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COMMAND SYSTEM FOR MOVEMENT CONTROL DEVELOPMENT

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ABSTRACT:

The paper presents research on robot's command recognition and motion capture. There is developed a command system, which is pre-defined and universal for the motion of a great amount of robots. The system perceives all commands given by the operator as a three-dimensional vector of values. In the process of experiments using machine learning methods, research and classification of signals for each of the commands and states of the robot based on the data received from the sensors was performed. For machine learning of the system, it was decided to use the MatLab program package

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

INTRODUCTION

Today, robotics is an integral part of all spheres of human activity and everyday life: millions of robots work in manufacturing and service enterprises; underwater manipulators are used in research and rescue work; robots and manipulators are widely used in space research [1]-[15]. The most demanded is the use of robots and robotic systems to perform difficult, harmful, tiring and monotonous work [16]-[18].

Modern mobile robots are able to independently explore the environment, solve a set of tasks provided by the developers. However, in some applications, this does not guarantee their complete autonomy. Incomplete determination of technological situations, random external influences, insufficient information about the state of the environment require constant identification of the states of the robot and the environment, for which intelligent control algorithms are used [19]-[26]. Various methods and approaches can also be used here [27]-[38].

Modern mobile robot control systems are divided into three types: automatic, biotechnical and interactive. The use of automatic control systems is impossible in the case of incomplete certainty of technological situations, so biotechnical and interactive types have gained popularity. The biotechnical type of control allows a person to gain full control over a robotic system [39]-[41]. The interactive type allows for combined control of the system, both in automatic mode and human control. When using a biotechnical or interactive type of control, there is a need to set up human-machine communication. For this, command recognition systems are used.

Command recognition systems are an integral part of remote control of a mobile robot. Today, command recognition systems that use the principles of: motion capture are popular; visual control; control of levers and buttons; etc. The variety of commands and methods of setting them makes it possible to clearly and unambiguously make the system understand the operator's wishes.

However, the command recognition system based on the principle of motion capture is not well developed in the modern world.

The development of a command recognition system for intelligent control technology of a mobile robot is an urgent scientific task, as there are cases in which a mobile robot cannot make a decision on its own and needs remote control.

Related works

The problem of command recognition and motion capture has become extremely relevant with the advent of new sensors and increasing requirements for the accuracy and speed of positioning of mobile robots. Many scientific works are devoted to its solution, let is consider some of them.

In article [42] authors synthesize and evaluate studies investigating the use of motion capture technologies in industry-related research. They note that motion capture sensors, such as visual cameras and inertial measurement units, are frequently adopted in industrial settings to support solutions in robotics, additive manufacturing, teleworking and human safety.

The study [43] proposes an approach to improve the performance of mobile robot systems for optimal path planning. The technique utilizes motion capture technology to collect real-time data on the robot's movements, generate optimal path planning strategies, and enable remote control and monitoring of the robot's activities.

Scientists in [44] present research on methods of a wheeled mobile robot localization using an optical motion capture system. The results of localization based on the model of forward kinematics and odometric measurements were compared.

The paper [45] proposes a performance evaluation protocol that takes the characters of both optical motion capture and robotic 3C (Computer, Communication, and Consumer Electronics) product assembly operations into account.

The researchers in [46] consider the ball-catching system. It was composed of an omni-directional wheeled mobile robot and an image processing system that included a dynamic stereo vision camera and a static camera, was used to capture a thrown ball. The thrown ball was tracked by the dynamic stereo vision camera, and the omni-directional wheeled mobile robot was navigated through the static camera.

Lighthouse technology, commercially known as SteamVR tracking, is a 3D motion capture system developed for virtual reality applications that couples light-based and inertial tracking methods [47]. Authors [47] benchmark its performance in motion tracking for possible applications in biomechanics and robotics. The tracking performance of the system was evaluated to determine the accuracy and repeatability for pose measurements from dynamic studies.

Command system for movement control development

This study is a continuation of the works [48] and [49].

When developing a control system for a mobile robot, a set of actions for which it is intended or programmed is pre-defined. Since the system being developed must be universal (it can be used for various mobile robots), it makes sense to issue universal commands only for controlling the movement of the robot, since each of the robots has its own specific functionality and its own specific purpose. The set of universal commands includes: move forward, move back, stop, turn right 45º, turn left 45º, turn right 90º and turn left 90º. Each of the operator's commands must be pre-defined and machine-trained for its recognition.

In order to achieve high accuracy in recognizing the operator's commands, the number of experimental fixations of values from the sensors must be quite large. In machine learning of the system, the accuracy of operator command recognition has a direct dependence on the size of the sample. Since the sensor continuously sends data about the state of the motion capture system, this data must first be filtered.

The proposed system of commands for controlling the movement of a mobile robot has a three-dimensional (three-axis) nature. The system will perceive all commands given by the operator as a three-dimensional vector of values $\bar{a}=[x_n,y_n,z_n]$. At the machine learning stage, each command must be assigned to a certain command class. For example, the forward movement command can be represented as a vector $\bar{a}=[x_n,y_n,z_n]$, and this vector can be specified as following:

$$\bar{a}_1=[x_n,y_n,z_n],\ \bar{a}_2=[x_n,y_n,z_n]\dots\ \bar{a}_m=[x_n,y_n,z_{n.}]. \quad (1)$$

The system of commands in the form of classes and their corresponding states of the sensors is generally presented in Table 1.

In the control process, the robot must transmit data from the sensor and information about its current state or movement process. This information must undergo a filtering procedure and be recognized by establishing its belonging to the appropriate class of signals corresponding to a particular command. The system of states of a mobile robot in the form of states of sensors and corresponding classes of states of the robot is generally presented in Table 2.

Table 1: Command system in general

Command class	Command in the form of a vector of sensor values
Movement forward	$\bar{a}_1=[x_1,y_1,z_1]$, $\bar{a}_2=[x_2,y_2,z_2]$ … $\bar{a}_m=[x_n,y_n,z_{n.}]$
Movement backward	$\bar{b}_1=[x_1,y_1,z_1]$, $\bar{b}_2=[x_2,y_2,z_2]$ … $\bar{b}_m=[x_n,y_n,z_{n.}]$
Stop	$\bar{c}_1=[x_1,y_1,z_1]$, $\bar{c}_2=[x_2,y_2,z_2]$ … $\bar{c}_m=[x_n,y_n,z_{n.}]$
Left turn 45°	$\bar{d}_1=[x_1,y_1,z_1]$, $\bar{d}_2=[x_2,y_2,z_2]$ … $\bar{d}_m=[x_n,y_n,z_{n.}]$
Right turn 45°	$\bar{e}_1=[x_1,y_1,z_1]$, $\bar{e}_2=[x_2,y_2,z_2]$ … $\bar{e}_m=[x_n,y_n,z_{n.}]$
Left turn 90°	$\bar{g}_1=[x_1,y_1,z_1]$, $\bar{g}_2=[x_2,y_2,z_2]$ … $\bar{g}_m=[x_n,y_n,z_{n.}]$
Right turn 90°	$\bar{h}_1=[x_1,y_1,z_1]$, $\bar{h}_2=[x_2,y_2,z_2]$ … $\bar{h}_m=[x_n,y_n,z_{n.}]$

Table 2: Robot state class system in general

The state of the sensors in the form of a vector of values	Robot status class
$\bar{i}_1=[x_1,y_1,z_1]$, $\bar{i}_2=[x_2,y_2,z_2]$ … $\bar{i}_m=[x_n,y_n,z_{n.}]$	The robot is moving
$\bar{j}_1=[x_1,y_1,z_1]$, $\bar{j}_2=[x_2,y_2,z_2]$ … $\bar{j}_m=[x_n,y_n,z_{n.}]$	The robot is standing
$\bar{k}_1=[x_1,y_1,z_1]$, $\bar{k}_2=[x_2,y_2,z_2]$ … $\bar{k}_m=[x_n,y_n,z_{n.}]$	The robot turns left
$\bar{l}_1=[x_1,y_1,z_1]$, $\bar{l}_2=[x_2,y_2,z_2]$ … $\bar{l}_m=[x_n,y_n,z_{n.}]$	The robot turns right

In the process of experiments using machine learning methods, research and classification of signals for each of the commands and states of the robot based on the data received from the sensors was performed. Such training is an iterative experimental process, which includes the following stages:

– system training for operator teams;
– teaching the system to the states of the mobile robot;
– training of the decision-making system.

The basis of these processes are the solving of classification and recognition problems.

Planning experiments with system elements

Commands to the operator can be given in various ways, depending on the control conditions. They can be limited by the sensitivity of the sensor or the conditions of the command task. Therefore, it became necessary to establish the minimum necessary and optimally necessary number of movements of the operator to control the mobile robot with the specified accuracy. According to the specifications, the recognition accuracy should be equal to or at least 98%. From this it follows that the maximum permissible error of recognition $\partial_{n.p.} = 0,02.$

For machine learning of the system, it was decided to use the MatLab program package, as it has all the necessary technical capabilities for this.

The quality of system learning depends on such parameters as:

– study time;
– model training accuracy;
– accuracy of teaching within classes;
- prediction speed.

Also, quality assessment is performed using graphic methods. With the help of the MatLab environment, it is possible to generate: a scatter diagram, an error matrix, an ROC curve and a graph of parallel coordinates.

The error matrix shown in Figure 1 is a special type of contingency table, with two parameters ("actual" and "predicted") and identical sets of "classes" in both dimensions (each combination of dimension and class is a variable in the contingency table).

Figure 1: Example of an error matrix

The error matrix necessary for calculating the values of precision, recall, and F-measure is presented in Figure 2. The parallel coordinates graph is presented in Figure 3.

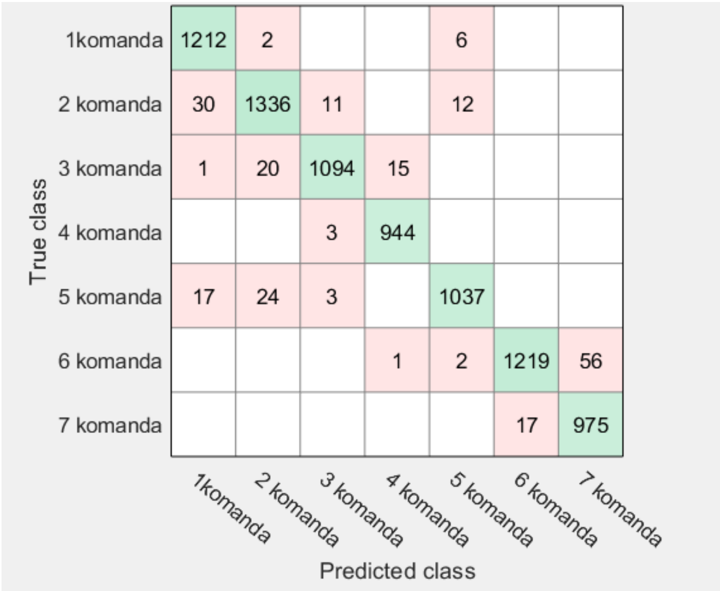

Figure 2: Error matrix

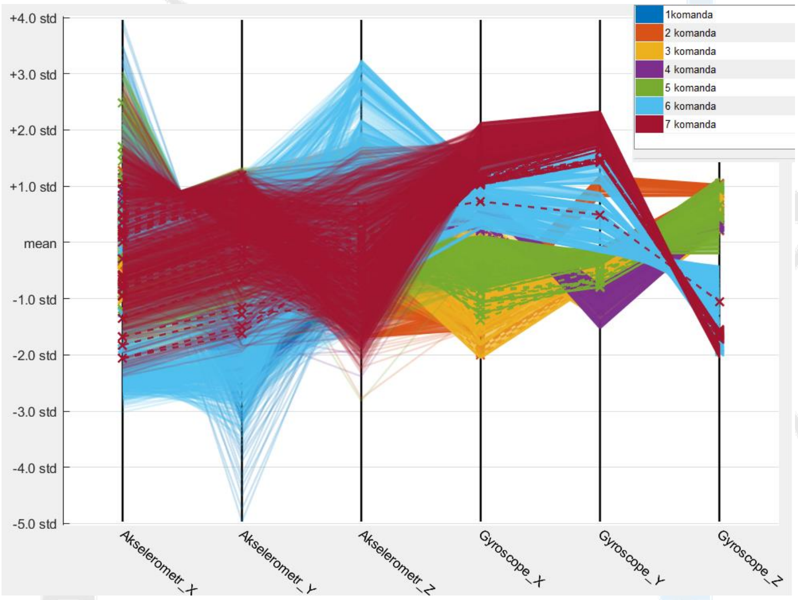

Figure 3: Parallel coordinates graph

CONCLUSION

The analysis of ROC curves showed that command № 7 has the smallest AUC area of 0.96, which significantly worsens the recognition accuracy indicator. On the graph of parallel coordinates, there is a clear dash-dotted line of false recognition of command №7, which shows the need to replace it with another command or re-form the training sample with a more accurate submission by the operator of this command to achieve higher recognition accuracy.

REFERENCES:

1. Attar, H., Abu-Jassar, A. T., Yevsieiev, V., Lyashenko, V., Nevliudov, I., & Luhach, A. K. (2022). Zoomorphic Mobile Robot Development for Vertical Movement Based on the Geometrical Family Caterpillar. Computational intelligence and neuroscience, 2022, 3046116.

2. Abu-Jassar, A. T., Al-Sharo, Y. M., Lyashenko, V., & Sotnik, S. (2021). Some Features of Classifiers Implementation for Object Recognition in Specialized Computer systems. TEM Journal: Technology, Education, Management, Informatics, 10(4), 1645-1654.

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THE MULTIDISCIPLINARY JOURNAL OF SCIENCE AND TECHNOLOGY

VOLUME-4, ISSUE-6

3. Al-Sharo, Y. M., Abu-Jassar, A. T., Sotnik, S., & Lyashenko, V. (2021). Neural networks as a tool for pattern recognition of fasteners. International Journal of Engineering Trends and Technology, 69(10), 151-160.

4. Sotnik, S., Mustafa, S. K., Ahmad, M. A., Lyashenko, V., & Zeleniy, O. (2020). Some features of route planning as the basis in a mobile robot. International Journal of Emerging Trends in Engineering Research, 8(5), 2074-2079.

5. Mustafa, S. K., Yevsieiev, V., Nevliudov, I., & Lyashenko, V. (2022). HMI Development Automation with GUI Elements for Object-Oriented Programming Languages Implementation. SSRG International Journal of Engineering Trends and Technology, 70(1), 139-145.

6. Nevliudov, I., Yevsieiev, V., Lyashenko, V., & Ahmad, M. A. (2021). GUI Elements and Windows Form Formalization Parameters and Events Method to Automate the Process of Additive Cyber-Design CPPS Development. Advances in Dynamical Systems and Applications, 16(2), 441-455.

7. Lyashenko, V., & et al. (2023). Automated Monitoring and Visualization System in Production. Int. Res. J. Multidiscip. Technovation, 5(6), 09-18.

8. Sotnik, S., & Lyashenko, V. (2022). Prospects for Introduction of Robotics in Service. Prospects, 6(5), 4-9.

9. Ahmad, M. A., Sinelnikova, T., Lyashenko, V., & Mustafa, S. K. (2020). Features of the construction and control of the navigation system of a mobile robot. International Journal of Emerging Trends in Engineering Research, 8(4), 1445-1449.

10. Al-Sharo, Y. M., Abu-Jassar, A. T., Sotnik, S., & Lyashenko, V. (2023). Generalized Procedure for Determining the Collision-Free Trajectory for a Robotic Arm. Tikrit Journal of Engineering Sciences, 30(2), 142-151.

11. Sotnik S., & et al.. (2022). Key Directions for Development of Modern Expert Systems. International Journal of Engineering and Information Systems (IJEAIS), 6(5), 4-10.

12. Sotnik, S., & et al.. (2022). Agricultural Robotic Platforms. International Journal of Academic Engineering Research, 6(4), 14-21.

13. Sotnik, S., & et al.. (2022). Analysis of Existing Infliences in Formation of Mobile Robots Trajectory. International Journal of Academic Information Systems Research, 6(1), 13-20.

14. Sotnik, S., & et al.. (2022). Modern Industrial Robotics Industry. International Journal of Academic Engineering Research, 6(1),. 37-46.

15. Lyashenko, V., & et al.. (2021). Modern Walking Robots: A Brief Overview. International Journal of Recent Technology and Applied Science, 3(2), 32-39.

16. Shcherbyna, V., & et al. (2023). Mobile Robot for Fires Detection Development. Journal of Universal Science Research, 1(11), 17-27.

17. Yevsieiev, V., & et al. (2023). A Small-Scale Manipulation Robot a Laboratory Layout Development. International independent scientific journal, 7, 18-28.

18. Nevliudov, I., & et al. (2023). A Small-Sized Robot Prototype Development Using 3D Printing. In XXXI International Conference CAD In Machinery Design Implementation and Educational Issues, 12.

19. Stetsenko, K., & et al. (2023). Exploring BEAM Robotics for Adaptive and Energy-Efficient Solutions. Multidisciplinary Journal of Science and Technology, 3(4), 193-199.

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THE MULTIDISCIPLINARY JOURNAL OF SCIENCE AND TECHNOLOGY

VOLUME-4, ISSUE-6

20. Yevsieiev, V., & et al. (2024). Object Recognition and Tracking Method in the Mobile Robot's Workspace in Real Time. Technical Science Research In Uzbekistan, 2(2), 115-124.

21. Shcherbyna, V., & et al. (2023). Mobile Robot for Fires Detection Development. Journal of Universal Science Research, 1(11), 17-27.

22. Yevsieiev, V., & et al. (2024). The Canny Algorithm Implementation for Obtaining the Object Contour in a Mobile Robot's Workspace in Real Time. Journal of Universal Science Research, 2(3), 7-19.

23. Maksymova, S., & et al (2024). The Bipedal Robot a Kinematic Diagram Development. Journal of Universal Science Research, 2(1), 6-17.

24. Yevsieiev, V., & et al. (2024). Active Contours Method Implementation for Objects Selection in the Mobile Robot's Workspace. Journal of Universal Science Research, 2(2), 135-145.

25. Yevsieiev, V., & et al. (2024). Using Contouring Algorithms to Select Objects in the Robots' Workspace. Technical Science Research In Uzbekistan, 2(2), 32-42.

26. Nevliudov, I., & et al. (2023). Mobile Robot Navigation System Based on Ultrasonic Sensors. In2023 IEEE XXVIII International Seminar/Workshop on Direct and Inverse Problems of Electromagnetic and Acoustic Wave Theory (DIPED),IEEE, 1, 247-251.

27. Lyashenko, V., & et al.. (2021). Wavelet ideology as a universal tool for data processing and analysis: some application examples. International Journal of Academic Information Systems Research (IJAISR), 5(9), 25-30.

28. Babker, A. M., Abd Elgadir, A. A., Tvoroshenko, I., & Lyashenko, V. (2019). Information technologies of the processing of the spaces of the states of a complex biophysical object in the intellectual medical system health. International Journal of Advanced Trends in Computer Science and Engineering, 8(6), 3221-3227.

29. Al-Sherrawi, M. H., Lyashenko, V., Edaan, E. M., & Sotnik, S. (2018). Corrosion as a source of destruction in construction. International Journal of Civil Engineering and Technology, 9(5), 306-314.

30. Khan, A., Joshi, S., Ahmad, M. A., & Lyashenko, V. (2015). Some effect of Chemical treatment by Ferric Nitrate salts on the structure and morphology of Coir Fibre Composites. Advances in Materials Physics and Chemistry, 5(1), 39-45.

31. Lyashenko, V., Deineko, Z., & Ahmad, A. (2015). Properties of Wavelet Coefficients of Self-Similar Time Series. International Journal of Scientific and Engineering Research, 6, 1492-1499.

32. Lyubchenko, V., & et al.. (2016). Digital image processing techniques for detection and diagnosis of fish diseases. International Journal of Advanced Research in Computer Science and Software Engineering, 6(7), 79-83.

33. Lyashenko, V. V., Matarneh, R., Kobylin, O., & Putyatin, Y. P. (2016). Contour Detection and Allocation for Cytological Images Using Wavelet Analysis Methodology. International Journal, 4(1), 85-94.

34. Sotnik, S., & et al.. (2023). Development Features Web-Applications. International Journal of Academic and Applied Research (IJAAR), 7(1), 79-85.

ISSN: 2582-4686 SJIF 2021-3.261,SJIF 2022-2.889,
2024-6.875 ResearchBib IF: 8.848 / 2024

THE MULTIDISCIPLINARY JOURNAL OF SCIENCE AND TECHNOLOGY

VOLUME-4, ISSUE-6

35. Sotnik, S. Overview: PHP and MySQL Features for Creating Modern Web Projects/ S Sotnik, V. Manakov, V. Lyashenko //International Journal of Academic Information Systems Research (IJAISR). – 2023. – Vol. 7, Issue 1. – P. 11-17.

36. Kuzomin, O., Lyashenko, V., Dudka, O., Radchenko, V., & Vasylenko, O. (2020). Using of ontologies for building databases and knowledge bases for consequences management of emergency. International Journal of Advanced Trends in Computer Science and Engineering, 9(4), 5040-5045.

37. Khan, A., Ahmad, M., Joshi, S., & Lyashenko, V. (2016). Synthesis of Alumina Fibre by Annealing Method using Coir Fibre. American Chemical Science Journal, 15(2), 1-7.

38. Kuzemin, A., & Lyashenko, V. (2008). Conceptual Foundations of Construction of the Models and Procedures for Prediction of the Avalanche-dangerous Situations Initiation. International Journal INFORMATION THEORIES & APPLICATIONS, 15(2), 153-158.

39. Al-Sharo Y., & et al. (2023). A Robo-hand prototype design gripping device within the framework of sustainable development. Indian Journal of Engineering, 20, e37ije1673.

40. Maksymova, S., & et al. (2023). Prosthetic Hand 3d Model Development. Multidisciplinary Journal of Science and Technology, 3(5), 147-156.

41. Yevsieiev, V., & et al. (2022). A robotic prosthetic a control system and a structural diagram development. Collection of scientific papers «ΛΌГОΣ», 113-114.

42. Menolotto, M., & et al. (2020). Motion capture technology in industrial applications: A systematic review. Sensors, 20(19), 5687.

43. Al-Kamil, S. J., & Szabolcsi, R. (2024). Optimizing path planning in mobile robot systems using motion capture technology. Results in Engineering, 22, 102043.

44. Dudzik, S. (2020). Application of the motion capture system to estimate the accuracy of a wheeled mobile robot localization. Energies, 13(23), 6437.

45. Hu, H., & et al. (2021). Performance evaluation of optical motion capture sensors for assembly motion capturing. IEEE Access, 9, 61444-61454.

46. Kao, S. T., & Ho, M. T. (2021). Ball-catching system using image processing and an omni-directional wheeled mobile robot. Sensors, 21(9), 3208.

47. Sitole, S. P., & et al. (2020). Application and evaluation of lighthouse technology for precision motion capture. IEEE Sensors Journal, 20(15), 8576-8585.

48. Basiuk, V., & et al. (2024). Command recognition system research. Technical Science Research in Uzbekistan, 2(5), 50-61.

49. Basiuk, V., & et al. (2023). Mobile Robot Position Determining Using Odometry Method. Multidisciplinary Journal of Science and Technology, 3(3), 227-234.