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PROGRAMMED MODULE FOR TRANSPORTATION OF HUMANITARIAN MEDICAL CARGO BY DRONES IN EXTREME CONDITIONS

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Abstract*—The structure and functions of various drones (UAVs) for medical purposes were observed, their general analysis was done. The main goal and objectives of the work were outlined: to develop the structure of a container for UAVs for medical purposes, and to clarify the possibility of its transportation to programmatically defined object. These were done basing on the analysis of prototypes – versions of previously developed UAV modules for providing various types of medical assistance in extreme conditions. Different versions of modules for medical UAVs were characterized. The need to deliver a container to a specific object or person requires the creation of appropriate software to automate this process; developed software was based on face recognition technology – convolutional neural network. The work on the development of a container structure for medical purposes was disclosed in details. Its technical task was to present a version of medical container for multirotor type UAV with vertical take-off and landing. The medical container itself was made in the form of a streamlined cylinder to improve its aerodynamic characteristics, which reduces the value of air resistance during flight and increases the overall maneuverability and stability of the structures. Developed medical UAV was equipped with modules for diagnosing person's condition and providing them with appropriate medical care. Developed UAV can be used repeatedly, and modular systems of medical equipment and first aid supplies can be parachuted over the location of potentially injured person. The modules can be conditionally divided into several groups: diagnostic, resuscitation, a subgroup for transporting biomaterials, devices for detecting possible chemical contamination, etc. In process of the work, there were subdivided and developed several such modules (groups of devices) in the newly developed UAV. The data about the practical application of work results were given: possibility of introducing a UAV with a first aid container into the activities of emergency services (ambulance, other emergency services); use for detecting of chemical substances, environmental pollutants using chemo-specific detectors in conditions of potential danger to human life and health; provision of medical care in extreme conditions; delivery of necessary medications (vaccines, medical preparations) or performing the function of a courier for delivering biological samples to the nearest laboratory.*

Keywords—Modeling; unmanned aerial vehicle; drone; functional module; construction; medical cargo.

I. INTRODUCTION

Among the wide range of functions of UAVs, one of the most important is medical assistance, because human life has absolute value. To provide medical assistance, UAVs can be used to transport medicines, blood, transplants, vaccines, biological samples, devices for diagnosing the person's condition and resuscitating the victim. Moreover, the use of UAVs (drones) allows you to carry out a relief mission without risking the pilot's life in an unknown or potentially dangerous situation.

The importance of drones using to search for people and help them is growing in conditions of natural and man-made disasters, during anti-terrorist operations and combat operations. Such a significant practical potential of UAVs attracts the attention of scientists and inventors. Modern research is aimed at improving the structure of drones, developing new types of software, improving the range and speed of flight, and increasing the load capacity [1] – [9].

II. PROBLEM STATEMENT

Currently, work in the field of developing UAV modules is being carried out both in the theoretical aspect and being tested in practice. Scientists analyze the features of the development of UAVs in contemporary conditions, determine the basics of safe operation of unmanned aerial systems, and solve the

problems of data acquisition, processing [1] – [9]. Despite the presence of a wide range of research and the availability of patents on improving the structure and function of UAVs, it should be noted that there is an insufficient number of open access thorough works that would summarize data on the necessary technical and software characteristics of UAVs with a container for medical care [9]. Also insufficient, from our point of view, is the collaboration of contemporary professionals in technique with their colleagues in medical sciences, although the works in this direction exist and they are extremely important. The authors started to do their work in outlined direction basing on some their practical experience in this [9] and neighboring directions of technique [10] – [12], studying the effects in extreme conditions where drones usage is preferable, as well as preliminary development and use of some necessary specific mathematical methods.

The ***purpose*** of this work was to develop the structure of a container for UAVs for medical purposes and to clarify the possibility of its transportation by UAVs to a programmatically defined object or person. To do this basing on the analysis of prototypes – versions of previously developed UAV modules for providing various types of medical assistance in extreme conditions.

III. Problem Solution

A. Analysis of practical experience in developing a container for a UAV for transporting of medical cargo

In the process of the work, a number of prototypes and analogues of this construction were observed, and its main components were also highlighted: suggested structure of the UAV [9]; the structure of the container by itself. Necessary software of the UAV for performing of some tasks of medical care in extreme conditions was developed; the factor of extreme conditions was studied too [10], [11].

In process of the work the structure of the UAV as a carrier of container for medical care was analyzed: characteristics of the quadcopter frame, types of possible engines, power source, appropriate size and angle of inclination of the propeller blades, speed controller, drone air controller.

The quadcopter frame must be characterized by certain properties, namely: strength, lightness, aerodynamics, maintainability, balance.

The engine for a quadcopter is the main thing, because without it, the drone launch is impossible, as well as the flight itself. Engines are electric and internal combustion. Electric motors are divided into several types: commutator motor, commutator motor with gearbox, and brushless motor.

Propellers for quadcopters convert the energy of the shaft rotation into lifting force. The most important characteristics of the propeller are its size and the angle of inclination of the blades (pitch).

Speed controllers for quadcopters are designed to control the on/off of electric motors, as well as set the rotation rate. The speed controller performs the following functions: braking, reverse, opto-coupler. When choosing a speed controller, one should pay attention to the following indicators: maximum constant and peak voltage, battery voltage, internal resistance and pulse frequency.

The flight controller for a drone collects the data from sensors and commands from the user and makes some changes to the speed of motors rotation. All flight controllers have a basic set of sensors: a gyroscope (Gyro) and accelerometers (acc); some advanced configurations also have a barometer and magnetometer (compass). Also there is a connection point for all other peripherals such as global positioning system (GPS), light-emitting diodes (LEDs), sonar, etc.

The power source for a drone provides energy to all multicopter systems, and the duration of the flight depends on it. The main criteria that determine the choice of a particular battery are capacity, current conductor, internal structure of the battery, weight and dimensions.

Unmanned aerial vehicles can also be equipped with various modules depending on the purpose of their use. Thus, when equipping individual modules, they can be conditionally divided into several groups: diagnostic, resuscitation, a subgroup for transporting biomaterials, devices for detecting possible chemical contamination, etc.

So, the resuscitation team may include: a breathing bag for artificial lung ventilation, a mechanically driven aspirator, and a portable automatic external defibrillator.

The diagnostic group can be divided into two subgroups: direct diagnostics using appropriate devices and transportation of biomaterials for their further usage. Into the direct diagnostic subgroup can be included such devices, as: a three-channel electrocardiograph; a portable diagnostic monitor with the functions of measuring of blood pressure, determining the temperature; a portable clinical blood analyzer.

The subgroup of biomaterials transporting for their further usage (for example, for processing) requires the presence of special containers.

When providing medical care to a person in extreme conditions, especially in situations of possible chemical contamination, determining the

level of chemical pollution of the environment is of great importance. As a result, the development of detector devices that record chemical pollution of the environment is an urgent issue. For the development of chemo-sensitive surfaces of detectors, experience in studying the physicochemical nature of ion selectivity and specificity of artificially created and natural membranes is important.

A container for transporting biological samples and vaccines has to meet certain conditions: heat resistance, tightness, reliable fastening of test tubes with samples, and the possibility of disinfecting the inside of the container, the presence of a bactericidal air filter and aerodynamics of the shape.

The unmanned aerial vehicle that will be equipped with the above described container must have elongated support struts that allow placing the payload (medical container) in the lower part, which helps to lower the center of mass of the device and increase its stability during flight.

The need to deliver the container to a specific object or person requires the creation of appropriate software to automate this process. This software is based on the face recognition technology called a convolutional neural network (CNN). Information on the development of such software can be published by the authors in the future.

B. Various specific versions of UAVs medical modules and equipment for them

To provide effective first aid, in some cases it is not enough to have just a set of basic medical equipment. Saving of human life and health level of oxygen saturation, measuring preservation sometimes requires the use of technical diagnostic tools; to solve this problem, an unmanned aerial vehicle first aid complex can be proposed, which includes an unmanned aerial vehicle with fixed modular medical equipment systems and first aid means. In some cases, the drone must have connectors that will provide the ability to charge its batteries from the car's power supply system and from the household power supply network. It would be nice, if for some cases the body of the modular systems of first aid means contains a voice notification unit that automatically starts after the touching of the ground and turns off automatically: when the UAV is raised to a certain height above the ground or manually (by pressing a special button).

For the works in chemically polluted areas and for some tasks solution it is important to install chemosensitive sensors on unmanned aerial vehicles. Already now, the demand for UAVs is growing in the fields of emergency services (firefighters, police, ambulance), energy, mining, construction, geodesy (cartography), transportation, agriculture, etc. The methods of taking off and landing of UAVs are known, and control systems for their various types have been developed and are being developed accordingly. Today, scientific and technical groups of specialists are successfully solving the problem of remote detection of harmful chemicals using detectors installed on UAVs. To solve these problems, it is advisable to use UAVs, which are used in a variety of fields of activity, in different climatic conditions and solve numerous tasks; respectively, their popularity increases.

Scientists note [11], that for the development of physical models of some sensor elements of chemical pollution sensors of artificial and natural origin, a set of works on the selective chemosensitivity of surfaces of different types of glass can be used. Various samples of such glasses have specific chemosensitivity either by themselves or acting as artificial membranes - bases for coating them with layers of other specific substances. Relevant studies have shown that even for solving relatively simple tasks (for example, for removing current-voltage characteristics) when studying the selective membranes under study in living and artificial objects; one has to face significant difficulties. In the case of finding adequate physical solutions these difficulties can be eliminated.

C. Development of a container structure for medical purposes.

The technical task of this chapter is to present a variant of a medical container for a multirotor type UAV with vertical take-off and landing. The medical container itself is made in the form of a streamlined cylinder to improve its aerodynamic characteristics, which reduces the value of air resistance during flight and increases the overall maneuverability and stability of structures.

The proposed version of the container provides reliable fastening of medical test tubes with biomaterial or vaccine. It also provides for disinfection of the internal cavity of the medical container compartment in case of biomaterial leakage.

The medical container itself, to improve its aerodynamic characteristics, should be made in form of a streamlined cylinder, which reduces the value of air resistance during the flight and increases its maneuverability and stability. The medical container should ensure reliable fastening of the tubes with biomaterial and disinfection of the internal cavity of it medical compartment in case of biomaterial leakage.

This specified technical task is achieved by the fact that the UAV with vertical take-off and landing has elongated support struts that allow placing the

payload (medical container) in the lower part. This helps to reduce the center of mass of the device and increase its stability during the flight. In this case, the medical container is made in the form of a streamlined construction and a lid (cover) fixed in the lower part of the multirotor type of this drone. The structure of container is given on Figs 1 – 3.

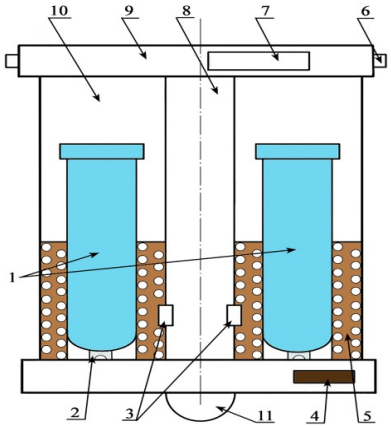

Fig. 1. The medical container includes: (1) test tubes with biomaterial; (2) biomaterial leakage control sensors; (3) electromagnetic valves; (4) power supply; (5) tube guides; (6) medical module mount; (7) bactericidal air filter; (8) container with disinfectant liquid (in the center of the structure); (9) container lid; (10) container body; (11) video camera. The central axis of the structure is indicated by a dotted line

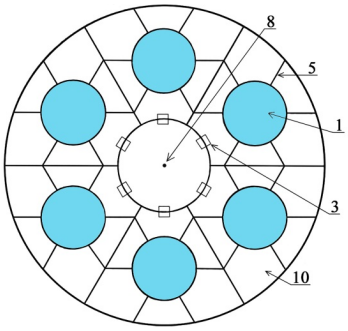

Fig. 2. Top view of the container structure: (1) tubes with biomaterial; (3) solenoid valves; (5) tube guides; (8) container with disinfectant liquid in the center; (10) surface of the container body. The center of the structure is marked with a dot

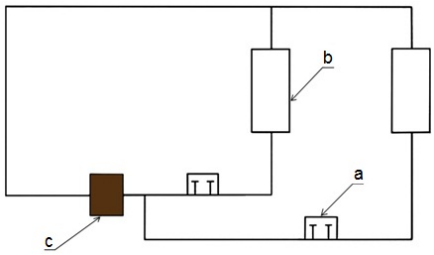

Fig. 3. Electrical diagram of a medical container for a drone: (a) biomaterial leakage control sensor; (b) solenoid valve; (c) power supply

This container lid is equipped (Figs 1 and 2) with a fastening mechanism and a bactericidal air filter that connects the container cavity with the atmosphere. The container body is divided into compartments for placing test tubes with biomaterials installed in perforated round holes that hold them in a vertical position. In the center of container there is a volume with a disinfecting liquid equipped with electromagnetic exhaust valves. In the lower part of the container compartments there are sensors for monitoring the leakage of biomaterials. In this case, each sensor for monitoring the leakage of biomaterials corresponds to an electromagnetic valve that connects this volume with disinfecting liquid with the container compartment for case of biomaterials leakage.

IV. Conclusions

The structure and functions of medical container for drones were described in present article. The practical significance of the work done, of the obtained results is in the possibility of the use of obtained results for the work in extreme conditions and provision of medical care in various types of such extreme conditions. Also the introducing UAVs with a first aid container into the activities of emergency services is a great idea (ambulance, other emergency services). Such container can be applied for detecting of chemical substances, environmental pollutants using chemo-specific detectors in conditions of potential danger to human life and health; delivery of necessary medications (vaccines, medical preparations) or performing the function of a courier for delivering biological samples to the nearest laboratory.

References

[1] "Order of the Ministry of Defense of Ukraine "On Approval of the Rules for Flights by Unmanned Aircraft Systems of State Aviation of Ukraine," dated: 08.12.2016 # 661. https://zakon.rada.gov.ua/laws/show/z0031-17#Text [in Ukrainian]

[2] "World experience in legal regulation of the use of drones – Information note prepared by the European Information and Research Center at the request of a People's Deputy of Ukraine," http://euinfocenter.rada.gov.ua/uploads/documents/28939.pdf [in Ukrainian]

[3] "Drones' evolution". https://bigpicture.ru/evolyuciya-bespilotnikov/ [in Ukrainian]

[4] K. V. Gumenyuk, and V. R. Horoshko, "A look from the past to the future: unmanned flying drones as an element of the evacuation of the wounded in the medical service of the Armed Forces of Ukraine," *Emergency Medicine*, vol. 5(16), 2020. [in Ukrainian]

http://webcache.googleusercontent.com/search?q=cache:-ov9uMZc9jUJ:emergency.zaslavsky.com.ua/article/download/212220/214318/483250+&cd=5&hl=uk&ct=clnk&gl=ua

[5] V. L. Savytskyi, "Medical support of the Armed Forces of Ukraine in the anti-terrorist operation: experience and directions of its improvement," *Military Medicine of Ukraine,* vol. 1, pp. 5–11, 2015. [in Ukrainian]

[6] V. B. Andronatiy, V. O. Zhakhovskyi, O. Yu. Bulakh, and V. G. Livinskyi, "The medical support system of the Armed Forces of Ukraine: current state and development directions in view of the trends of changes in the order of use of army troops," *Science and Defense,* vol. 3, pp. 23–29, 2014. [in Ukrainian]

[7] "The US is developing medical evacuation vehicles based on UAVs", *WeapoNews*. [in Ukrainian] https://www.weaponews.com/uk//4440-ssha-rozroblyayut-medichn-evakuatori-na-osnov-bpla.html

[8] *Patent* "Aviation system of support of rescue works". Patentscope. https://patentscope.wipo.int/search/ru/detail.jsf?docId=EA195389134&_cid=P21-KOO609-27342-2 .

[9] B. D. Moskalenko, N. S. Fomenko, A. G. Lizunova, and O. M. Klyuchko, "Biotechnological approaches in construction of drones for medical purposes," *Biotechnologia Acta*, 2025, vol. 2(18), pp. 63–67. https://doi.org/10.15407/biotech18.02.063

[10] O. M. Klyuchko, A. Ya. Biletsky, and D. O. Navrotskyi. "Method of application of biotechnical monitoring system with expert subsystem and biosensor," Patent UA 141863 u. G01N33/00, C12Q1/02, C12N 15/00. Publ.2019/2/11. Application u201804663

[11] O. M. Klyuchko, "Method for monitoring of chemicals influence on bioorganisms in few time intervals," Bulletin of NAU, vol. 2, pp. 105–112, 2009. *Patent* UA 134575 U; G01N33/00, C12N 15/00, A61P 39/00. Application: u201812443, Publ. 2019, Bull. 10.

[12] O. M. Klyuchko and R. P. Hayrutdinov, "Modeling of electrical signals propagation in neurons and its nanostructures," *Electr. Control Syst.,* vol. 2(28), pp. 120–124, 2011. https://doi.org/10.18372/1990-5548.28.870

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В. М. Шутко. Б. Д. Москаленко, О. М. Ключко, Н. С. Фоменко. Програмований модуль для транспортування вантажів гуманітарного медичного призначення дронами у екстремальних умовах
Розглянуто структуру та функції різних дронів (БПЛА) медичного призначення, виконано їх загальний аналіз. Викладено основну мету та завдання роботи: розробити структуру контейнера для БПЛА медичного призначення, а також з'ясувати можливість його транспортування до програмно визначеного об'єкта. Це зроблено на основі аналізу прототипів – версій раніше розроблених модулів БПЛА для надання різних видів медичної допомоги в екстремальних умовах. Охарактеризовано різні версії модулів для медичних БПЛА. Необхідність доставки контейнера до конкретного об'єкта або особи вимагає створення відповідного програмного забезпечення для автоматизації цього процесу; програмне забезпечення розроблялося на технології розпізнавання облич згортковою нейронною мережею. У деталях розкрито роботу з розробки структури контейнера медичного призначення. Її технічним завданням було виконати варіант медичного контейнера для БПЛА багатороторного типу з вертикальним зльотом та посадкою. Сам медичний контейнер виконано у формі обтічного циліндра для покращення його аеродинамічних характеристик, що зменшує значення опору повітря під час польоту, підвищує загальну маневреність та стійкість конструкцій. Розроблений медичний БПЛА оснащено модулями для діагностики стану людини та надання їй відповідної медичної допомоги. Розроблений БПЛА використовуватиметься багаторазово, модульні системи медичного обладнання та засоби першої допомоги будуть скидатися на парашутах над місцем розташування постраждалої особи. Модулі умовно розділити на кілька груп: діагностичний, реанімаційний, підгрупа для транспортування біоматеріалів, пристрої для виявлення можливого хімічного забруднення, тощо. У процесі роботи визначено та розроблено кілька таких модулів (груп пристроїв) у складі новоствореного БПЛА. Наведено дані про практичне застосування результатів роботи: можливість впровадження БПЛА з контейнером першої допомоги в діяльність служб екстреної допомоги (швидка допомога, інші служби екстреної допомоги); використання для виявлення хімічних речовин, забруднювачів навколишнього середовища за допомогою хемоспецифічних детекторів в умовах потенційної небезпеки для життя та здоров'я людини; надання медичної допомоги в екстремальних умовах; доставка необхідних ліків (вакцин, медичних препаратів) або виконання функції кур'єра для доставки біологічних зразків до найближчої лабораторії.
Ключові слова: моделювання; безпілотний літальний апарат; дрон; функціональний модуль; конструювання; медичний вантаж.

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