AVIATION TRANSPORT

UDC 519.6: 681.3(045)
DOI:10.18372/1990-5548.74.17354

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CLASSIFICATION OF MODERN UNMANNED AERIAL VEHICLES

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Abstract*—The article examines the issue of classification of unmanned aerial vehicles. The existing classifications of unmanned aerial vehicles are considered, as well as the characteristics by which unmanned aerial vehicles are classified. Like any aircraft, unmanned aerial vehicles can be classified by general characteristics such as type of aircraft, size, weight, engine type, degree of autonomy, application, and other characteristics. Due to dynamic development of the field of unmanned aerial vehicles, the number of their classification characteristics is increasing. Due to the rapid development of unmanned aerial vehicles, existing classifications of unmanned aerial vehicles do not consider some existing types of unmanned aerial vehicles. The main goal is to propose a classification of unmanned aerial vehicles, which takes into account great variety of modern unmanned aerial vehicles. The following characteristics were considered, according to which unmanned aerial vehicles are classified, namely - by type of aircraft, by size, by range and endurance, by degree of autonomy, by altitude, by engine type, by take-off and landing principle, by application. As a result of conducted analysis of characteristics by which unmanned aerial vehicles are classified, a classification of unmanned aerial vehicles is proposed based on their characteristics, designs and tasks they perform.*

Index Terms—unmanned aerial vehicle; characteristics; classification; methods; signs.

I. INTRODUCTION

Ukraine has a full cycle of developing aviation equipment and occupies a significant place on the world aviation market in the transport and regional passenger aviation sector, which allows for the development and production of aviation equipment. One of the promising areas today is the creation of unmanned aerial vehicles (UAVs) [1], [12]. UAVs are characterized by such advantages over manned aircraft as: no need for a crew and its life support systems, airfields; relatively low cost and low costs for their creation, production and operation. UAVs are implemented in all areas of human interest, and the emergence of areas of application where UAVs do not have a manned alternative is noted. A clear example of this technological development is the use of UAVs during the liquidation of emergency situations.

The variety of fields of application is determined by how technologically advanced UAVs are, which is characterized by classification features that determine the types of these aircraft and is the basis of their classification. Currently, there are a number of different approaches to the classification of UAVs, which take into account the relationship between the functions and tasks of UAVs. Thus, in the flight rules for unmanned aviation complexes of the state aviation of Ukraine, the classification of unmanned aerial vehicles of unmanned aviation complexes is given, which is general for the state unmanned aviation of Ukraine [14]. Based on the analysis of UAVs classifications, they mainly belong to the military sphere. To date, there is no regulatory and legal document in which the classification of unmanned aerial vehicles of unmanned aviation complexes, proper for the civil sphere, would be given.

Considering the mentioned issue of classification, defining the set of functions and tasks of unmanned aviation in the civil sphere is relevant for research with taking into account the experience of the leading countries of the world.

II. PROBLEM STATEMENT

There is no one standard when it comes to the classification of UAS. Defense agencies have their own standard, and civilians have their ever-evolving loose categories for UAS. People classify them by size, range and duration of flight, and use a tier system that is employed by the military [2].

According to NATO standards, UAVs, as well as aircraft with a pilot on board, are divided into 3 classes based on the total take-off weight (Table I):

I – total take-off weight up to 150 kg.

Class I is divided into categories:

- micro – up to 2 kg;
- mini – up to 15 kg;
- small – from 15 kg.

II – total take-off weight up to 600 kg.

III – total take-off weight of more than 600 kg.

In the NATO classification, UAVs are divided into classes according to the category of UAVs, the level of military operations, the altitude of use, the radius of action, the level of use [3].

The US Department of Defense uses five groups to classify UAVs, into which UAVs are divided according to size, maximum take-off weight, operating altitude and speed (Table II) [2].

In the NATO classification and the classification of the US Department of Defense, UAVs are divided into classes according to the total take-off weight, but the number of classes into which they are divided differs, as well as the weight by which they are divided.

Therefore, due to the lack of a single classification of unmanned aerial vehicles, a problem may arise when UAVs of the same model can be assigned to different classes according to different classifications.

TABLE I. NATO'S UAS CLASSIFICATION SYSTEM STANAG 4670 [3]

Class	Category	Normal Employment	Normal Operating Altitude	Normal Mission Radius	Primary Supported Commander	Example Platform
Class III (> 600 kg)	Strike/ Combat	Strategic/National	Up to 20 000 m	Unlimited (BLOS)	Theatre	Reaper
	HALE	Strategic/National	Up to 20 000 m	Unlimited (BLOS)	Theatre	Global Hawk
	MALE	Operational/Theatre	Up to 14 000 м	Unlimited (BLOS)	JTF	Heron
Class II (150–600 kg)	Tactical	Tactical Formation	Up to 5500 m	200 km	Brigade	Hermes 450
Class I (<150 kg)	Small (>15 kg)	Tactical Unit	Up to 1500 m	50 km	Battalion, Regiment	Scan Eagle PD-2
	Mini (<15 kg)	Tactical Sub -unit	Up to 900 m	Up to 25 km	Company, Platoon, Squad	Skylark
	Micro (<66 J)	Tactical Sub -unit	Up to 60 m	Up to 5 km	Platoon, Squad	Black Widow

TABLE II. UAV CLASSIFICATION ACCORDING TO THE US DEPARTMENT OF DEFENSE

Group:	Group 1	Group 2	Group 3	Group 4	Group 5
Size	*Small*	*Medium*	*Large*	*Larger*	*Largest*
Max take-off weight	< 20 lb (9.1 kg)	> 20 & < 55	> 55 & < 1320	>1.320 lb (600 kg)	>1.320 lb (600 kg)
Operating altitude	< 1,200 ft (370 m)	< 3.500 ft (1,100 m)	< 18.000 ft (5.500 m)	< 18.000 ft (5.500 m)	> 18.000 ft (5.500 m)
Speed	< 100 kn (190 km/h)	< 250 kn (460 km/h)	< 250 kn (460 km/h)	Any speed	Any speed

III. CLASSIFICATION OF UAV

Unmanned aerial vehicle classification methods are based on the use of various UAV features. Unmanned aerial vehicles can be classified using the following characteristics.

Classification of UAVs by type of aircraft. According to the type of aircraft, the main types of UAVs are aircraft-type, helicopter-type, and multi-rotor.

Aircraft-type UAV. Aircraft-type UAVs are also known as fixed-wing UAVs. In UAVs of this type, the lift force is created using aerodynamic method, using pressure of the air flowing on the fixed wing. Designs of UAV of this type, almost all layout schemes of the aircraft and types of fuselages found in manned aviation are used. In most cases, UAVs of this type are characterized by long flight duration, high maximum flight altitude and high speed.

Helicopter-type UAV. Helicopter-type UAVs are also known as rotary-wing UAVs (helicopter UAVs). The lift force in a helicopter-type UAV is created aerodynamically, due to the rotating propeller blades and not due to the wings. Wings are either completely absent or play an auxiliary role. The obvious advantages of helicopter-type UAVs are the ability to hover at a point and high maneuverability.

Multi-rotor: UAVs that have more than one rotor. The most commonly used designs are tricopters, quadcopters, hexa-copters and octacopters.

Fixed-Wing Hybrid VTOL: Hybrid UAVs with longer flight time. They have the stability of fixed-wing UAVs as well as the ability to hover, take off and land vertically. VTOL refers to vertical takeoff and landing [8].

For classification according to size, the following sub-classes can be used: Very small UAVs, Micro or Nano UAVs, Small UAVs, Mini UAVs, Medium UAVs, Large UAVs [2].

Very Small UAVs: The very small UAV class refers to UAVs, which size ranges from the size of a large insect to 30–50 cm in length. Insect-like UAVs with flapping or rotating wings are a popular micro-project. They are extremely small in size, very light. The larger ones use a conventional aircraft configuration. The choice between rotary or flapping wings depends on the desired maneuverability. Designs based on flapping wings allow landing on small surfaces. Examples of very small UAVs are the IAI Malat Mosquito, Aurora Flight Sciences Skate, and the Cyber Technology CyberQuad. Examples are shown on Fig. 1 [2].

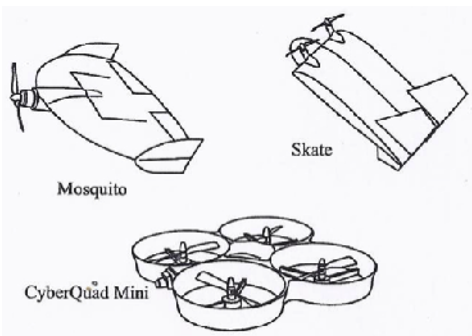

Fig. 1. Examples of very small UAVs

Small UAVs: The class of small UAVs (also sometimes called mini-UAVs) refers to UAVs that have at least one dimension greater than 50 cm and no larger than 2 meters. Many designs in this category are based on fixed-wing models, and most are launched manually by throwing them into the air. Some of the UAVs of this class are built on the basis of a rotary wing aircraft.

Medium UAVs. Medium UAVs refer to UAVs that are too heavy to be carried by one person, but are smaller than light aircraft. They usually have a wingspan about 5–10 m and has ability to carry a payload of 100 to 200 kg. Examples of medium fixed-wing UAVs are Hunter, Watchkeeper, Boeing Eagle Eye, RQ-2 Pioneer, BAE Skyeye R4E and RQ-5A. American Aerospace's RS-20 is another example of a crossover UAV that meets the specifications of both small and medium UAV. Examples of medium UAVs are shown of Fig. 2.

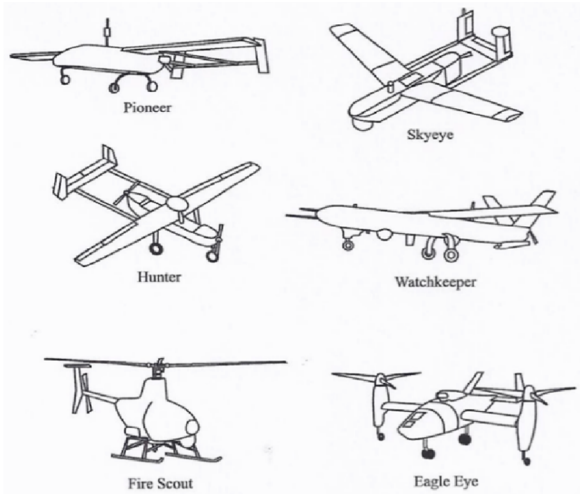

Fig. 2. Examples of medium UAVs

Large UAVs: The large UAV class refers to large UAVs used primarily for military operations. Examples of such large UAVs are the General Atomics Predator *A* and *B* and the Northrop Grumman Global Hawk [2].

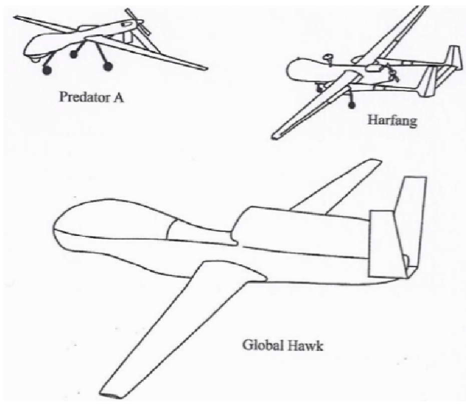

Fig. 3. Examples of Large UAVs

A. Classification by range and duration of flight

Very close-range UAVs: This class includes UAVs with a range of 5 km, an operating time of 20 to 45 minutes. UAVs of this class are very close to model airplanes.

Close Range UAVs: UAVs of this class has a range of 50 km and an operating time of 1 to 6 hours.

Short Range UAVs: includes UAVs of this class have a range of 150 km or more and an operating time of 8 to 12 hours.

Mid-range UAVs: This class includes UAVs which have ultra-high speed and an operating radius of 650 km.

Endurance UAVs: this class includes UAVs with a 36-hour operating time and a 300 km range. This class of UAV can operate at an altitude of 30,000 feet [2].

B. Classification by degree of autonomy: UAVs can also be classified by the degree of autonomy in flight

Level 0: No automation. The pilot is in complete control of every movement. UAVs are constantly controlled manually.

Level 1 – pilot assistance. The pilot continues to control the overall operation and safety of the UAV. However, a drone can take on at least one vital function for a limited period of time. It does not have continuous control of the UAV and never controls speed and direction simultaneously, but it can provide navigational support and/or maintain altitude and position.

Level 2 – partial automation. The pilot is still responsible for the safe operation of the UAV and must be ready to take control of the drone should something happen. However, under certain conditions, the drone is able to take control of heading, altitude and speed. The pilot is still in full control, monitors airspace, flight conditions and emergency response. Most manufacturers currently build drones at this level, where the platform can assist with navigation functions and allow the pilot to abandon some tasks.

Level 3 – conditional automation. As in Level 2, the drone has ability fly itself, but the human pilot must still be alert and ready to take over at any moment. The UAV notifies the pilot in case if intervention is need, so the pilot acts as a backup system. This level means that the drone can perform all functions "under certain conditions".

Level 3+ – automated drone deployment. Drone's autonomy can be measured in another way by considering its operating environment. Some manufacturers have made progress in automating the deployment of drones by creating "fully automated drone boxes." This means that there is no need for a person to supervise the flight.

Level 4 – high automation. A drone can be controlled by a human, but this is not always necessary. Under the right circumstances, it can fly on its own. The drone is expected to use backup systems so that if one system fails, it remains operational. Its behavior depends on a fixed set of rules or a fixed built-in functionality that defines the system's behavior.

Level 5 – full automation. The drone controls itself under any conditions, without waiting for human intervention. This includes full automation of all flight tasks under all conditions. There are no examples of UAVs of this type at the moment. However, they are expected to be able to use artificial intelligence tools to plan their flights, in other words, autonomous learning systems with the ability to change normal behavior [4].

C. Classification according to altitude

Low-altitude UAVs flies at an altitude of up to 1000m. These UAVs are the micro-UAV category.

Medium-altitude UAV has maximum altitude from 1.000 m to 10.000 m. A large UAV belongs to this category.

High-altitude UAVs are every UAVs that can fly at altitudes over 10.000 m. There is concern that operation of these UAVs could interfere with commercial and military piloted aircraft, and there are need for high-tech collision avoidance systems to be developed and integrated into these UAVs for flying in populated airspace [11].

D. Classification of UAVs by engine type

Piston engines. Advantages of a two-stroke engine: Two-stroke engines are used in UAVs widely because of lower mass; have high power-to-weight ratio (P/W); they have better SPED (density of propulsive energy) values. Disadvantages: High noise level compared to four-stroke engines and the Wankel engine.

Four-stroke engine. Advantages: Better fuel economy than a Wankel engine. Disadvantages: rather noisy, not commonly used due to heavy weight; very low power-to-weight ratios compared to a two-stroke engine.

Wankel engine Advantages: high power to weight ratio; simple construction; endurance and reliability of operation, so it is possible to work at high revolutions; valveless system; the center of mass of the piston overlaps the axis of the eccentric, providing full dynamic balancing; the possibility of using lower-octane fuel than in a traditional piston engine; easy start of the engine at low temperatures. Disadvantages: high emission of carbon dioxide;

higher cost of production compared to piston engines; high fuel consumption; relatively low torque [5].

Jet propulsion Advantages: very high power-to-weight ratio (low weight), very low weight with compared to other engines Disadvantages: very high fuel consumption, not used in small UAVs due to low fuel economy at low revs.

Turbojet engine: Advantages very high power-to-weight ratio (low weight), relatively light compared to others. Disadvantages: very high fuel consumption.

Turboprop engine Advantages: consumes cheaper fuel (aviation kerosene), efficient at low cruising speeds, light weight, its ongoing maintenance is less complicated than in other engines.

Electric motor. Advantages: more efficient than other technologies, low weight, good power-to-weight ratio. Disadvantages: low SPED value (density of propulsive energy), not suitable for long distances due to low energy values in batteries [5].

Classification according to take-off and landing principle: Horizontal takeoff and landing (HTOL), vertical takeoff and Landing (VTOL), using means of launch and landing.

Horizontal takeoff and landing is considered as continuation of fixed-wing aircraft. They have a high cruising speed and a smooth landing. VTOL drones has ability to hover vertically in flight and land vertically, but they cruising speeds are limited due to the deceleration of the retreating propellers [10].

Classification according to control methods: linear flight controllers: UAVs controls using linear methods are conventional flight control algorithms such as proportional integral derivative (PID), H∞ controller, gain scheduling, and linear quadratic regulator (LQR)

PID-control. The PID controller has been widely used in system control with a simple algorithm. This method determines the errors between the set value and the real value according to equation (1). The controller includes three factors: proportional (K_P), integral (K_I) and derivative (K_D). The strategy reduces the errors to zero using the PID equation given in equation (2)

$$\text{Error} = \text{Setpoint} - \text{Feedback}, \qquad (1)$$

where "Error" is different value between setpoint and feedback "Setpoint" and "Feedback" are the desired value and actual value.

$$u(t) = K_P e(t) + K_I \int_0^t e(t)\,dt + K_D \frac{de(t)}{dt}, \qquad (2)$$

where $u(t)$ is the control factor of the UAVs, K_P, K_I, and K_D are respectively proportional, integral, and derivative gain coefficients, and $e(t)$ is deviation between setpoint and feedback.

Classical PID control is a simple method that can be used to control unmanned aerial vehicles (UAVs). The main control tasks are stabilization and hovering motion, robustness, and good performance for the UAVs.

New PID controllers are optimized by adding intelligent algorithms such as fuzzy logic, particle swarm optimization (PSO) and neural networks to improve dynamic performance

LQR controller. The LQR algorithm is an optimal linear controller for controlling the dynamic system with minimum costs shown in equation 3. LQR usually uses noise conditions and missing information to perform UAV's flight. The control input minimizes the following cost function

$$J_{\text{LQR}} = \int_0^\infty y_i^T(t) Q_y(t) + u_i^T(t) R u_i(t)\,dt, \qquad (3)$$

where J_{LQR} is a quadratic cost function, u_i and y_i are the control input and control output, Q and R are weight matrices of dimensions.

H∞ controller. H∞ algorithm is an effective method to deal with issues of uncertain parameters and external disturbances encountering the flight process of the UAVs.

Nonlinear flight controllers: To overcome some of the shortcomings of the linear controller, various nonlinear controllers have been developed and applied to UAVs. These non-linear flight controllers are derived from the original UAV dynamic model. Thus, the design processes of nonlinear controllers are more complicated than those of linear controllers, but have better control performance. Nonlinear flight controllers are: feedback linearization, inverse step, sliding mode control, adaptive control, and predictive model control.

Feedback linearization. Feedback linearization is a powerful control algorithm for designing nonlinear systems. The main idea of this approach is to algebraically transform the dynamics of a nonlinear system into a partially or fully linearized system so that the feedback control technique can be applied. Dynamic model inversion is a special case of feedback linearization that has been effectively investigated for applications to manned and unmanned aerial vehicles.

However, dynamic model inversion can be vulnerable to modeling errors and uncertainties. Therefore, such an approach requires accurate modeling. In addition, it does not withstand external obstacles.

Backstepping. Backstepping control is a well-known recursive algorithm for general nonlinear control systems. The main idea of this method is to put the controller decomposition into several steps to complete. Its advantage is convergence rate fast and it can handle external disturbance well, while its limitation is low reliability.

Sliding mode control (SMC). Sliding mode control is an easy-to-implement nonlinear control algorithm that implements a discontinuous control signal to the system to command it to slide along a given trajectory. Its main advantages are low sensitivity to external disturbances, good tracking ability and quick response.

Adaptive control. Adaptive control is an effective and robust control method for systems with unmodeled dynamics and parametric uncertainties. This control algorithm automatically compensates for parameter changes in the system dynamics by adjusting the controller characteristics in such a way that the overall performance of the system remains unchanged or is maintained at an optimal level.

Model predictive control (MPC). Model Predictive Control (MPC) is another non-linear technique that has also been used for UAV control. MPC uses a dynamic system model to predict future states of the system with minimized error by solving the optimal control problem.

Complex control algorithms. It can be seen that a single nonlinear controller has some limitations in the UAV control process. To overcome this problem, there are researches that combine the advantages of two or more algorithms together to improve the performance of the controller [13].

E Classification according to application

Personal: Used for tasks such as videography and entertainment. Commercial: Used for tasks such as product delivery, infrastructure monitoring, and aerial imaging. Government and Law enforcement: Used for tasks such as firefighting and patrolling.

Military: Used for tasks such as surveillance and combat attacks [8].

So, taking into account all the characteristics that have been considered, it is possible to classify UAVs Table III.

TABLE III. UAV CLASSIFICATION

Characteristic	**Types**
Type of aircraft	Aircraft-type UAV (fixed-wing UAV), example: Global Hawk Helicopter-type UAV, example: Fire Scout Multi-rotor, example: CyberQuad Mini Fixed-Wing Hybrid VTOL, example: Eagle Eye
Size	Very small UAVs examples: IAI Malat Mosquito, Cyber Technology CyberQuad Small UAVs UAVs examples: RQ-11 Raven RQ-7 Shadow Medium UAVs examples: Boeing Eagle Eye, RQ-2 Pioneer Large UAVs examples: General Atomics Predator, Northrop Grumman Global Hawk
Range and duration of flight	Very close-range UAVs (range of 5 km, duration of flight 20 to 45 minutes) Close range UAVs (range – 50 km, duration of flight 1 to 6 hours) Short range UAVs (range – 150 km or longer, duration of flight 8 to 12 hours) Mid-range UAVs (radius 650 km) Endurance UAVs (radius of 300 km, duration of flight 36 hours)
Degree of autonomy	Level 0: No Automation Level 1 – Pilot Assistance Level 2 – Partial Automation Level 3 – Conditional Automation Level 3+ – Automized Drone Deployment Level 4 – High Automation Level 5 – Full Automation
Altitude	Low altitude (up to 1000 m) examples (FPASS, Pointer and Dragon Eye) Medium altitude (1000 m and 10000 m) High altitude (over 10000 m) examples (X-45, predator B, Darkstar and Global Hawk)
Engine type	Piston engine (Two-stroke engine, Four-stroke engine, Wankel engine) Jet propulsion (Turbojet engine, Turboprop engine) Electrical engine
Take-off and landing principle	Horizontal takeoff and landing (HTOL) vertical takeoff and Landing (VTOL) With the help of means of launch and landing

Application	Personal Commercial Government and Law enforcement Military
Control methods	Linear flight controllers (PID-control, LQR controller, H∞) Nonlinear flight controllers (Feedback linearization, Backstepping, Sliding Mode Control (SMC), Adaptive control)

IV. CONCLUSIONS

The article analyzes the existing types of UAVs and their features. Various methods and approaches to the general classification of UAVs have been studied. Signs and characteristics by which it is possible to classify UAVs and their features are also considered.

In the result of the analysis, a classification of UAVs was proposed, which highlights all the variety of UAVs that exist today, and also allows you to choose a further path of development, which is directly related to both the experience of their creation and the features of its application in modern conditions and in the future.

REFERENCES

[1] *Ministry of Internal Affairs of Ukraine "Instructions on the use by military personnel of the National Guard of Ukraine of technical devices and technical means that have the functions of photo and film shooting, video recording, photo and film shooting equipment, video recording" from* 13.01.2021 https://zakon.rada.gov.ua/laws/show/z0294-21 [in Ukrainian].

[2] *Classification of the Unmanned Aerial Systems* https://www.e-education.psu.edu/geog892/node/5

[3] Vittorio Castrillo,& Angelo Manco,& Domenico Pascarella & Gabriella Gigante, "A Review of Counter-UAS Technologies for Cooperative Defensive Teams of Drones," *Drones*, 2022, 6(3), 65. https://doi.org/10.3390/drones6030065.

[4] *DRONEII: Tech Talk – Unraveling 5 Levels of Drone Autonomy* https://dronelife.com/2019/03/11/droneii-tech-talk-unraveling-5-levels-of-drone-autonomy/

[5] Taha Elmokadem & Andrey Savkin, "Towards fully autonomous UAVs: A survey," *Sensors*. 2021, 21. 6223. https://doi.org/10.3390/s21186223.

[6] Miroslaw Adamski, "Analysis of propulsion systems of unmanned aerial vehicles," *Journal of Marine Engineering & Technology*, 16:4, 291–297, 2017. https://doi.org/10.1080/20464177.2017.1383337

[7] S. Nagarajan, Jagannathan Panneerselvam, Raj Mohmed Sadiq Batcha, "Nano Unmanned Aerial Vehicles – Drone or Helicopter in Military," *International Journal of Engineering Research & Technology (IJERT) CONFCALL*, vol. 7, Issue 11, 2019.

[8] Vinay Chamola & Pavan Kotesh Aayush & Agarwal & Navneet Gupta & Mohsen Guizani & Naren Naren, "A Comprehensive Review of Unmanned Aerial Vehicle Attacks and Neutralization Techniques," *Ad Hoc Networks*, vol. 111, 2021, 102324. https://doi.org/10.1016/j.adhoc.2020.102324.

[9] Mohamed Zakaria & Moatassem Abdallah & Adnan Elshaafi, *Design and Production of Small Tailless Unmanned Aerial Vehicle (SAKR 2)*, 2012. https://doi.org/10.21608/amme.2012.36970

[10] G. Singhal, B. Bansod, and L. Mathew, "Unmanned Aerial Vehicle Classification, Applications and Challenges: A Review," *Preprints*, 2018, 2018110601 https://doi.org/10.20944/preprints201811.0601.v1.

[11] Maziar Arjomandi, "Classification of Unmanned Aerial Vehicles," *The University of Adelaide*, 2007, 49 p. [in Australia].

[12] I. S. Romanchenko, O. I. Lysenko, S. M. Chumachenko, O. M. Tachinina. et al., *Models of application of information and telecommunication technologies based on unmanned aircraft systems in emergency situations*. Monograph, Kyiv: NAU, 2016, 335 p. [in Ukrainian]

[13] Hoa Nguyen & Toan Quyen & Van-Cuong Nguyen & Anh Le & Hoa Tran & Minh Nguyen, "Control Algorithms for UAVs: A Comprehensive Survey," *EAI Endorsed Transactions on Industrial Networks and Intelligent Systems*, vol. 7, Issue 23, e5, 2020. https://doi.org/10.4108/eai.18-5-2020.164586.

[14] *Order of the Ministry of Defense of Ukraine About approval of Rules of performance of flights by unmanned aviation complexes of the state aviation of Ukraine. From December 8, 2016 #661*. Retrieved from https://zakon.rada.gov.ua/laws/show/z0031-17#Text [in Ukrainian].

Received October 25, 2022.

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О. М. Тачиніна, О. І. Лисенко, В. О. Кутєпов. Класифікація сучасних безпілотних літальних апаратів

В статті досліджено питання класифікації безпілотних літальних апаратів. Розглянуто існуючі класифікації безпілотних літальних апаратів а також ознаки, за якими безпілотні літальні апарат класифікуються. Як і любий літак, безпілотні літальні апарати можуть бути класифіковані за різними ознаками, такими як тип літального апарату, розмір, вага, тип двигуна, рівень автономності, тип двигуна, за призначенням та іншими ознаками. В зв’язку з динамічним розвитком сфери безпілотних літальних апаратів, збільшується кількість їх класифікаційних ознак. Через швидкий розвиток безпілотних літальних апаратів, існуючі класифікації безпілотних літальних апаратів не розглядають деякі існуючі види безпілотних літальних апаратів. Основна мета – запропонувати класифікацію безпілотних літальних апаратів, яка брала за увагу велике різноманіття сучасних безпілотних літальних апаратів. Були розглянуті наступні ознаки, за якими безпілотні літальні апарати класифікуються, а саме – за типом літального апарату, за розміром, за дальністю дій і витривалістю, за рівнем автономності, за висотою, за типом двигуна, за типом зльоту та посадки, за використанням. В результаті проведеного аналізу ознак, за якими класифікуються безпілотні літальні апарати, запропонована класифікація безпілотних літальних апаратів на основі їх характеристик, конструкції та завдань, які вони виконують.

Ключові слова: безпілотні літальні апарати; класифікація; методи; ознаки; характеристики.

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Освіта: Національний авіаційний університет, Київ, (2021).
Напрям наукової діяльності: безпілотні літальні апарати.
Кількість публікацій: 3.
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