Bionic Method for Controlling Robotic Mechanisms during Search and Rescue Operations

Gulmira Berdibayeva
Almaty University of power engineering and telecommunications, Almaty, Kazakhstan
Email: horli@mail.ru

Oleg Bodin
Penza State University, Penza, Russia
Email: bodin_o@inbox.ru

Kasymbek Ozhikenov
Satbayev University, Almaty, Kazakhstan
Email: kas_ozhiken@mail.ru

Rat Berdibayev
Almaty University of power engineering and telecommunications, Almaty, Kazakhstan
Email: r.berdybaev@aues.kz

***Abstract*—The article is devoted to the development and study of a bionic method of controlling robotic mechanisms during search and rescue operations in order to minimize medical consequences in an emergency based on a heterogeneous group of unmanned aerial vehicles with a hierarchical organization of information interaction. It is shown that the use of the bionic method in voice control systems for a heterogeneous group of unmanned aerial vehicles increases the efficiency of search and rescue operations and the provision of emergency medical assistance to victims, providing the necessary medical assistance in the "golden hour" of disaster medicine.**

Distinctive features of the solution proposed by the authors to the problem of minimizing medical consequences in an emergency are:

1. The use of unmanned aerial vehicles, which significantly reduces the time spent on information processing and increases the likelihood of providing medical assistance to victims within the "golden hour".

2. The use of a bionic method of control of unmanned aerial vehicles, which makes it possible to implement all stages of search and rescue operations and increase the safety of employees in life-threatening situations.

3. Equipping the injured with portable cardiac analyzers, which makes it possible to assess the functional state of the victim's organism and carry out medical triage of the injured.

4. Correction of the order of the victims, which allows the provision of emergency medical assistance to those in need, first of all, to the victims.

***Index Terms*—bionic control method, heterogeneous group of unmanned aerial vehicles, disaster medicine, mobile telemedicine complex, sorting algorithm for victims, voice control system, recognition of speech commands.**

I. Introduction

The current state of society is characterized by a constant increase in the number and scale of the negative consequences of various anthropogenic and natural disasters, recorded as emergency situations (ES). The number of victims of natural disasters on the planet annually increases by an average of 6%. According to scientists, the expected maximum aggregate material damage with the cost of emergency response can be 10% of gross domestic product (GDP) per year.

Society becomes dependent on the technosphere - its destruction is tantamount to disaster, and uncontrolled unlimited growth of technosphere can lead to environmental degradation. Therefore, protecting the population from emergencies is an obligatory social function of the state. In the event of an emergency resulting from the disaster, the number of those affected who need emergency medical care (EMC) exceeds the ability to provide it in time with the forces and means of the health system.

In emergency situations, the impossibility of providing EMC to all those in need is obvious. The coronavirus pandemic has confirmed this position.

II. Problem Statement

The doctrine of disaster medicine is medical sorting (MS), based on the need to provide medical care as soon as possible, to as many victims as possible, who have a

Manuscript received September 8, 2020; revised February 1, 2021.

doi: 10.18178/ijmerr.10.3.128-136

chance to survive. It is known that the main condition for the successful provision of EMC is its ***timeliness***. In disaster medicine, there is the concept of a "golden hour" - this is the time during which the medical care provided on the spot or the prompt delivery of the victim to the hospital guarantees him the maximum chance of survival and the least risk of complications after injuries. The human body, falling into an extreme situation, reacts instantly by turning on compensatory and protective mechanisms, and at the maximum level, in order to maintain vital activity for at least an hour. Then the blood supply to the main organs: the heart and brain begins to decrease, while the chances of doctors to save the victim are sharply reduced [1].

The optimal period for providing EMC is up to 30 minutes after injury. When victim stop breathing, this time is reduced to 5-10 minutes. The importance of the time factor is emphasized by the fact that among people who received EMC during the first 30 minutes after an injury, complications occur two times less than in people who received it later. According to the World Health Organization (WHO), one in twenty out of a hundred who died in peacetime accidents could have been saved if they had been given EMC at the scene of the incident. Timely medical care is crucial to preserve the life and health of victims, reduce disability and mortality.

The purpose of the work is to improve the capabilities of the mobile telemedicine complex (MTMC) for providing EMC to victims during search and rescue operations (SRO) based on the implementation of new methods of obtaining and processing measurement information.

Achievement of this goal, according to the authors, is ensured by the use of a bionic method of controlling robotic mechanisms during SRO to minimize medical consequences in emergency conditions based on a heterogeneous group of unmanned aerial vehicles (UMAV) with a hierarchical organization of information interaction.

The subject of research is the MTMC to provide EMC to victims during the SRO.

Subject of study is:

– Bionic control method for robotic mechanisms in emergency situations;

– Structure and operation of the MTMC using the heterogeneous UMAV group;

– Measures to ensure EMC to victims during SRO.

To achieve the goal, the following tasks are solved:

1. Justification and development of a bionic method for controlling robotic mechanisms during SRO to minimize the medical consequences in emergency situations.

2. Development of the structure and functioning algorithm of MTMC.

3. Justification and development of an automated subsystem for accounting for victims of emergency situations based on an assessment of the functional state of the body.

III. Problem Decision

A. Bionic Control Method by Robotic Mechanisms in Emergency Situations

The construction of biotechnological systems is based on a bionic methodology, which involves the study of structural features and functioning of a living organism, which are necessary and sufficient to solve specific problems of synthesis of systems for a specific purpose.

Thanks to scientific and technological progress and the development of information technology, it became possible to apply the principles of organization, properties, functions and structures of wildlife in technical devices and systems and the development of a new branch of science called bionics. Bionics is an interdisciplinary science, it accumulates existing knowledge in biology and radio engineering, chemistry and cybernetics, physics and psychology, biophysics and instrument engineering.

The main areas of work in bionics are as follows:

– the study of the nervous system of humans and animals and the modeling of nerve cells (neurons) and neural networks to further improve computer technology to improve the capabilities of the mobile telemedicine complex (MTMC) for providing EMC to victims during search and rescue operations (SRO) based on the implementation of new methods for obtaining and processing measurement information. The achievement of this goal, according to the authors, is ensured by the use of the bionic method of controlling robotic;

– the develop new elements and devices for automation and telemechanics (neurobionics);

– investigation of the sensory organs of other receptive systems of living organisms with the aim of developing new sensors and detection systems;

– the study of the principles of orientation, location and navigation in various animals to use these principles in technology; study of morphological, physiological, biochemical characteristics of living organisms to put forward new technical and scientific ideas.

By the bionic method of controlling objects is meant a control system for mechanisms and devices, in which various manifestations of the organism’s vital functions are used as control signals, with the exception of most voluntary movements.

The control action in bionic control can be: bioelectric potentials generated by various excitable tissues, mechanical and acoustic phenomena that accompany the functioning of the cardiovascular system and respiration, fluctuations in body temperature, etc. Bioelectric systems and voice control systems are most widespread. In bioelectric control systems biopotentials are generated by skeletal muscle, heart, brain, and nerves. In voice control systems the biopotentials generated by the brain are converted by the human speech path into acoustic vibrations, which are transmitted to the control system, where they are converted into electrical signals, and then also processed by filtering and amplification, analyzed and implemented as command, control signals.

The authors have developed a technique for applying the bionic control method (BCM) in emergency situations [2]. The essence of the proposed method lies in the implementation by robotic mechanisms of the SRO algorithm described in [3]. This algorithm includes the following mandatory steps: ***reconnaissance*** of the emergency zone, ***search*** for victims and determination of their location, ***minimization*** of the levels of exposure to damaging factors (DF), ***provision*** of medical assistance to victims, ***evacuation*** of victims.

A distinctive feature of the implementation of the SRO algorithm by the robotic mechanisms is that all stages of the SRO algorithm are implemented on the basis of the bionic method using a team of unmanned aircraft (UMAV), consisting of vessels of various functional purposes: UMAV for coordinating purposes (CP), UMAV for search purposes (SP), UMAV for environmental purposes (EP), UMAV for medical purposes (MP) and UMAV for evacuation purposes (EvP). Consider the functioning of the UMAV during the SRO in emergency situations. Before the launch of the UMAV, a preliminary assessment is made of the presence and values of the damaging factors (DF) in the emergency zone. A preliminary assessment is carried out on the basis of the analysis of the available maps of the area and forecasts made in advance for this object in accordance with the requirements and according to the methods given in [4]. It is estimated that what could happen at the facility, is happen, and based on this, the entire emergency zone is dividing into sections as shown in Fig. 1.

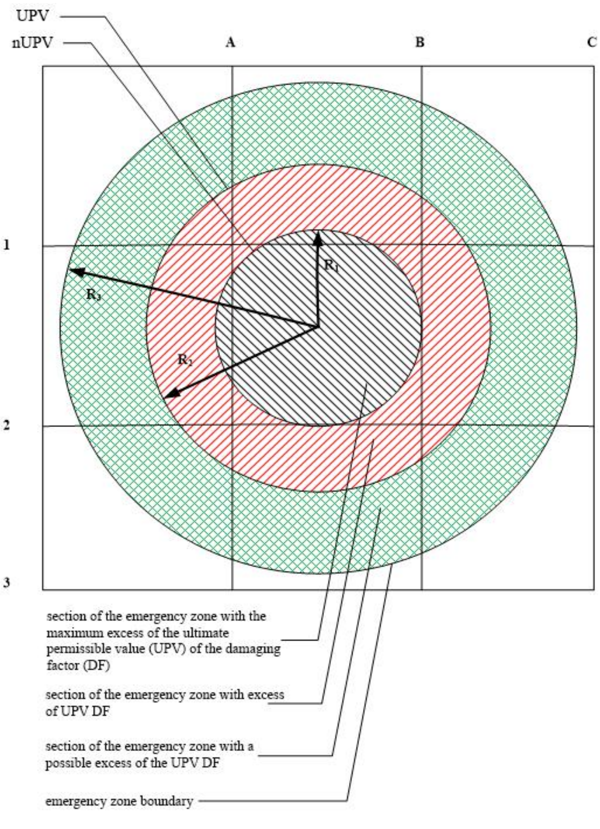

Figure 1. Emergency zones.

At the same time the operational staff forms and distributes UMAV teams in emergency zones. For this the full composition of the UMAV team is sent to the section of the emergency zone with the maximum excess of the ultimate permissible values (UPV) of the DF: UMAV CP, UMAV SP, UMAV EP, UMAV MP and UMAV EvP;

To the section of the emergency zone in excess of the UPV DF unmanned aircraft UMAV CP, UMAV SP, UMAV EP are sent;

The UMAV MP and the UMAV EvP are sent to area where victims are found there;

A section of the emergency zone with a possible excess of the UPV DF inspects the UMAV SP, and if necessary, send UMAV EP, UMAV MP and UMAV EvP.

At the **reconnaissance** stage, the MTMC operator manages the UMAV using a set of motion control commands:

– start - stop;
– forward - backward;
– up - down;
– right - left;
– compress-decompress.

At the **search stage for victims**, the MTMC operator uses a voice notification system to ensure dialogue with the victim.

Minimization of the impact of DF levels is carried out by UMAV EP. To do this, it flies around a given section of the emergency zone and, using a gas analyzer, as well as an infrared and a video camera, detects DF sources: depressurized process tanks and pipelines with chemicals, chemical spills, combustion centers, destroyed electrical installations, transformer substations, etc. And when detection of sources, DF takes measures to eliminate or minimize the levels of DF: leak detection and sealing in containers or pipelines, neutralization of spills, extinguishing fires, de-energizing electric current sources, etc.

At this stage of the SRO, the MTMC operator, in addition to the set of control commands for the movement, gives specialized commands to the UMAV EP: sealing; extinguishing; spraying; blackout.

According to the authors, the bionic control method during SRO in emergency situations is characterized by the following advantages:

1. Under extreme emergency conditions, the MTMC operator is psychologically more comfortable to control a robotic mechanism.

2. The MTMC human-machine interface shortens the physical distance between a person and a robotic mechanism and allows the MTMC operator, without risking his life, to conduct SRO in extreme emergency situations.

3. The human-machine interface of MTMC increases the efficiency and mobility of communication between a person and a robotic mechanism.

Thus, UMAV increases the efficiency and mobility of the SRO.

B. *Structure and Functioning Algorithm of MTMC*

MTMC is a complex of diagnostic medical and telecommunication equipment, including satellite communications, mounted on an off-road chassis or any other vehicle. This allows you to transfer, if necessary, the data of examinations in digital form to central medical institutions, where doctors and highly qualified specialists analyze these data and inform the MTMC staff of the necessary conclusions and recommendations. MTMC are equipped with everything necessary for long-term autonomous operation, even in conditions of lack or complete absence of the necessary medical and telecommunication infrastructure. MTMC contains the following functional modules:

– heterogeneous group of UMAV;
– the automated subsystem for the account of victims in emergencies (ASAVES).
– diagnostic equipment (DE);
– telecommunication equipment (TCE).

The structural diagram of MTMC is shown in Fig. 2.

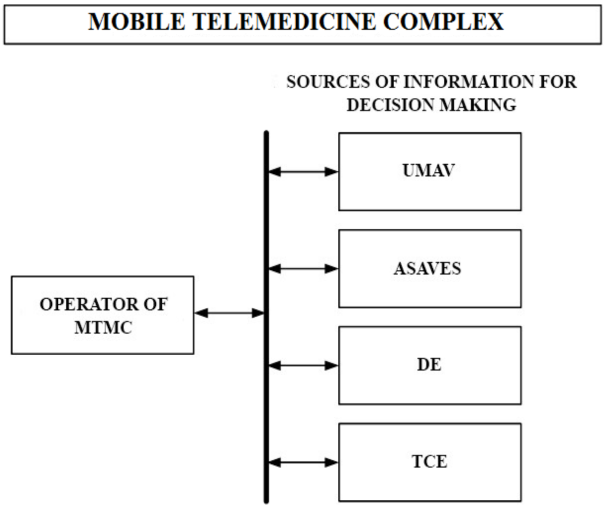

Figure 2. Structural diagram of MTMC.

The following medical and evacuation measures are assigned to MTMC:

– Search and medical sorting of victims;
– Participation (together with emergency rescue and other units) in providing first aid to victims and their evacuation from the lesion;
– Organization and provision of first aid;
– Organization and provision of qualified and specialized medical assistance to victims,
– Creating favorable conditions for their subsequent treatment and rehabilitation;
– Organization of medical evacuation of victims;
– Organization and conduct (if necessary) of a forensic medical examination of the dead and forensic medical examination of the victims.

A distinctive feature of the proposed structural scheme of MTMK (see Fig. 2) is the presence of a heterogeneous group of UMAV and ASAVES, which increase the efficiency of MTMC due to the timely provision of EMC to victims.

As UMAV use a remotely piloted aircraft vertical takeoff and landing with a variable angle power plants, equipped with a radio repeater for data exchange with the operator MTMC [5]. Table I shows the technical characteristics of modern UMAV [6].

TABLE I. TEHNICAL PARAMETRS MODERN DRONS

1	2	3	4	5	6	7	8
DJI Matrice 600 Pro		15	6	16	2500	65	5
FreeFly Alta 8		18	8	-	300	40	15
Green Bee 1200		-	20	20	-	-	-
Vulcan UAV Black Widow Black Widow		0,85	-	30	240	50	2
Versadrones Heavy Lift Octocopter (HLO)		-	12	-	2000	70	

The numbers in the first row of Table I denote the names of the columns:

1. Name UMAV.
2. The appearance of the UMAV.
3. The take-off weight of the UMAV, kg.
4. Payload UMAV, kg.
5. Flight time, min.
6. Flight height, m.
7. Speed, km / h.
8. Flight range, km.

The authors have developed an original algorithm for the operation of MTMC using UMAV, which can be used to search for and provide EMC to victims in emergency situations. The scheme of the functioning algorithm of the UMAV MTMC is shown in Fig. 3.

During the SRO after start-up, take-off is performed and the UMAV is sent to the emergency zone [7]. The operator independently controls the UMAV from MTMC, analyzing the data received from the detected devices. At the same time, the MTMC operator sees everything that the UMAV sees and detects. In addition to determining the location of obstacles and the presence of fire, using a color and infrared video cameras and a 3D laser scanner, the level of carbon dioxide in the atmosphere at the location of the victim is measured using the built-in gas analyzer to determine the level of environmental aggressiveness.

The MTMC Global Navigation Satellite System unit is responsible for accurate positioning. The flight altitude chosen by the MTMC operator affects the scanning depth, since the ultra-wideband radar (UWR) used only works at a distance of up to 30 meters, and, accordingly, the deeper the victim is located, the lower the altitude of the UMAV . During the scanning of the UWR, the transmitter sends a signal; if it hits the victim, the signal is reflected and received by the UWR receiver.

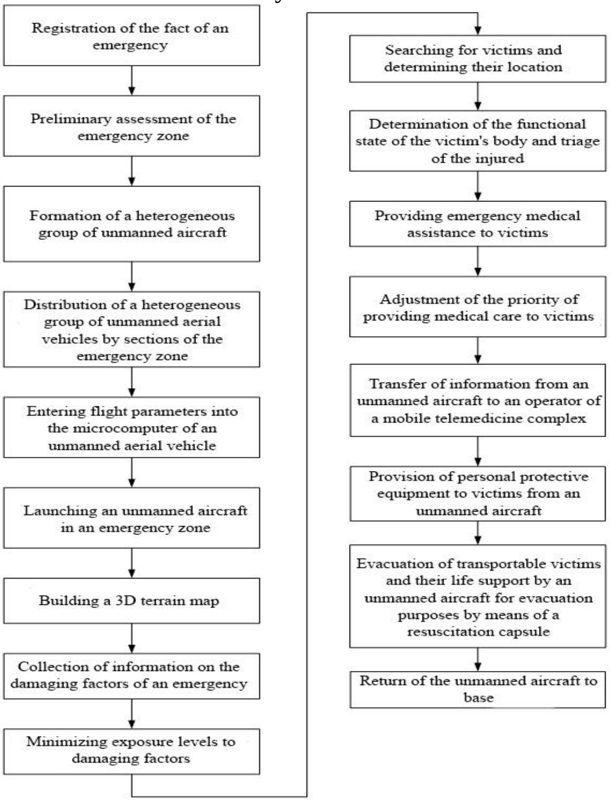

Figure 3. The scheme of the functioning algorithm of the UMAV MTMC.

Experimental work showed that UWR signals are well reflected from the body of a living person. Moreover, the forms of the reflected signals depend on the physiological parameters of the person (cardiac activity: pulse rate and amplitude of movement of the chest - respiration rate). This dependence is laid in the basis of the functioning of the UWR during SRO. Fig. 4 shows typical signals of UWR, which is located at a distance of 3 meters from a brick wall having a thickness of 50 centimeters and allows the victim to be observed behind the wall, both when moving around the room and in a stationary position - according to the movement of the chest.

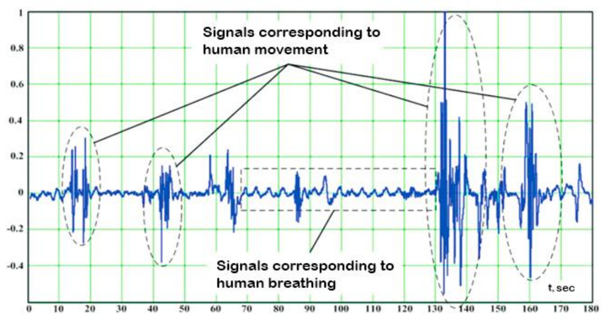

Figure 4. UWR signals when a victim is detected.

The short duration of the signal (a few nanoseconds) ensures high accuracy of determining the location of the victim behind the obstacle and the stable operation of the UWR in conditions of multiple reflections from surrounding objects. UWR measures the power of a signal reflected from an object, the time and direction of its propagation. When the victim moves, information appears about his speed in the controlled area due to the Doppler frequency shift proportional to the radial component of this speed. If the victim is motionless, information about his presence behind the barrier can be obtained by changing the Doppler frequency shift of the signal reflected from the movement of the human chest during breathing and heart contractions.

All the data received is sent to the UMAV microcomputer, which processes it and sends it to the MTMC operator’s computer via the radio command line. The data presented in the computer of the MTMC operator allows the MTMC team to determine the rescue priorities, ways to save the victims and quickly carry out a rescue operation.

After the victim was discovered, a signal is issued on the MTMC operator’s computer and data is displayed on the depth of its location, its functional state of the organism (FSO) and its environment, then the MTMC operator reports the exact location of the victim to the MTMC brigade.

After the victim’s UMAV is detected, the MTMC operator switches to the UMAV manual control mode for the delivery of personal protective equipment (PPE), a first-aid kit and a mobile phone to communicate with the MTMC brigade if the victim is conscious and on the ground.

Since the UMAV is an apparatus for vertical take-off and landing, the delivery of the payload to the victim is carried out quite accurately. After landing, a container is opened next to the victim in UMAV, which contains personal protective equipment, a mobile phone for communication with the MTMC brigade, and a first-aid kit.

Then, using the automatic return function, the UMAV flies to the base at a given point.

Thus, as a result of the implementation of MTMC using UMAV, the time spent on processing information is significantly reduced and the likelihood of providing medical care within the framework of the "golden hour".

C. Measures to Provide Victims with EMC during SRO

1) Medical sorting

Sorting is one of the basic principles of disaster medicine. The essence of sorting is the distribution of victims into groups according to the principle of need in the same treatment, prophylactic and evacuation measures, depending on medical indications and specific environmental conditions.

The purpose of sorting is to accelerate and timely provide all victims with emergency medical care (EMC) and provide them with further, rational evacuation.

The great Russian surgeon N.I. Pirogov noted that “a well-organized sorting of victims at dressing stations and military temporary hospitals is the main means to provide proper assistance and to prevent helplessness and harmful consequences in their consequences” [8].

By now, there are a large number of works devoted to medical sorting and quite adequately covering various aspects of this problem [9, 10, 11]. The main difficulties are associated with the presence of a number of factors, in particular, a significant level of a priori uncertainty about the functional state of the organism in emergency situations. According to the authors, it is necessary to create information support for those who provide first aid in making an independent decision on the provision of assistance, and to determine the place and method of transportation.

For UMAV MTMC, the authors propose a scheme of the medical sorting algorithm shown in Fig. 5.

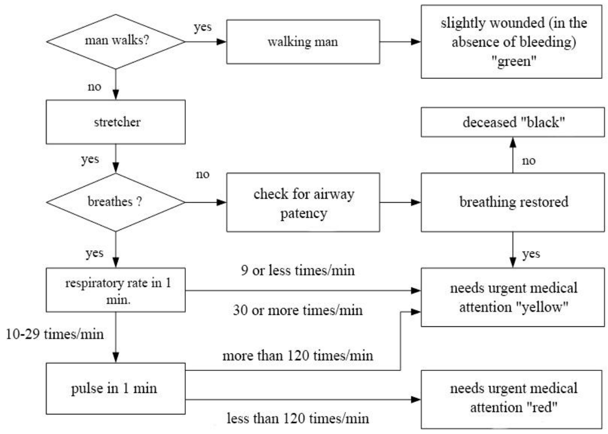

Figure 5. Diagram of a medical sorting algorithm.

Thus, in the proposed mobile telemedicine complex, medical sorting of victims is carried out in four categories: “black”, “red”, “yellow” and “green”.

The authors also developed an algorithm for adjusting the sequence of victims, a diagram of which is shown in Fig. 6.

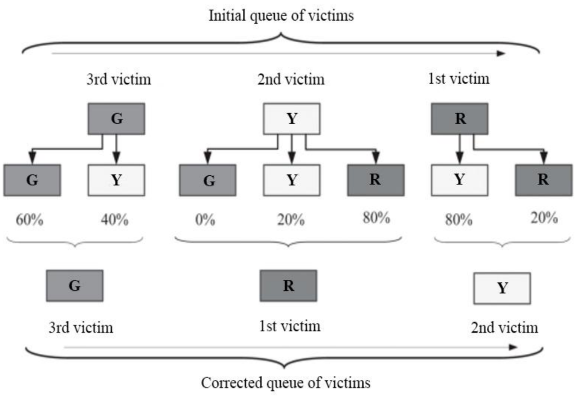

Figure 6. Diagram of the algorithm for adjusting the sequence of victims.

The decision to change the "color" and, accordingly, the sequence of emergency medical care is taken by the rescue doctor from the MTMK based on the analysis of data on the functional state of the body (FSO) of the victims.

2) Providing emergency medical assistance to victims

UMAV for EMC provision is equipped with a medical manipulator (MM) [12, 13, 14, 15], which is installed on the corpus and is designed to provide EMC in the absence of a person near the victim of an emergency. MM is managed by the same MTMC operator. The kinematics of manipulators is considered in detail in [16].

After receiving information about the victim's FSO, the doctor-operator analyzes the situation and makes a decision to provide EMC. Then, copying their movements with the help of a manipulator and a 3D video camera, at a distance provides EMC to the victim before the arrival of the MTMC brigade. Implementation options for the manipulator are shown in Fig. 7.

Figure 7. Manipulator of UMAV.

Capture with two degrees of freedom and one drive allows you to take a variety of objects with minimal movements.

The capabilities of this manipulator allow you to install defibrillation electrodes on the victim’s chest, for example, Zoll AED Plus, which was created for use by people without a medical education. The device is equipped with a special unit that allows you to register an electrocardiosignal (ECS) and transmit it to the MTMC operator, using an understandable interface. Technical characteristics of the device Zoll AED Plus are shown in Table II.

TABLE II. TECHNICAL PARAMETRS ZOLL AED PLUS

Parameter	Characteristics
Charging time, sec	10
Accumulator capacity	300 discharge or 1,5 work hours
Size (H,Th, L), sm	13,3 x 24,1 x 29,2
Weight, kg	3,1

As can be seen from Table II, the device is equipped with a built-in battery and therefore its operation does not affect the energy consumption of the UMAV.

In addition to working with equipment for the restoration of cardiac activity, MM can install a cardiac analyzer [17, 18], designed to record the ECS and transmit it to the doctor-operator MTMC in real time, so that the doctor constantly has information about the patient's condition, and, if necessary, using the same MM, can give the victim an injection of the desired drug.

Possibilities of MM allow to stop bleeding using the XSTAT applicator [19]. Inside the applicator are special hemostatic capsules. When in contact with blood, these capsules expand rapidly in the wound and create a barrier to blood flow (see Fig. 8).

a) the method of introducing capsules into the wound | б) wound condition before application | в) wound condition after application

Figure 8. The action of blood stopping capsules.

Thus, the capsules stop bleeding and gradually close the wound. Capsules have not only a hemostatic effect, they include a special x-ray contrast marker, which improves the quality of x-rays. The applicator contains 92 compressed cellulose capsules, which can absorb up to 300 milliliters of blood.

The manufacturer claims that this compact device can save the lives of victims with lacerations penetrating, as it stops bleeding in just 15 seconds. Currently, scientists are working on two types of applicators: with a diameter of 30 millimeters for wounds with a large area, and 12 millimeters for wounds with a narrow inlet and outlet.

Experts recommend the use of this device when the use of a traditional tourniquet is not possible or less effective. The use of capsules is designed for 4 hours after injury. In order to deliver the victim from the emergency zone to a medical facility, this time is enough.

Known that during World War II, approximately 50% of combat losses occurred from blood loss. Half of them could probably have been saved if the victim had received proper help in a timely manner.

Thus, even before arriving at the emergency site, MTMC doctors have at their disposal basic information about the location and severity of the injured. Given the data, the travel time to the emergency site can be used to prepare equipment and personnel for EMC.

3) Assessment of the functional state of the body.

When conducting SRO, a mandatory action in assessing the functional state of the organism (FSO) of the victim is to determine the presence of diseases from the category of sudden cardiac death (SCD) and the need for emergency cardiological care. The method proposed by the authors serves to represent the state of the patient's heart in real time according to the analysis of the electrocardio signal (ECS) [20]. The essence of the method is:

– Determination of hemodynamically significant arrhythmia (HSA);
– Use in conditions of free activity;
– Emergency medical and cardiological care.

As a harbinger of HSA, both congenital and acquired forms of lengthening of the QT interval on ECS are used, which are predictors of fatal rhythm disturbances, which, in turn, lead to sudden death of patients. The flowchart of the method of providing emergency cardiological care is shown in Fig. 9.

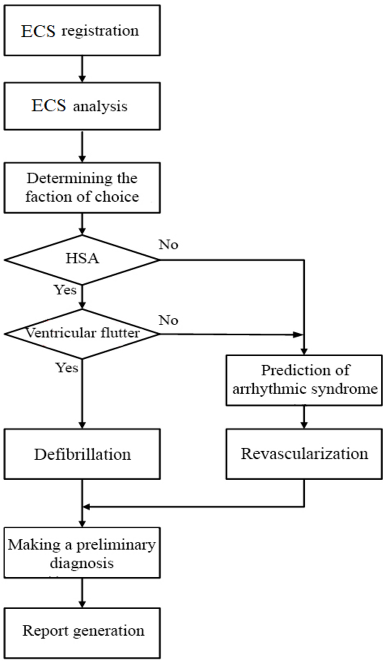

Figure 9. Algorithm diagram of a method for providing emergency cardiological care.

Simultaneous fulfillment of two conditions:

1. The fact of lengthening the QT interval on the ECS.

2. Determination of the ejection fraction (EF) <50% for at least three subsequent cardiocycles, will identify the HSA.

The duration of the QT interval depends on the heart rate and gender of the patient. Therefore, they use not the absolute, but the corrected value of the QT interval (QTc), which is calculated by the Bazetta formula

$$QT_c = k \cdot \sqrt{R_1R_2} \quad (1)$$

Table III shows the conditions and methods for providing emergency cardialogical care.

TABLE III. CONDITIONS AND METHODS OF EMERGENCY CARDIOLOGICAL ASSISTANCE

Emergency cardiology help / Availability pathological signs		Methods for the provision of emergency cardiac care	
EF < 50 %	Three subsequent cardiocycles with ventricular extrasystoles	Defibrillation	Revascularization
+	+	+	-
-	+	+	-
+	-	-	+
-	-	-	-

The procedure for applying emergency cardiological care methods depending on the results of an ECS analysis is shown in Table III. As follows from its analysis, the presence of extensive ventricular extrasystole is determined and hemodynamically significant arrhythmias in the case when expression (1) is true and a decrease in EF is observed in three or more subsequent cardiocycles.

With three or more subsequent ventricular extrasystoles, a malfunction is observed leading to ventricular fibrillation. Obviously, this requires defibrillation.

In the case when expression (1) is true, and in three or more subsequent cardiocycles no decrease in EF is detected, the presence of hemodynamically insignificant arrhythmia is diagnosed. In this case, defibrillation is not required, and, according to the algorithm shown in Fig. 9, conduct revascularization.

In the event that expression (1) is false, the severity of the arrhythmic syndrome is predicted, and when predicting severe arrhythmic syndrome, revascularization is performed.

Equipping MTMC with “quick response” means increases the efficiency of EMC provision. The inclusion of UMAV in MTMC ensures the provision of EMC during the "golden hour", reduces the burden on the rescue doctor by providing timely and reliable information about the location and FSO of the victim.

IV. Conclusion

Thus, the bionic method of controlling robotic mechanisms has been substantiated to increase the safety of employees involved in emergency response in life-threatening situations.

A new approach has been developed to the construction and operation of a mobile telemedicine complex in emergency situations, characterized by the use of:

- a heterogeneous group of unmanned aerial vehicles;
- adjusting the sequence of victims;
- original methods and means of treatment and assessment of the functional state of the injured organism,

which ensures the provision of emergency medical care during the “golden hour” of medicine and an increase in the effectiveness of search and rescue operations in terms of minimizing the medical consequences of emergencies.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Gulmira K. Berdibayeva conducted the main research throughout the paper and contributed to the development of the method in Section III A, B; Oleg N. Bodin wrote part III C 1, 2; Kassymbek A. Uzhkenov analyzed the data in section II; Rat Sh. Berdibayev has contributed to the writing of Introduction and part III C 3; all authors had approved the final version.

References

[1] S. V. Zhukov, Selected Lectures on Disaster Medicine / - Tver: Publishing house of Tver State University, 2007 - 120 p.

[2] G. K. Berdibaeva, O. N. Bodin, Method of conducting search and rescue operations, RU Patent 2694528 July 16, 2019

[3] O. N. Bodin, Concept of providing emergency medical care to victims in emergency situations / Vestn. Ross. military-med. acad. - 2015. - No. 3 (51). - p. 143-147.

[4] G. A. Korsakov Calculation of emergency zones / G. A. Korsakov. - St. Petersburg: Publishing house SPGLTA, 1997. – 112 p.

[5] F. Sh. Ilyasov, Radars for detecting people behind optically opaque obstacles / Civil security technologies, volume 7. - 2009. - № 3-4 (21-22). p. 86-90.

[6] What drones are used in world cinema https://itnan.ru/post.php?c=2&p=298959

[7] Amin Rajawana and Pruittikorn Smithmaitrie, “Mathematical Modeling and Validation of the Aerial Robot Control System with the Pixhawk Flight Controller”, *International Journal of Mechanical Engineering and Robotics Research Vol. 9, No. 7,* pp. 1065-1071, *July 2020*

[8] S. F. Goncharov All-Russian Disaster Medicine Service is one of the best subsystems of the Unified State System for Prevention and Elimination of Emergency Situations // Federal Directory "Healthcare in Russia", volume No. 11.

[9] L. I. Kolb, S. I. Leonovich, I. I. Leonovich, Medicine of disasters and emergencies. - Minsk: V Sh, 2008. – 447p.

[10] Organization of emergency medical aid to the population in case of natural disasters and other emergencies. Ed. V. V. Meshkov. - M., 1992.

[11] O. N. Bodin, Mobile telemedicine complex RU Utility Model Patent 141202, May. 27, 2014

[12] Priyam A. Parikh, Reena Trivedi and Jatin Dave, “Trajectory Planning for the Five Degree of Freedom Feeding Robot Using Septic and Nonic Functions”, *International Journal of Mechanical Engineering and Robotics Research* Vol. 9, No. 7, pp. 1043-1050, July 2020

[13] On-line gas analyzers URL: http://www.tpklion.spb.ru/category.php?cat_id=2&subcat_id=124 ?utm_source=yandex&utm_medium=cpc&utm_campaign=gazoan alisator_poisk|26804971&utm_content3|de65vice_poisk|26804971 &utm_content3|de65vice desktop | gr-75 | ob-1 & utm_term = gas analyzer% 20 carbon dioxide% 20 gas & utm_network = search & utm_placement = none.

[14] LIDAR for UAV URL: http://art-geo.ru/catalog/airscanner_bpla/vozdushnye-lazernye-skanery-dlya-bpla/riegl-vux1-series

[15] Flexible Roboterarme: Diese Drohne greift zu https://www.giga.de/extra/drohne/videos/flexible-roboterarme-diese-drohne-greift-zu/

[16] Zhumadil Zh. Baigunchekov and Rustem A. Kaiyrov “Direct Kinematics of a 3-PRRS Type Parallel Manipulator”, *International Journal of Mechanical Engineering and Robotics Research Vol. 9, No. 7,* pp. 967-972, *July 2020*

[17] A. Kuzmin, “Mobile heart monitoring system prototype” in Tools and Technologies for the Development of Cyber-Physical Systems 2020 P. 23.

[18] M. Safronov, “Mobile ECG Monitoring Device with Bioimpedance Measurement and Analysis” presented at the IEEE 24th Conference of Open Innovations Association (FRUCT), 2019.

[19] XSTAT https://www.revmedx.com/xstat

[20] O. N. Bodin, "A method of providing emergency cardiac care" RU Patent 2644303 Febrary 8, 2018,

Gulmira K. Berdibaeva was born on 23.03.1969, Master of Technical Sciences, Senior Lecturer of the Department of Electronics and Robotics AUPET. Research interests: application of robotics in emergency situations, biomedical engineering.

Oleg N. Bodin was born 05.08.1955, Doctor of Technical Sciences, Professor at Penza State University. Research fields on System analysis, information technology in medicine, non-invasive processing of cardiographic information: analysis, modeling, visualization.

Kassymbek A. Ozhikenov was born 09.05.1962, Candidate of Technical Sciences, Doctor of Science, Honoris Causa IANH, Head of the Department Robotics and Engineering Tools of Automation, Professor at Satbayev University. Research areas: robotics and mechatronics, biomedical engineering, non-invasive processing of cardiographic information.

Rat Sh. Berdibayev was born on 24.02.1968, Candidat of Politican Sciences. Head of the Scientific and Technical Center for Information Security Problems, Associate Professor at AUPET. Scientific directions: political and technical aspects of information security