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PRACTICAL APPLICATION OF THE NEW DISINFECTION ROBOT IN THE FIGHT AGAINST VIRAL INFECTIONS

Abstract. The article presents modern methods of combating dangerous viruses in medical institutions. It was noted that disinfection robots can perfectly cope with the replacement of medical workers when performing various logistics tasks, patient care tasks and disinfection of medical premises. All this can reduce the likelihood of people becoming infected with dangerous pathogens. A prototype of a mobile disinfection robot was designed and created to carry out chemical treatment with disinfectants and treatment by the action of ultraviolet rays of medical premises. This robot consists of a wheeled mobile platform and a system for spraying disinfectants in combination with the possibility of irradiation with ultraviolet rays. Thanks to the thoughtful integration of various hardware components and software, a prototype of a disinfection robot was made for experimental research. At the same time, a simulation study of the disinfection model was carried out. The model of the disinfection robot was tested practically in the premises of the medical appointment. The results of the designed and built prototype of the disinfection robot showed high efficiency in disinfection of medical premises.

Keywords. Medical robotics, disinfection robots, mobile robotic systems, viral infections, automation of medical institutions.

Introduction.

At the end of 2019, the worldwide pandemic of a new coronavirus infection (COVID-19) claimed the lives of a large number of the world's population, which completely affected the public health system. Various methods of distancing, personal protective equipment, as well as developed rules for disinfection of medical premises were able to reduce the spread of this threat.

The emerging disinfection robots during this period were able to effectively reduce mortality from this infectious disease [3-5] and are recognized as suitable solutions for diagnostics, screening, disinfection, surgery, telemedicine, logistics and manufacturing [6] due to immunity to pathogenic infections. These robots have been classified according to various methods of application based on various methods of their application [7] in various institutions and can be used for disinfection of hard-to-reach places, in the field of diagnostics [8,9], as well as for distributing food and medicines to patients in closed rooms [10]. Remote control of them ensures the safety of medical personnel in the working environment in the absence of cooling and ventilation [11].

Various pathogenic microorganisms can be viable for several weeks and lead to infection of a healthy person. Due to the fact that disinfection of premises in medical institutions is carried out by people, the probability of infection with viruses of healthy people increases in the absence and improper use of personal protective equipment. At the same time, disinfection robots would perfectly cope with the task of disinfection [3].

Various disinfectants have found active use in disinfection of air and various surfaces in the room. When hydrogen peroxide decomposes, oxygen and water that are safe for humans are formed [12]. Hydrogen peroxide with a concentration below 10% can be sprayed directly indoors. There are methods using evaporated hydrogen peroxide and dry hydrogen peroxide (DHP) [13], which significantly reduce the cost of disinfection and sterilization of premises, since smaller particles (0.5–5 microns) are obtained [14].

For more reliable disinfection, the disinfection robot is equipped with ultraviolet lamps producing ultraviolet rays (UVC) [15]. The effect of disinfection by UV rays decreases when moving away from the lamps due to energy loss. UV rays do not pass through opaque surfaces, which leads to the fact that certain areas of a complex environment are not irradiated.

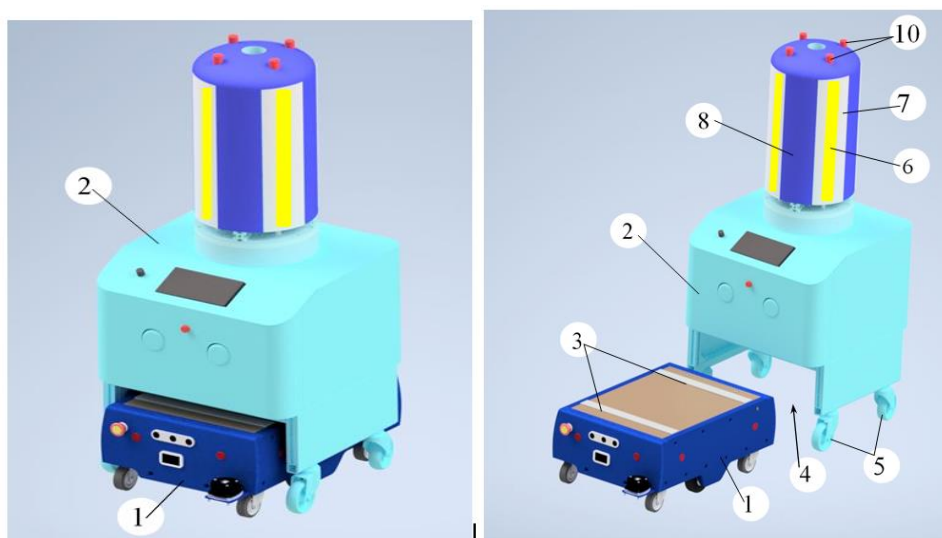
Hydrogen peroxide is highly effective against nosocomial infections, as it interacts with the protein envelope and affects the structures of molecules carrying hereditary information of viruses [16]. It has been shown that hydrogen peroxide actively destroys the H1N1 influenza virus [17], a coronavirus of transmissible gastroenteritis having a similar structure to the COVID-19 virus [18].

Materials and methods.

The design process of the disinfection robot is presented below.

The design of the mechanism of the disinfection robot

An autonomous mobile platform and a disinfection module-a sprayer of disinfectants and ultraviolet lamps are the basis of the CAD model of the designed disinfection robot shown in Figure 1. A sprayer is installed on the wheeled platform of the disinfection module [19], which converts disinfectants into a dry mist of micrometer size.



1) mobile robot platform; 2) disinfection platform; 3) lifting mechanism; 4) "P" shaped portal; 5) wheels; 6) disinfection liquid spraying system and UV lamps; 7) reflectors; 8) housing; 9) a closed cylindrical protective cavity, inside which there are ultraviolet lamps; 10) human presence sensors.

Figure 1 - CAD model of the developed disinfection robot.

The wheeled moving platform includes a mobile robot with two differential driving wheels for moving forward, backward and turning around.

The support frame of the disinfection robot can be used to transport disinfection equipment and other parts. For disinfection and sterilization, a container is used, which is built

into the middle part of the support frame of the disinfection robot. At the same time, the height of the entire disinfection robot is no more than 1200 mm.

Probing procedure and management implementation

In the system for obstacle avoidance, localization, traffic planning and navigation, environmental perception sensors are used in the disinfection work [20-21]. So, this can be done with the help of robotic vision and laser scanners [22]. To navigate the disinfection robot, data analysis is carried out on significant elements-objects and scenes in the environment, and thus the initial trajectory of movement is planned [23,24].

Figure 2 shows the circuit in which the control hardware and the power supply are connected. The scheme provides additional auxiliary elements - control boards, lidar and battery. It is planned to spray hydrogen peroxide or other disinfectant at a rate of 900-1600 ml/h using a disinfection module in the premises of a medical institution.

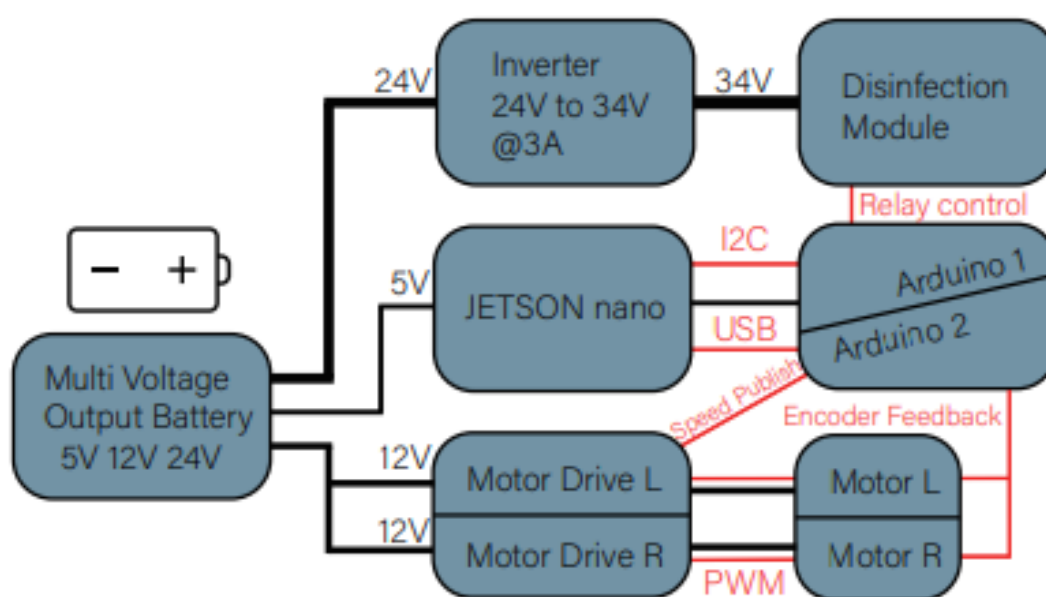


Figure 2 - Connection diagram of the control hardware and power supply

To control the disinfection robot, a controller is provided that processes data from the input and output channels. The input data is considered to be data from lidar, which is collected to detect obstacles in the environment. The obtained data are compared with odometry data from the sensor of the driving wheels. In this way, navigation maps of premises in a medical institution can be generated. The output data is used to calculate the speed of the disinfection robot, to create an image from the built-in camera and to provide other functions. Data can be sent from the computer to the remote control.

System integration and control modes of the disinfection robot.

The created prototype of the disinfection robot includes the above-mentioned hardware components, a platform, a support frame, a container with a disinfectant solution and a sprayer, ultraviolet lamps, sensors and a control board. Schematically, this is shown in Figure 3. The control program of the disinfection robot is compiled for the Linux operating system and includes three modes - two automatic and one manual.

In manual control mode, the operator uses a remote control or keyboard to control the movement and switching of the robot. This mode of operation can be used to scan the environment and create a map of the environment.

Next, an automatic mode can be performed based on the data on the created map. When starting the first automatic mode, you must manually enter the necessary key points. A special

control mode for the disinfection robot allows you to plan the right route for disinfection of the room. In the second automatic mode, there is a route planning function.

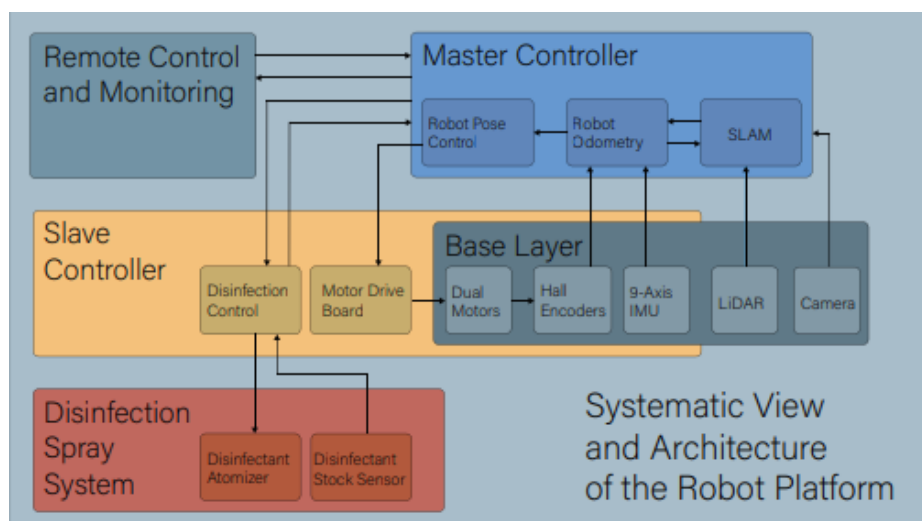


Figure 3 - Schematic view of the software architecture for the developed disinfection robot

At the same time, the key points and the target angle of inclination of the disinfection robot are set. The obstacle avoidance function is also supported in this mode.

The arrows indicate the sending/receiving of data, the flow of commands and the communication between each part.

Results and discussion.

The developed multifunctional robot has three disinfection methods: the method of ultraviolet radiation, the method of disinfection with spraying of disinfecting liquid and the method of air filtration (recirculation) [25]. The robot, depending on the needs for disinfection of the room, can use several disinfection modes individually or in any combination. Also, the satellite robot of the disinfection robot provides simultaneous wet cleaning of the room. To carry a robot satellite, the disinfection robot is equipped with a lifting and lowering mechanism with a socket for a robot satellite.

Figure 4 shows the working positions of the ultraviolet lamps of the disinfection robot.

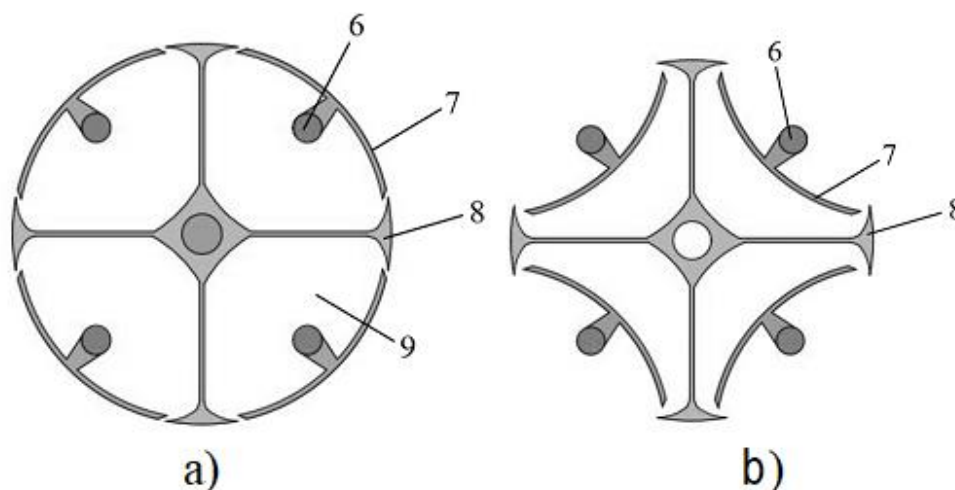
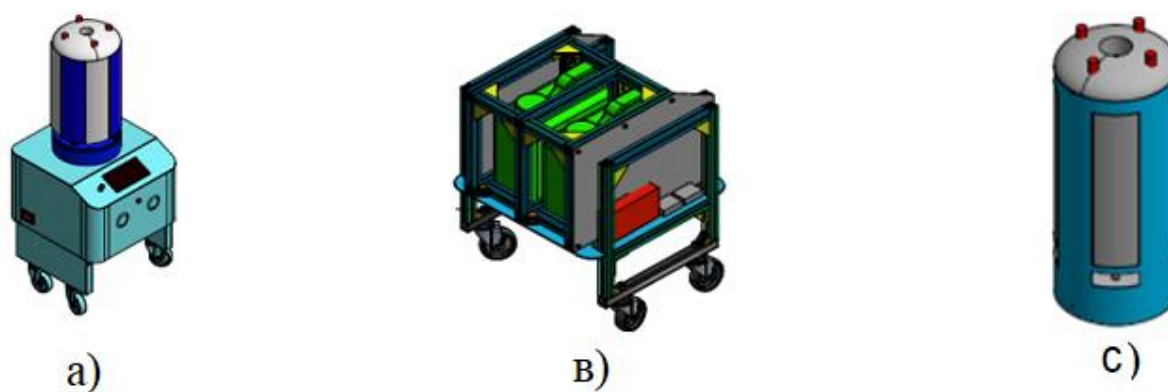


Figure 4 – Working positions of UV lamps

UV lamps with reflectors are designed to be rotated 180 degrees and have two working positions. In the first working position (Figure 8 (b)), the ultraviolet lamps are located outside relative to the lamp body and operate in the mode of ultraviolet irradiation of the environment. In the second working position (Figure 8 a)), the lamps with reflectors are rotated 180 degrees and the reflectors with the housing form a closed cylindrical protective cavity, inside which there are ultraviolet lamps, while the robot operates in the air recirculation mode [25].

The design and control panel of a multifunctional disinfection robot has been developed, which will operate in three modes: ultraviolet radiation, disinfection with spraying of disinfecting liquid and air filtration (recirculation).

The PKD of a multifunctional disinfection robot is presented in Figures 5.



a) general appearance, i) the lower part of the robot for liquid disinfection, c) the upper part of the robot designed for UV disinfection and for operation in the recirculator mode

Figure 5 – 3D model of the disinfection robot

The dimensions of a four-link articulated mechanism designed for lifting and lowering a satellite robot are also obtained. A kinematic analysis of a four-link hinge mechanism has been carried out, which confirms the operability of the resulting mechanism.

A complete study of the kinematics and calculations for the strength of the gear mechanism designed for turning ultraviolet lamps [25] has been carried out. The load factor is determined separately for each of the main performance criteria of gears. The main performance criteria for gears are fatigue contact strength, as well as the strength of the teeth during bending.

The synthesis of a four-link articulated mechanism for lifting and lowering a robot satellite was also carried out and the dimensions of the mechanism were obtained.

A complete study of the kinematics of a four-link hinge mechanism has been carried out.

A computer model of kinematic analysis of a four-link mechanism designed for lifting and lowering a satellite robot has been developed.

The disadvantage of such a design may be the complexity of manufacturing individual parts.

The development of this development consists in carrying out work on the development of a control system for the disinfection robot, where the dynamic characteristics of the robot will be taken into account when the robot moves, the introduction of dynamic system models will also be accompanied by the introduction of regulators.

There are many studies on the work of robots with UV disinfection, on the work of disinfection robots with DHP -very rarely. The methods of computer modeling and computational fluid dynamics made it possible to create a flow field model for DHP diffusion in a limited space. At the same time, there are a number of studies on DHP concerning the sterilization and destruction of various pathogens. Work [26] is devoted to the disinfection model

with DHP in the hospital operating room, in which it was supplied together with the flow of conditioned air.

Optimal concentration of the disinfectant

The optimal concentration of DHP for the destruction of the COVID-19 virus is not clearly defined. It was shown in [17] that DHP destroys the H1N1 influenza virus within 150 seconds of 10 ppm with 99% efficiency [17]. Thus, in [27] it was found that hydrogen peroxide with a concentration of 0.5% will effectively reduce the concentration of human coronavirus when treating the surface of premises.

Setting up the test environment.

To build the model, an L-shaped medical room was used. At the same time, a disinfection robot with dimensions of 0.31 m × 0.21 m × 0.56 m with an inlet pipe with a diameter of 0.05 m and a length of 0.65 m was used. The robot was placed at a distance of 0.2 m from the inner wall of the room. DHP was sprayed using an outlet mounted on a disinfection robot. During disinfection, the ventilation fan located in the corner of the room is closed.

Boundary conditions of the created model

In the created model, the effect of the buoyancy airflow was not taken into account, and the air was taken as incompressible matter. The diffusion calculations were performed on the basis of the energy equation. DHP with a concentration of 7.1% was injected at a rate of 3.1 m/s.

Route planning of the disinfection robot.

To create automatic navigation of the disinfection robot [28], a system based on geometric, topological or semantic navigation was used, which allowed localization, route planning and navigation strategy to be carried out online [29].

Using geometric navigation SLAM for the disinfection robot.

The SLAM system [30,31] was used to create metric maps with the choice of the direction of movement on the map in medical premises [32].

Usage of Gmap.

Gmapping in the disinfection robot allows processing localization and display data using conditional joint distribution [33]. At the same time, the Gmapping algorithm also uses odometry data.

Development of the route of the disinfection robot.

The safe operation of the disinfection robot was created taking into account the multipoint disinfection of sections of medical premises based on a 2D map grid and solving the problem of path planning. The model for the route planner uses data from the global and local path planner together, which allows the disinfection robot to reach its destination without hindrance.

Conclusion.

This article presents a model of a disinfection robot for disinfection of air and the surface of medical premises using hydrogen peroxide or other disinfectants, as well as ultraviolet irradiation. The prototype of the robotic system was created at the U.A. Joldasbekov Institute of Mechanics and Engineering and manufactured by integrating navigation, route planning and disinfection functions. The developed robotic system was deployed and tested in real premises, including a laboratory, hospital, etc. The results of the disinfection test showed that the developed disinfection robot demonstrates great effectiveness in combating the COVID-19 pandemic and other infectious pathogens. In future works, various disinfectants will be tested and the work of the disinfection robot will be tested in practice.

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ВИРУСТЫҚ ИНФЕКЦИЯЛАРМЕН КҮРЕСТЕ ЖАҢА ДЕЗИНФЕКЦИЯЛЫҚ РОБОТТЫ ПРАКТИКАЛЫҚ ҚОЛДАНУ

Аңдатпа. Мақалада медициналық мекемелердегі қауіпті вирустармен күресудің заманауи әдістері келтірілген. Дезинфектор Роботтар әртүрлі логистикалық тапсырмаларды, пациенттерге күтім жасау және медициналық үй-жайларды дезинфекциялау кезінде медицина қызметкерлерін ауыстыруды жақсы жеңе алатындығы атап өтілді. Мұның бәрі адамдардың қауіпті қоздырғыштармен жұқтыру ықтималдығын төмендетуі мүмкін. Дезинфекциялық заттармен химиялық өңдеу және медициналық мақсаттағы үй-жайларды ультракүлгін сәулелермен өңдеу үшін мобильді дезинфекциялық роботтың прототипі жасалып, жасалды. Бұл робот тұрады дөңгелекті мобильді платформа және жүйесін тозаңдатуға арналған дезинфекциялық заттарды біріктіріп мүмкіндігімен сәулелендіру ультракүлгін сәулелерімен. Әртүрлі аппараттық компоненттер мен бағдарламалық жасақтаманың ойластырылған интеграциясының арқасында тәжірибелік зерттеулерге арналған дезинфекциялық роботтың прототипі жасалды. Сонымен бірге дезинфекция моделіне Имитациялық зерттеу жүргізілді. Дезинфектор роботының моделі медициналық мақсаттағы үй-жайларда дерлік тексерілді. Дезинфектор-роботтың жобаланған және салынған прототипінің нәтижелері медициналық мақсаттағы үй-жайларды дезинфекциялау кезінде жоғары тиімділікті көрсетті.

Түйінді сөздер. Медициналық робототехника, дезинфектор-роботтар, мобильді роботтандырылған жүйелер, вирустық инфекциялар, медициналық мекемелерді автоматтандыру.

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ПРАКТИЧЕСКОЕ ПРИМЕНЕНИЕ НОВОГО РОБОТА-ДЕЗИНФЕКТОРА В БОРЬБЕ С ВИРУСНЫМИ ИНФЕКЦИЯМИ

Аннотация. В статье представлены современные методы борьбы с опасными вирусами в медицинских учреждениях. Было отмечено, что роботы-дезинфекторы могут отлично справиться с заменой медицинских работников при выполнении различных задач логистики, задачи по уходу за пациентами и дезинфекция помещений медицинского назначения. Все это способно снизить вероятность заражения людей опасными патогенами. Для проведения химической обработки дезинфицирующими веществами и обработки действием ультрафиолетовых лучей помещений медицинского назначения был спроектирован и создан прототип мобильного робота-дезинфектора. Данный робот состоит из колесной мобильной платформы и системы для распыления дезинфицирующих веществ в комбинации с возможностью облучения ультрафиолетовыми лучами. Благодаря продуманной интеграции различных аппаратных компонентов и программного обеспечения был изготовлен прототип робота-дезинфектора для экспериментальных исследований. При этом было проведено имитационное исследование модели дезинфекции. Модель робота-дезинфектора была проверена практически в помещениях медицинского назначения. Результаты спроектированного и построенного прототипа робота-дезинфектора показали высокую эффективность при дезинфекции помещений медицинского назначения.

Ключевые слова. Медицинская робототехника, роботы-дезинфекторы, мобильные роботизированные системы, вирусные инфекции, автоматизация медицинских учреждений.
