment with MAVLink protocol works with high accuracy. Although error warnings occur, this situation is corrected with system software and the aerial vehicle moves in accordance with its purpose.
- TOMHA flight stabilization is quite good.
- Landing problems have been eliminated with the landing gear update.
- Flight modes operate smoothly.
- With a flight time of 14 minutes, a flight range of 8571 meters is achieved, and a vehicle that completes its flight smoothly at a speed of approximately 5714 meters and 70 kilometers per hour is being designed.

- It has also been observed that the use of 14000 rpm engines gives better performance when used at 6 points compared to the use on four wings.

The results of the study clearly show that the designed TOHMA performs well. Some suggestions for future research can be listed as follows:

- FPV camera should be used instead of action camera. In this way, there is no need to make many optimization settings.
- All calibration settings should be made in an area away from electromagnetic waves.
- Compass in Pixhawk should be disabled after GPS module calibration. Because it is just below the battery, it can be exposed to electromagnetic waves and give wrong results. The mismatch between the information from the GPS and the information from the Pixhawk adversely affects the driving.

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References

[1] S. Murat, “İnsansız Hava Aracı Görüntülerinden Derin Öğrenme Yöntemleriyle Nesne Tanıma,” M. Eng. thesis, Maltepe Institute of Science, İstanbul, Turkey, Feb. 2021.

[2] TÜBAV, “Real-Time Vehicle Detection By Using Deep Learning Methods,” 2020.

[3] K.E. Kolaylı, A. Bayraktar, G. Durmuş, A. Altıntaş, “Göklerin Hâkimi Teknofest İstanbul Havacılık, Uzay ve Teknoloji Festivali Savaşan İha Yarışma Kritik Tasarım Raporu,” 2021.

[4] P. Kumar, S. Batchu, N. Swamy S. and S. R. Kota, "Real-Time Concrete Damage Detection Using Deep Learning for High Rise Structures," in IEEE Access, vol. 9, pp. 112312-112331, 2021, doi: 10.1109/ACCESS.2021.3102647.

[5] A. Kaçar, “Üç Dönerkanatlı ve Döner-Rotorlu İnsansız Hava Aracının Tasarımı,” Tech. Rep., 2013.

[6] E. Avşar, M. Yalçın, N. Boran, and Z. Ay,. “Döner Kanatlı İnsansız Hava Aracı Tasarımı,” Tech. Rep., 2021.

[7] A. Akbulut, E. Ömer, F. Er, and B. Sofu, “Ankara Üniversitesi Bilimsel Araştırma Projesi Sonuç Raporu,” 2016.

[8] Ş. Yıldırım , N. Çabuk ve V. Bakırcıoğlu , "Alti Rotorlu Ve Sekiz Rotorlu İnsansiz Hava Araçlarinin Farkli Bozucu Etki Altinda Uçuş Performanslarinin Karşilaştirilmasi", Konya Journal of Engineering Sciences vol. 8, pp. 552-562, 2020, doi:10.36306/konjes.594701

[9] Y. T. Wu, Z. Qin, A. Eizad, and S. K. Lyu, “Numerical İnvestigation of the Mechanical Component Design of a Hexacopter Drone for Real-Time Fine Dust Monitoring,” Journal of Mechanical Science and Technology, vol. 35, no. 7, pp. 3101–3111, Jul. 2021, doi: 10.1007/s12206-021-0632-y.

[10] A. Demirtaş, “Döner Kanatlı İnsansız Hava Araçları ile Görsel Verilere Dayalı Erken Yangın Algılama Sistemi,” Ankara University, Institute of Science, Ankara, Turkey, 2019.

[11] R. Çömert, “Uluslararası Deprem Mühendisliği ve Sismoloji Konferansı,” 2017. Available: http://www.tdmd.org.tr/TR/Genel/4UDMSK/pdf2017/3858.pdf

[12] K. Ramesh, B. Priya Dharshini, K. Haridass, S. Deepak Kumar, R. Gokul Raj, and V. Hariprasad, “Sanitization using Hexacopter Autonomous Drone,” in IOP Conference Series: Materials Science and Engineering, Feb. 2021, vol. 1059, no. 1. doi: 10.1088/1757-899X/1059/1/012043. Available: https://iopscience.iop.org/article/10.1088/1757-899X/1059/1/012043/pdf

[13] D. Lee, W. Gyu La and H. Kim, "Drone Detection and Identification System using Artificial Intelligence," 2018 International Conference on Information and Communication Technology Convergence (ICTC), 2018, pp. 1131-1133, doi: 10.1109/ICTC.2018.8539442.

[14] C.Y. Taş, “Teknofest İstanbul Havacılık, Uzay ve Teknoloji Festivali Savaşan İha Yarışması,” 2019. Accessed: Nov. 03, 2021. [Online]. Available: https://teknofest.org/pdfler/savasan_iha_yar%C4%B1smas%C4%B1_doner_kanat_blackb%C4%B1rd_iha_tak%C4%B1m_raporu.pdf

[15] L. Meier, P. Tanskanen, F. Fraundorfer and M. Pollefeys, "PIXHAWK: A system for autonomous flight using onboard computer vision," 2011 IEEE International Conference on Robotics and Automation, 2011, pp. 2992-2997, doi: 10.1109/ICRA.2011.59802