Robotic and Smart Service for People with Disabilities

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***Abstract*—The article presents and discusses the problem of developing a robotic system for the care and supervision of people with disabilities. The main functions of the robotic system are telecommunications between patients and their guardians, automatic management of platform movement, manipulator movement and gripper. An overview of existing solutions (devices) on the robotics market that implement similar capabilities is presented. Each device is a complex and expensive system. In order for a robotic system to be widely accessible to all people, it is necessary to reduce the cost of its components. Inexpensive mechanical components have disadvantages in terms of movement accuracy. We propose a hypothesis about the possibility of using artificial intelligence to improve the accuracy of actions performed by a robotic system. Analysis of the video image of the manipulator movement can allow to adjust the speed and angle of rotation of the motors in the joints of the manipulator, thereby making the movements more accurate.**

***Keywords*–Robotics; Remote control; Manipulator; Alarm system; Smart capture.**

I. Introduction

The value of human health and life is a priority for everyone individually and for humanity as a whole. The development of technologies allows to gradually exclude people from those processes where they are forced to work physically, monotonously and with a strain of attention. A special role in this process belongs to robotics.

Science fiction writers have formed the image of a robot as a thinking human-like mechanism that can interact with humans and the environment. In reality, robots are complex software and hardware complexes, mostly located in dark, unheated workshops, away from humans. The reason for the discrepancy between reality and ideas is the fact that human likeness or anthropomorphism is an extremely complex property. It is extremely difficult to create an artificial intelligence equal in flexibility and power to the human one. However, the ideal robot image remains as one of the goals of technology development, including mechatronics, sensors, electronics, mathematics, and information technology.

The level of technology development today allows us to replace a person with software and hardware systems that can perform part of human duties related to industrial production and other areas of activity.

Robots from workshops and fenced spaces step into the space of a human and the human is in the zone of action of robots. It is clear that such interaction should be effective and safe. Robots need to be adapted to human environment and to interact with people just like any of us.

A current trend in robotics is the development of robots for the social sphere of life of an individual and society as a whole [1].

If a robot becomes a part of a humans life, if it interacts with a person and has the intelligence to perform certain tasks, then it can be considered as part of the Ambient Intelligence [2].

The purpose of this research is to develop a robotic system designed for monitoring and telecommunications with people with disabilities, as well as to help them perform manipulations with various objects (for example, to pick up a fallen object). At the same time, the robotic system should not be bulky to move freely inside a small, limited room, and expensive to be accessible to patients with a low income level.

Nowadays, a robot for individuals is a complex and very expensive system. Low-cost components have a number of shortcomings, the main ones being non stability and non precision of movements. The main hypothesis is to use capabilities of artificial intelligence to compensate shortcomings of low-cost components and to construct robotics system available for any person.

The rest of this paper is organized as follows. Section II describes the robotic system proposed, its designated purpose, main functions and architecture. Section III lists the main problems that arise when implementing a robotic system and required solutions using artificial intelligence. Each of the listed tasks can be considered as a separate one, without reference to the robotic system proposed. There are various approaches to solve these tasks. The most relevant approaches are presented in Section IV. Some of the approaches have already been implemented to some extent in existing robots. Section V describes the existing robotic systems, in which some tasks are partially solved. We conclude the work in Section VI.

II. Description of the robotic system

Robotics technology can be deployed in healthcare [3]. Robotics for healthcare presents a major research challenge due to the strong requirements to deal with humans. The proposed solution belongs to the assistive robotics subdomain. This subdomain requires more flexible and compact systems able to navigate in public areas, to grasp and manipulate soft and delicate objects as stated in the Multi-Annual Roadmap For Robotics in Europe [1]. Great importance is attached to the use of artificial intelligence in such systems.

The aim of this research is to develop a robotic system designed for the care and supervision of people with disabilities (patients). There are often cases when the patient lives alone, or remains alone for a long time. At the same time, the patient can have certain autonomy, but can not be left unattended. It

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is also important for the patient to communicate, first of all with their guardian (relatives) and to have the psychological confidence that they will not be abandoned and can ask for help at any time. In such a situation, the best decision, of course, is to have some person that will be constantly near the patient. A human person can look after a patient, serve him, help him, and talk to him. But, at the same time, a human person can get tired and distracted. In addition, the number of such people should be quite large.

The robotic system being developed is designed to replace a person in such a situation.

The system functions include remote manual and autonomous movement in an indoor environment (house, apartment, ward), two-way video data exchange in real time between the patient and their guardian, tracking the patient's condition, detecting dangerous conditions of the patient and transmitting an alarm signal to the guardian or immediately to the rescue service, remote manual and autonomous control of the manipulator and the gripper.

To implement these functions, the robotic system must have a wheeled platform, a manipulator with a gripper, a video camera, a screen, a set of sensors, a wireless data transmission system, and a system controller. The robot is controlled in autonomous mode and in manual or semi-autonomous mode with the remote device.

This architecture has a number of advantages. Through the use of the manipulator, there is an opportunity to interact with objects located near the robot. For example, give the patient a bottle of water or pick up a fallen item from the floor. The video camera and screen provide a two-way exchange of video data in real time using the Internet, as well as allow the robot to receive commands from the patient, and allow the operator to remotely manage the platform and the manipulator. The system controller provides interaction of all subsystems of the robot. The set of sensors includes sensors for determining the distance to objects, for measuring the force effect. Sensors can also include a video camera and microphone.

Thus, the patient and their guardian can be separated in space at any distance within a sufficiently high-speed Internet, staying constantly in touch. The guardian is able to remotely provide assistance within the capabilities of the manipulator.

A prototype of the robotic system will be presented at the St. Petersburg Technical Fair (PTFair) 2020.

III. Tasks of the robotic system

The robotic system must operate in manual mode and automatic mode. Its main actions are the movement of the platform, movement of the manipulator and clamping the gripper. When performing these actions in manual mode, the operator (guardian) controls all mechanisms (wheel motors, manipulator servos and gripper), relying on the video image transmitted from a video camera installed on the platform, as well as from video cameras permanently installed in the room. Even under these conditions, the completeness of the view may not be achieved, and the accuracy and safety of the movements may not be sufficient to achieve the goal. Therefore, in manual control mode, the system needs help to ensure that these criteria are met. Moreover, these criteria become more relevant, when robotic system work in automatic mode.

Let us formulate the important tasks for managing the robotic platform that require solutions in the field of artificial intelligence:

- Creation of the route of the platform movement, avoiding dynamically appearing obstacles, recognizing their shape and gaining experience in circumventing them, and possibly moving them to free the passage;
- Creation of the trajectory of the manipulator with similar functions, but different degrees of freedom;
- Selection of the position to capture depending on the shape of the object to be manipulated;
- The choice of the grabbing force depends on the characteristics of the object to be manipulated, so that on the one hand the object will not be broken, and on the other hand the object will not fall (is firmly held);
- The prediction actions in repetitive situations of working with objects and obstacles;
- The detection abnormalities in the patient's behaviour and deciding whether to trigger an alarm.

Navigation, perception and cognition technologies provide a robot with the means to measure and interpret its environment, to learn of intelligent behaviour. During care processes, the database of typical motion and interaction patterns can be accumulated by the robots themselves and transferred to a shared knowledge base. Then, this knowledge will be used as needed from this shared repository, thus this will be a novel network ecosystem for robots.

A network centralized knowledge base and remote data processing will reduce the energy requirements for individual computing nodes of robotic systems. These nodes themselves can be simpler and cheaper. In addition, the released resources could be spent on improving the ergonomics of the design of the robotic system.

Thus, it is the task of computer vision with deep processing of the scene and environment surveillance, the task of the obtaining additional information about objects from the Internet and the task of the gaining experience in manipulating with various objects. That is the core of the intelligent system.

IV. Overview of solutions being developed

The problem of path planning for an automation moving in a two-dimensional space has been known for a long time [4]. Navigation in indoor environment can occur in conditions where the map or plan of the place is known and when such a map needs to be made first. When generating a route, it is necessary to take into account the dimensions of the robotic platform, as well as possible angles of its rotation. In the course of patient activity, the location of objects may change, which leads to generation of new routes in real time [5]. Now, the ways to get information about the surrounding space are being improved, the ability to process large amounts of information is being accelerated, and path planning algorithms based on the use of various types of information and deep processing of information are being developed [6].

The sources of information are lidars that measure distances to surrounding objects in the range of 360 degrees, video cameras, stereo-video cameras that receive flat and three-dimensional images in different electromagnetic wave spectra.

The movement is transferred from a flat surface to a surface that has a slope, where the power of the motors needs to be taken into account to overcome the path. The movement is considered in three-dimensional space and the path is being created for flying robots that must avoid obstacles from left, right, above and below.

Truly smart devices must correctly identify obstacles. If glasses are lying on the floor, the smart mobile robot must understand that this is not just an uneven surface, but an extra object lying on the floor. Is it possible to drive through it? Should the robot go around the object? No, the glasses must be picked up and put in a safe place. These tasks have not yet been solved. For example, systems like Smart Walkers implement some of these functions and are designed to help people who have problems related to balance and gait stability [7].

Determining the trajectory of movement is also necessary for the manipulator. This task is even more difficult, since the manipulator has a greater number of degrees of freedom and operates in more complex conditions of external space. Its task is not only to achieve the goal, but also not to hook other objects with the manipulator. In [8], a vision system is used to recognize both different target objects and their poses that allow the robot to do pick-and-place operation, that includes selecting the gripper type or the grip angle.

The theoretical base of the planning and implementation of fast and absolute path accuracy motions for industrial manipulators constrained to a given geometric path is developed in [9][10]. The asymptotic orbital stabilization of motions and a novel analytical method for analysis and redesign of system's dynamics is achieved by use of a feedback control.

The next problem is gentle grabbing. One of the solutions is based on an electrically controllable adhesion mechanism [11]. In [12], a mobile robot able to autonomously pick-up from the floor objects a human is pointing at is presented. The robot decides by itself if an object is suitable for grasping by considering measures of size, position and the environment suitability.

V. Overview of existing devices

Today, robotization takes place most actively in the following civil industries:

- Transport and logistics
- Agriculture, forestry, water management
- Medicine
- Production
- Civil infrastructure
- Commerce and service

A. Transport and logistics

In this industry, there are three close areas:

- Unmanned vehicles (cargo and passenger)
- Remote inspection systems for complex or dangerous objects
- Warehouse automated systems

A lot of publications are devoted to the progress of driverless vehicles. This direction is the most promising and closest to the production of final products.

To solve the problem of remote inspection of complex objects, autonomous systems are used. They operate in automatic and semi-automatic mode. A special feature of these systems is the need to operate at a great distance from the operator, in conditions where direct control is not possible. In such situations, autonomous systems are forced to solve the problem of moving along a given trajectory along the object under study in offline mode, relying on a system of sensors and artificial intelligence. In the case of flying and floating systems, it is necessary to take into account and compensate for the unpredictable effects of wind or water currents.

Flyability Elios (Figure 1) is the world's first flying robot for technical inspection of industrial facilities and search and rescue operations. It implements the following functions: search for injured climbers in the cracks of the glacier; visual and thermal inspection of steam boilers; inspection of container ship's ballast tanks; inspection and monitoring of mining equipment [13].

Figure 1. Flying robot Flyability Elios [14].

The Naturaldrones StillFly flying robot is designed to survey high voltage power lines using multispectral and high resolution cameras [15]. It operates under the operator's control in semi-automatic mode. It allows to monitor the condition of wires and structures of high-voltage supports.

The warehouse robots that transport goods in Amazon warehouses are 4-5 times more efficient than the company's employees who perform similar work [16].

B. Agriculture and forestry management

There is no doubt that there are many heavy, monotonous, strenuous activities in this industry that humans would be happy to hand over to robots.

The ecoRobotix weeding robot is equipped with a computer vision system designed to identify weeds. After detecting a weed, the robot sprays it with a small dose of herbicide [17].

AGROBOT E-Series (Figure 2) is the first robotic harvester for careful strawberry harvesting [18]. The flexible platform is equipped with 24 independent manipulators, easily adapts to any farm configuration, and is able to work at night. The robot is able to determine the location of the berry and its level of ripeness in real time. To solve this problem, graphics processors are used that process information received from short-range integrated color and infrared depth sensors. Manipulators are able to grab the stalk of a ripe berry selected by the AI with high precision, then cut the stalk and move the fruit into a special transport container without harming the berry. The developers also took care of the safety of people interacting with the robot. Special lidars take care of the safety of the surrounding field workers. Crossing the virtual perimeter stops the work of the robot, so as not to harm the person.

Figure 2. AGROBOT E-Series [18].

TreeRover is a Canadian robot for the planting of trees when conducting regeneration works [19]. A cassette with seedlings and a special burrowing device is installed on the robot's wheel platform. The robot follows the route based on GPS data and places seedlings from the cassette at a specified distance from each other along the way.

C. Medicine

A prominent representative of clinical systems is the Da Vinci robot surgeon (Figure 3), designed for performing surgical operations [20]. As an executive device, it allows the surgeon to see the operation area in a high-precision three-dimensional format and operate with high-precision manipulators in hard-to-reach places. In the future, robot surgeons will be able to significantly reduce the trauma of operations, making them remotely through small incisions. It is also possible that the movements of the scalpel and other instruments will be synchronized with the breathing, heartbeat and other micro-movements of patients, which will also increase the safety of operations and reduce the number of tissue injuries.

Figure 3. The da Vinci surgical system [21].

Auxiliary medical robots perform the functions of nannies and nurses. Robear (Figure 4) is the most developed representative of this group of robots. The robot presented in [22] is the third experimental example of a robot that can lift a patient out of bed and put him in a wheelchair. It is equipped with sensors that allow it to avoid colliding with medical staff, patients, furniture and fit into doorways. A particularly important quality of auxiliary medical robots is human safety. A patient can be moved only in a narrow range of accelerations, be touched only with carefully dosed effort and in precisely defined places.

Figure 4. Experimental nursing care robot Robear [23].

D. Cobots for production

Apart from specialized robots, it should be consider such types of robots as cobots (collaborative robots) (for example, cobots Hanwha2 (Figure 5)). Their purpose is to perform work in the same workspace with a person, without causing harm to them [24]. Collaborative robots are used in small companies where it is necessary to quickly and frequently reconfigure production lines and integrate them into the existing production process. Cobots successfully cope with complex, monotonous physical actions, without requiring a salary increase and a lunch break. But the main advantage of such robots is their safety for humans when performing joint actions. In addition, collaborative robots are open systems, which allows us to program them to perform exactly the actions that are required at the moment, as well as reprogram them after to perform other actions.

E. Applicability of the solutions presented

Among the developments listed above, the most suitable for implemented the functions we are interested in is AGROBOT. It includes "Real Time Artificial Intelligence" for determining ripe berry of strawberry, but, only strawberry. It provides human safety, but it moves only in a special organized space. It provides precise moving to target and gentle grabbing. Table I presents the main features of the robotic systems listed.

Thus, the market already has solutions that allow to implement almost all the functionality of the proposed robotic system. At the same time, the cost of such a solution will be quite high. On the other hand, low-cost components allow to

Figure 5. Cobot Hanwha HCR-5 [25].

TABLE I. FEATURES OF ROBOTIC SYSTEMS

Robotic systems	*Features*
Flyability Elios	• Obstacle avoidance • Eliminating potential harm to workers • Video translation
Naturaldrones StillFly	• Obstacle avoidance • Video translation
Amazon warehouse robots	• Route planning • Obstacle avoidance
ecoRobotix	• Computer vision • Object recognition • The targeting an object
AGROBOT E-Series	• Computer vision • Object recognition • The targeting an object • Gentle grabbing • Human security
TreeRover	• Route planning • Manipulation
Da Vinci	• Exceptional accuracy • Manipulation • Video translation
Robear	• Route planning • Obstacle avoidance • Manipulation • Gentle grabbing
Hanhwa	• Manipulation • Human security

get a similar product, but with rather poor characteristics of movement accuracy. And here, too, artificial intelligence can come to help. The capabilities of artificial intelligence with use of feedback control can compensate for the shortcomings of the mechanical system.

One of the main problems in the development of the system is mechanical flaws in the design of the manipulator and the servos used in it, which do not guarantee an accurate rotation at a given angle. Each movement is performed with a small error, which accumulates in several joints of the manipulator, leading to a significant error in reaching the target position. It is of interest to investigate the trajectories of the manipulator using tracking with a video camera and teach the manipulator to adjust the speed and angle of rotation of the motors in its joints by analysing the video image. This approach is based on methods presented in [10]. Memorizing the movements will allow to use them in subsequent operations. An important point here is the establishment of the limits of the motor errors, within which compensation is still possible, since in other cases compensation can lead to oscillations around the target without reaching it.

Artificial intelligence will be used to analyze video images and other sensors data and to form a knowledge base for manipulating manipulator elements in similar external conditions.

The functionality of the system being developed is supposed to be endowed with the system properties listed below.

Configurability – the ability to easily and quickly reconfigure software and hardware to maximize the system's compliance with a wide range of tasks.

Adaptability – a response to changes in the work environment, including the ability to self-learn and apply autoconfiguration strategies.

Interaction – the ability to interact with the operator, patients, other robots, and other systems in the work environment.

Mobility – the ability to move in relation to the kinematics and dynamics of manipulators, as well as positioning and navigation within the working environment.

Manipulation – the ability to handle material objects and tools, regardless of their shape, density and trajectory of movement, approximately as a person does in natural conditions.

Perception - the ability to choose the measurement method, to perform an effective analysis of signals and data received from a complex of heterogeneous sensors, as well as to obtain the maximum information output from the available data.

Autonomy – the ability to determine of the maximum level of responsibility in the processes of system management, task control, taking into account the context when interacting with the patient, the operator and the work environment.

Cognition – the ability to implement functions that reduce programming and configuration requirements in deployed systems.

The implementation of these system features will allow to create a system that fully corresponds to the task at hand, while being safe for humans, easy to intuitively manage and quite flexible in both hardware and software.

VI. CONCLUSION

This article examines the problem of developing a robotic system for the elderly and people with disabilities. The main purpose of the system is related to the implementation of the telecommunications of the patient with the guardian, of the remote manual control of platform and manipulator by the

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guardian, and the autonomous control of the platform and the manipulator. The implementation of a robotic device requires solving a number of theoretical and technical problems. For this purpose, the review of the current state of industrial robotics and analytical problems of control was performed. As a result, it was shown that the theoretical problems of constructing the route of the platform, manipulator and gripper are partially solved. The considered robotic systems used in various sectors of the economy have the functions and characteristics that the developed system should have. At the same time, there is no device that fully meets the stated requirements on the market yet. The implementation of some functions, in particular, the correct capture of objects that differ in structure and properties, is not represented in existing robotic devices. In addition, all implemented devices have a high cost, which makes it difficult to use them widely. In addition, the problem of population ageing is becoming more urgent. The article hypothesizes that expensive components can be replaced with cheaper, but less accurate ones. To overcome the emerging problem of movement accuracy and solve the problem of universal capture, it is proposed to use artificial intelligence. In the future, it is planned to conduct experiments to test the hypothesis and determine the limits of applicability of artificial intelligence methods for correcting inaccurate manipulator movements. This will allow to create robotic systems that are more adapted to the diversity of the real world and more versatile and flexible.

In general, it is shown that robotic systems are actively implemented in the professional activity and daily life of a person. Solving the problem of reducing the cost of robotic systems will lead to a wider introduction of robotics into everyday life, which will make human life longer and more comfortable.

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