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COMMAND RECOGNITION SYSTEM RESEARCH

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ABSTRACT:

This article presents experimental studies of a previously developed command recognition system. The details of the proposed mobile robot are described in detail. The setup of two experiments is presented, as well as an analysis of the results obtained. The conclusions provide recommendations for improving the accuracy of command recognition.

Key words: Mobile Robot, Control Command, Command Recognition, Robot Control System, Manufacturing Innovation, Industrial Innovation.

INTRODUCTION

Due to the introduction of the increasingly popular Industry 4.0 technology, the use of mobile robots is increasingly used [1]-[14].

Accordingly, for their widespread use, the development of control systems for such robots is necessary. All over the world, scientists are developing more and more new algorithms and ways to control mobile robots [15]-[38]. Some of these algorithms are quite simple; their advantage is speed of operation, including data processing and decision making. However, the accuracy is not always high enough. There are also complex algorithms, they often work slower, but show greater accuracy.

Mobile robot motion control is a broad field that covers various technologies and techniques to control the motion of robots. There are different types of such control: control based on remote control, program control, autonomous control, control based on artificial intelligence, hybrid control methods.

The choice of control method depends on the specific requirements of the task, the environment and available resources [39]-[43].

In this paper, we will consider autonomous control methods collectively (this method allows the robot to make decisions about movement based on information received from sensors. Autonomous robots use various types of sensors, such as distance sensors, cameras, gyroscopes and accelerometers, to perceive the

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environment and make decisions about their movement) and control based on artificial intelligence (the use of machine learning and artificial intelligence methods allows robots to learn and adapt to various situations), that is, a hybrid control method.

Related works

A huge number of scientists are studying the problem of controlling the movement of mobile robots. Let us look at some recent works on this topic.

The study [2] first expresses the significance of smart industrial robot control in manufacturing towards future factories by listing the needs, requirements and introducing the envisioned concept of smart industrial robots. Secondly, the current trends that are based on different learning strategies and methods are explored.

Existing manipulator control methods, such as position control, vision-based control method, fail to meet the requirements of autonomous learning [39]. The paper proposes a quality model to utilize deep reinforcement learning scheme to achieve an end-to-end manipulator control.

Authors [40] propose an efficient evolutionary learning algorithm to find the Pareto set approximation for continuous robot control problems, by extending a state-of-the-art RL algorithm and presenting a novel prediction model to guide the learning process.

Research [41] provides a concise but holistic review of the recent advances made in using machine learning to achieve safe decision-making under uncertainties, with a focus on unifying the language and frameworks used in control theory and reinforcement learning research.

Che, C., & et al. in [42] consider computer vision system for robot control system. They note that computer vision technology plays a crucial role in enabling robots to perceive and understand their surroundings, leading to advancements in tasks like autonomous navigation, object recognition, and waste management.

Scientists in [43] propose a new algorithm we call Graph Policy Gradients (GPG) that exploits the underlying graph symmetry among the robots to solve the problem of learning policies to control a large number of homogeneous robots.

So, we see that the scope of controlling mobile robots is very wide. Further in this article we will look at various control methods for the proposed in [25] device.

Experimental studies of the command recognition system

This study is a continuation of the work [25]. The purpose of this work is to develop a command recognition system based on motion capture technology for intelligent control of a mobile robot. A wheeled robot based on Arduino Mega was used to perform experimental research. This robot consists of the following

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components: 4 DC motors; engine driver based on the L298N chip, 3-axis gyroscope; accelerometer MPU-6050; 3 ultrasonic sensors HC-SR04. The power source of this robot is a portable power bank with a volume of 10200 mAh. We have two Bluetooth HC-06 4pin RS232 TTL modules and 2 USB-AB type cables of 3 m length for the connection of the robot with the computer and the computer with the motion capture system. The appearance of the mobile robot is presented in Fig. 1 – Fig. 3.

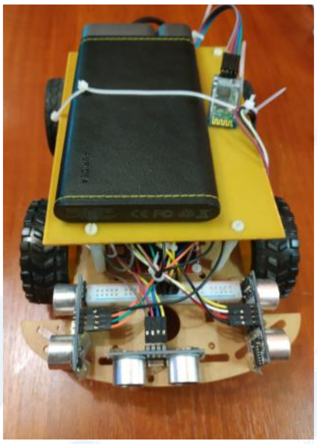

Figure 1: Mobile robot appearance, projection1

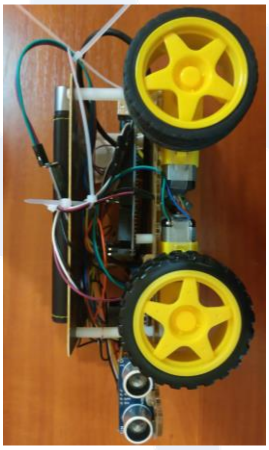

Figure 2: Mobile robot appearance, projection2

Figure 3: Mobile robot appearance, projection3

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A computer with the following specifications was used for information processing:

– operating system: Windows 10 Corporate;

– processor: Intel Core i5-3230M with a clock frequency of 2.6-3.0 GHz, depending on the load;

– RAM: 8GB, Samsung;

– SSD: Kingston A400, 240 GB;

– video card: Nvidia GeForce GT 750M.

To obtain information on increasing the efficiency index relative to other systems, it is necessary to conduct a number of experiments. Each of the experiments will allow to evaluate the quality of the elements of the developed system and the system as a whole.

To achieve the goal, it was decided to conduct the following experiments:

– comparison of the mobile robot passing the same route when using automatic control and control using operator motion capture;

– impact on the quality of control of the "Robot-Computer-Operator" communication system using wireless and wired technologies;.

Each of the experiments was assigned a number according to the order given above.

For the first experiment, the following main quality indicators were chosen: the time of passing the maze and the maximum distance of the robot's deviation from the route. In the case of automatic control of secondary indicators, the number of times the algorithm stops is selected, and in the operator control mode - the number of times when the system does not respond to the command. To conduct the first experiment, it was used to connect the operator's motion capture system to the computer via a wire, and the computer to the mobile robot via Bluetooth.

For the second experiment, the main quality indicators were chosen to be the execution time of a complete set of commands, the number of recognition errors.

Machine learning of the recognition system was performed using a combined operator command style and adapted software to automatically control the mobile robot. The use of a combined style of providing operator commands allows to reduce the number of movements required by the operator to control and according to [11] has an advantage in terms of recognition accuracy. Command submissions were performed by the same operator who performed the commands to form the training sample for machine learning. An exception was the last experiment, in which commands were administered to two different individuals, to examine the effect of changing the operator on recognition accuracy. Using one person to issue commands

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allows you to more accurately predict how the system will behave in certain conditions.

For the first experiment, a labyrinth measuring four by two meters was developed. To overcome the maze, the robot must travel a path 13.5 meters long without deviation. To pass the maze with the robot in the operator control mode, the following commands must be executed: "move forward" - 6 times; "turn to the right" - 3 times; "left turn" - 3 times; "stop" - 6 times. The scheme of the maze, which was used in experiment #1, is presented in Figure 4.

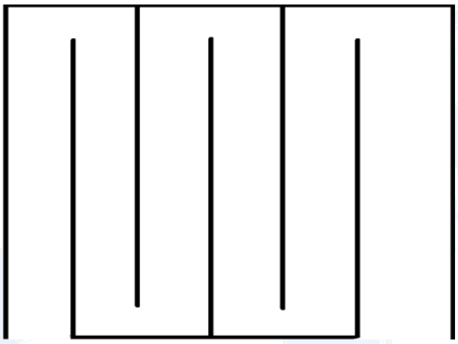

Figure 4: Labyrinth for experiment №1

To overcome the labyrinth in automatic control mode, the robot uses information about the distance received from three ultrasonic sensors located on its body. Its movement is determined by the following algorithm: performing forward movement and parallel checking of information about the distance from the sensor located in front (if the distance is less than 10 cm, a stop is performed); during a stop, distance information is checked from the sensors located on the left and right (as a result of comparing the distances, the robot turns in the direction where the distance is greater and, after completing the turn, stops). Stopping the robot at the end of the maze is done in manual mode.

The disadvantage of this movement algorithm is the possibility of its stopping, which occurs if: information about the distance from the sensors located on the left and right coincides (the robot hits a corner); if the robot deviates from the route, it will come close to the wall and will not be able to move for 3 seconds.

Table 1: Results of the experiment in automatic control mode

№	Labyrinth passage time, s	Maximum deviation from the route, sm	The number of algorithm stops
1	163	12	1
2	155	9	1
3	189	16	2
4	166	13	1

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5	159	11	0
6	181	15	1
7	184	14	2
8	175	13	1
9	171	12	1
10	177	13	1
Average	172	12,8	1,1

Table 2: Results of the experiment in operator control mode

№	Labyrinth passage time, s	Maximum deviation from the route, sm	Not responding to the command cases number
1	167	10	4
2	174	16	4
3	165	9	3
4	170	12	3
5	172	12	4
6	160	8	1
7	166	10	3
8	171	11	4
9	163	10	2
10	160	10	2
Average	166,8	10,8	3

According to the calculations, the system has a deviation from the ideal value of 6.923% in terms of the labyrinth passage time in the operator control mode, while when using the automatic control mode, the deviation is 20.279%. This shows that the use of the operator control mode is more effective, as the results in terms of the transit time indicator are 2.9 times better. In terms of the maximum deviation from the route, the system, according to experimental data, has an improvement of 20% when using the operator control mode, which is approximately 2 cm.

The execution of the second experiment was divided into several stages. At the first stage, the parts of the system were connected by wire technologies. To increase the reliability of the results, 10 experiments were performed. For the obtained results, the average value was calculated according to the formula (3.1). The robot executed a full set of commands ("forward", "turn left", "turn right", "stop", "backwards", "turn 360 left", "turn 360 right"). The execution time of a

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complete set of commands and the number of recognition errors are given in Table 3.

Table 3: Results of the experiment using wired technologies

№	Execution time of a complete set of commands, s	The number of recognition errors
1	36	1
2	41	1
3	33	0
4	31	0
5	37	1
6	30	0
7	38	1
8	34	0
9	35	1
10	33	0
Average	34,8	0,5

In the second stage of the experiment, the robot was connected to the computer using a wire, and the motion capture system was connected to the computer using Bluetooth. In the third stage, the motion capture system was connected to the computer using a wire, and the robot was connected to the computer using Bluetooth. The execution time of the complete set of commands and the number of recognition errors are presented in Table 4.

At the fourth stage, the elements are connected using Bluetooth technology. The results of the experiment are presented in Table 5.

Table 4: Results of the experiment using combined connection technologies

№	Execution time of a complete set of commands, s		The number of recognition errors	
	The second stage	The third stage	The second stage	The third stage
1	44	35	2	1
2	31	38	0	1
3	37	33	1	0
4	44	39	2	1
5	38	34	1	1
6	33	30	0	0
7	42	32	1	0
8	30	32	0	0

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9	40	40	1	1
10	38	37	1	1
Average	37,7	35	0,9	0,6

Table 5: Results of the experiment using Bluetooth Technology

№	Execution time of a complete set of commands, s	The number of recognition errors
1	38	1
2	36	1
3	46	2
4	39	1
5	35	1
6	38	1
7	44	1
8	38	1
9	43	1
10	48	2
Average	40,5	1,2

Table.6: Calculation results

Connection type	Average execution time of one command, s	Recognition error,%
Wire technologies	4,97	7
Technology combination №1	5,39	12,8
Technology combination №2	5	8,5
Wire technologies	5,79	17

CONCLUSION

When using wired technology, the recognition error is 7%, which is an acceptable value, and when using wireless technology, the error increases more than twice and is 17%, which has a significant impact on recognition. The way out of this situation is the use of a combination of technologies. In practice, when performing experimental studies, the combination of connecting the computer with the motion capture system to the operator - by wire, and working with the computer - via Bluetooth proved itself well. The increase in the average execution time of one command was only 0.03 s, which is a minor deviation, and the recognition error increased by 1.5%. To improve accuracy using wireless technology, higher-end modules must be used, as they are less sensitive to environmental noise. When using

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modules of a higher class, there will be an increase in their cost, which will lead to a decrease in the economic effect.

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