UDC 681.532:624
DOI https://doi.org/10.32782/2664-0406.2025.47.2025.5

Nevliudov I. S.
Doctor of Technical Sciences, Professor, Head of the Department of Computer-Integrated Technologies, Automation and Robotics
Kharkiv National University of Radio Electronics, Kharkiv
ORCID: 0000-0002-9837-2309

Sotnik S. V.
Ph.D., Associate Professor at the Department of Computer-Integrated Technologies, Automation, and Robotics
Kharkiv National University of Radio Electronics, Kharkiv
ORCID: 0000-0002-6035-2388

DESIGN OF THE STRUCTURE AND MOTION CONTROL SYSTEM OF A STATIONARY ROBOT MANIPULATOR FOR CONSTRUCTION WORK

Abstract. *The article presents the results of a comprehensive study dedicated to the development of a stationary robotic manipulator (palletizer) for performing technological operations in the construction industry. The work presents an integrated approach to designing a stationary robotic manipulator, encompassing its structural, hardware, and software aspects. A structural diagram of the automated control system has been developed, which establishes functional connections between the controller, feedback sensors, actuators, and the database for storing operational parameters. This diagram outlines the architecture of the robot's key components, providing a conceptual framework for implementing the system. A comparative analysis of modern software environments for three-dimensional modeling, including Blender, SolidWorks, and Autodesk 3ds Max, has been conducted based on criteria such as accessibility, functionality, testing capabilities, ease of learning, and support for engineering formats. Based on the analysis results, the choice of the Blender platform as the optimal tool is justified, as it provides the best balance between accessibility, visualization capabilities, and manipulator kinematics animation. The modeling methodology is described in detail, including the stages of planning, creating basic geometric primitives, detailed modeling using various tools, and the Mirror, Subdivision Surface, and Boolean modifiers for geometry optimization, as well as creating a skeletal framework to simulate the robot's movements. A fully functional three-dimensional model of a stationary palletizing robot manipulator has been created, which reproduces its structural features, spatial arrangement of components, and kinematic capabilities. The model allows for the visualization of the movement trajectories of individual manipulator segments and the verification of the design's functionality in a virtual environment before the physical manufacturing stage. The hardware part of the system was implemented using the Autodesk Tinkercad platform, which allowed for virtual modeling of the electronic circuit connections of components without the need for physical devices. Software has been implemented based on the Arduino microcontroller using the Servo.h library to control servomotors through pulse-width modulation. The practical significance of the obtained results lies in the creation of a functional prototype of a stationary palletizing robot control system, which can be used for educational purposes, demonstrating the principles of robotics in construction, and for further modification. The obtained results provide a basis for expanding the system's functionality through the integration of additional sensors for automatic object position detection, implementation of autonomous trajectory control algorithms, development of wireless control interfaces, and adaptation of the design for specific construction operations involving the palletization of materials at construction sites.*

Key words: construction, stationary, robot manipulator, robotics in construction, motion control system, 3D model, Blender, Tinkercad.

Problem statement. The modern construction industry requires the implementation of innovative technologies aimed at increasing efficiency, accuracy, and safety in work execution. Traditional construction methods, which involve a significant share of manual labor, are characterized by low productivity, high labor costs, and the risk of worker injuries. In this regard, the use of robotic systems capable of automating monotonous, dangerous, or high-precision operations is relevant [1-2].

Special attention is deserved by stationary robotic manipulators (SRMs) for construction work, which can perform functions such as handling materials, moving structural elements, applying mortars, or carrying out welding operations. However, the main challenges in creating such robots are ensuring the reliability of the design, positioning accuracy, stability of manipulator movements, as well as integrating the hardware and software components for real-time motion control.

To date, there are no standardized approaches to designing SRMs for construction work that take into account the peculiarities of the construction environment – variable loads, vibrations, dust exposure, temperature fluctuations, and so on. At the same time, it is important to be able to model the structure and test its functionality in a virtual environment before the stage of physical production. Thus, there is a need to create an integrated model of a stationary robot for construction work that combines optimal design solutions with an effective motion control system. Solving this problem involves developing a 3D model of the robot with the capability to simulate its actions, as well as creating software that ensures interaction between the controller, sensors, and actuators.

Thus, the main scientific and technical problem lies in designing the structure and control system of a stationary robot, which will allow the automation of certain stages of construction processes, increase their productivity, and reduce the human factor in hazardous working conditions.

Analysis of recent studies. Analysis of scientific research in recent years indicates a growing focus on the implementation of robotic systems in the construction industry. This is driven by the need to increase productivity, accuracy, and safety in production processes.

Yes, in works [3, 4], a review and analysis of the use of various robots in construction was conducted with the aim of improving efficiency, accuracy, and safety of work performance. In particular, areas of their application were considered – from performing hazardous and routine tasks (dismantling, inspection, maintenance of buildings and structures) to carrying out specialized operations. Different types of robotic systems are described: remotely controlled manipulator robots, drones, unmanned ground vehicles, climbing robots, cable robots, and microrobots.

It has been found that after 2015, interest in construction robots sharply increased, and their designs evolved into compact and mobile platforms [4]. In the context of construction, researchers' main efforts are focused on stationary [5] and mobile robots [6]. Today, mobility is an important and key task for various construction activities, such as loading and unloading operations and site cleaning, among others.

Recent research trends focus on the integration of artificial intelligence systems [7, 8], computer vision [9], and Internet of Things (IoT) technologies to enhance the autonomy and adaptability of construction robots [10]. Such solutions enable automatic trajectory planning, object recognition on construction sites, and real-time quality control of completed work.

At the same time, a number of unresolved issues remain, including the high cost of robotic systems, the difficulty of adapting to unpredictable construction site conditions, and the need for standardization and safe interaction between robots and workers [11, 12]. Thus, current research indicates an active development of robotic systems in construction, aimed at increasing autonomy, accuracy, and work safety. Further scientific studies focus on creating intelligent, energy-efficient, and versatile robots capable of functioning effectively in the dynamic conditions of construction production. Therefore, the need to develop an efficient design and control system for a stationary robot to perform construction tasks remains relevant.

The purpose of the study is the development of a three-dimensional model of a stationary robotic manipulator for construction work and its motion control system, including the hardware scheme and software, which will allow the automation of certain stages of construction processes and reduce the human factor in hazardous working conditions.

Research results. Automation of technological processes is one of the key factors

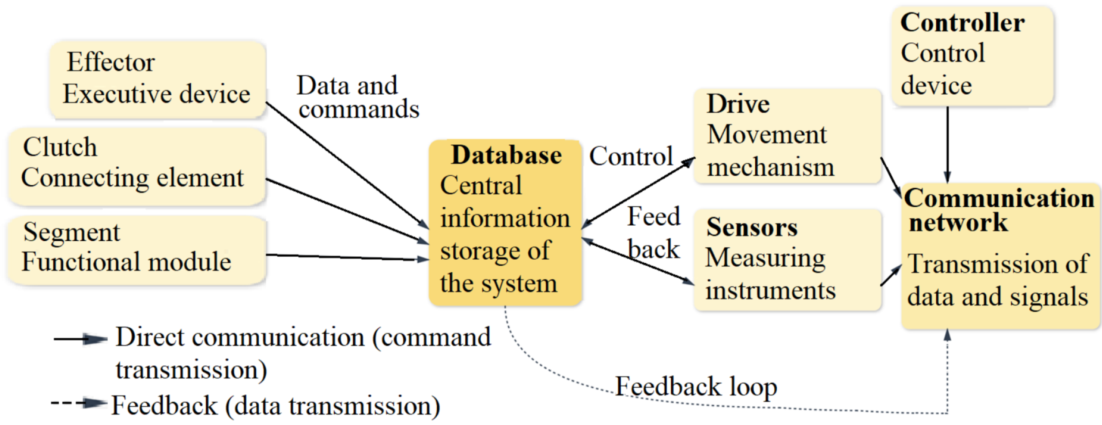

Fig. 1. Structural diagram of the automated control system of SRMs for construction work

in increasing efficiency and competitiveness in modern production [13–16]. The contemporary construction industry develops through intensive implementation of innovations, particularly via process automation [17]. An important vector of this transformation is the creation and application of SRMs for performing various operations at construction sites. Designing the structure of SRMs is a crucial stage in ensuring its functionality and productivity at the construction site. Key criteria in this process include stability, maneuverability, load capacity, and safety. To achieve optimal characteristics, it is planned to integrate advanced engineering solutions. Special significance is given to the development of a motion control system, which is key to effective operation.

The structural features of SRMs for construction work are determined by their functional purpose and the specifics of the construction operations performed. To begin with, we present a structural diagram of an automated control system for a stationary robot in construction, where the main hardware components and their functional relationships are shown (Fig. 1).

The diagram (Fig. 1) shows the main components of the SRM control system and their interconnections. The controller generates control commands for the actuators through the communication network, while the sensors provide feedback and transmit measurement data to the database. The effector, clutch, and segments perform executable functions during construction operations, and the database serves as the central information repository for processing and analyzing system performance parameters. For the detailed development of the robot's design, taking into account all depicted components and their spatial arrangement, it is necessary to select an appropriate design software environment.

During the conducted study, a comparison of development environments was carried out, presented in Table 1. Therefore, we justify the choice of the environment that is most suitable for the development of a 3D model.

Table 1. Comparison of the development environment for a 3D model of a stationary construction robot

Characterization	Blender	SolidWorks	Autodesk 3ds Max
Program accessibility	1	3	3
Functionality	2	1	2
Support for all platforms	1	1	1
Better in animation	1	3	1
Ability to conduct testing (strength, load, kinematics)	3	1	2
Ease of learning	2	2	3
Support for engineering file formats for robot design	2	1	2

Note: 1 – best, 2 – average, 3 – worst.

Based on a comparative analysis of 3D model development environments for SRMs for construction work (Table 1), Blender was chosen. Although the program is inferior to specialized CAD systems in performing engineering calculations, it offers high accessibility, versatility, ease of visualizing and animating robot movements, and supports the main 3D model formats necessary for further integration into the control system. This makes Blender an optimal choice for creating a visual model and simulating SRM operations at the design stage.

So, the Blender environment was used for modeling, as it is better than other approaches for project development.

Let's describe the process of modeling SRMs for construction work:

1. Planning. Before starting the modeling, the overall concept of the object was defined – its shape, proportions, and structural features. At this stage, basic sketches and ideas about the appearance and structure of the model were created (Fig. 2), which served as the foundation for further work.

2. Creating primitives. Blender allows objects to be formed based on basic geometric elements – cubes, spheres, cylinders, etc. These primitives were used to build the main components of the model and determine the general proportions of the structure.

3. Detailed Modeling. At this stage, the shape and geometry of the object were refined. Edges, faces, and vertices were added to create more complex elements. Tools such as Extrude, Loop Cut, Bridge Edge Loops, and others were used, allowing the creation of a detailed and realistic model (Fig. 2).

4. Application of Modifiers. Built-in Blender modifiers were used to optimize the modeling process, including Mirror (mirroring), Subdivision Surface (surface smoothing, resolution enhancement), and Boolean (union and subtraction operations of objects). This allowed for increased accuracy and symmetry of the model.

5. Rigging and Animation. To enable control over the robot's movements, a skeletal rig was added to the model. This made it possible to create various types of animations – segment movements, rotations, deformations, and more. Blender has advanced rigging and animation tools that allow modeling the robot manipulator's movements and checking its kinematics in motion.

During the design process, a three-dimensional model of a stationary manipulator robot was created, reflecting its structural features, component interactions, and possible movements. However, to ensure the full functioning of the system, it is necessary to develop the software part, which implements motion control algorithms, interaction with sensors, and actuators. The efficiency and flexibility of the software largely depend on the choice of the development environment, which should provide convenient integration with the hardware, support for the necessary libraries, and data exchange protocols. Thus, for the development of the software part, the Autodesk Tinkercad environment was chosen – a free online platform for 3D modeling and electronic circuit design, created by Autodesk (USA).

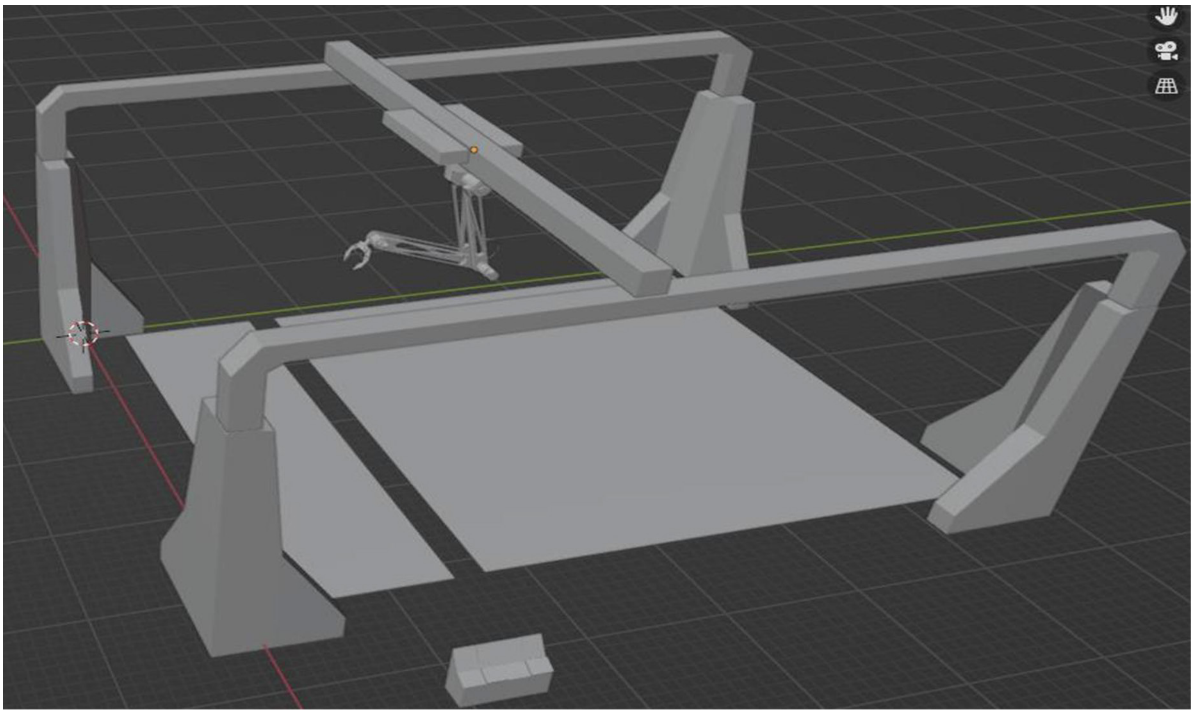

Fig. 2. Developed 3D model of the SRMs of the palletizer

The main reason for choosing Autodesk Tinkercad is its convenience, accessibility, and extensive capabilities for integrating the hardware and software parts of the system. Tinkercad provides the user with an extensive component library, including Arduino controllers, sensors, and actuators, allowing the modeling of real electronic circuits without the need for physical devices. The built-in simulator ensures the verification of correct connections, program performance analysis, and detection of possible errors during the design stage. Additionally, the environment supports writing code directly in the browser, which simplifies debugging control algorithms for robot movements and interacting with sensors. The simple interface and the ability to visually verify circuit operation make Tinkercad an optimal choice for developing the software part of a stationary construction robot. This environment combines the advantages of learning simplicity and engineering precision, allowing effective testing of control logic before transitioning to the physical implementation of the system.

To verify the correctness of the interaction between hardware components and software code in the Tinkercad environment, a virtual connection diagram was created. This diagram (Fig. 3) includes an Arduino microcontroller, sensors, and actuators, and serves as the basis for further simulation of the system's operation.

Fig. 3 demonstrates the hardware and software components of the control system for a stationary robotic manipulator. The constituent elements in the diagram (Fig. 3) are:

– Arduino Uno – the central controller that receives signals from potentiometers (controllers) and controls the servomotors;

– potentiometers (4 pcs.) – used to set the position or speed of each servomotor (e.g., manipulator segments);

– servomotors (3 pcs.) – simulate the movements of the robot's joints;

– L293D driver – a chip for controlling DC motors or servomotors, providing direction and power of movement;

– power supply (3 × AA 1.5 V battery pack) – supplies power to the circuit;

– connecting wires – transmit signals between components.

The developed hardware circuit (Fig. 3) requires software that would implement the algorithms for controlling the movements of SRMs and ensure the interaction of all components of the system. The software part is critically important for the functioning of the robot, as it defines the logic for processing signals from sensors and generating commands for the actuators. For the implementation of the control system, the Arduino UNO R3 board was chosen to serve as the central controller. The

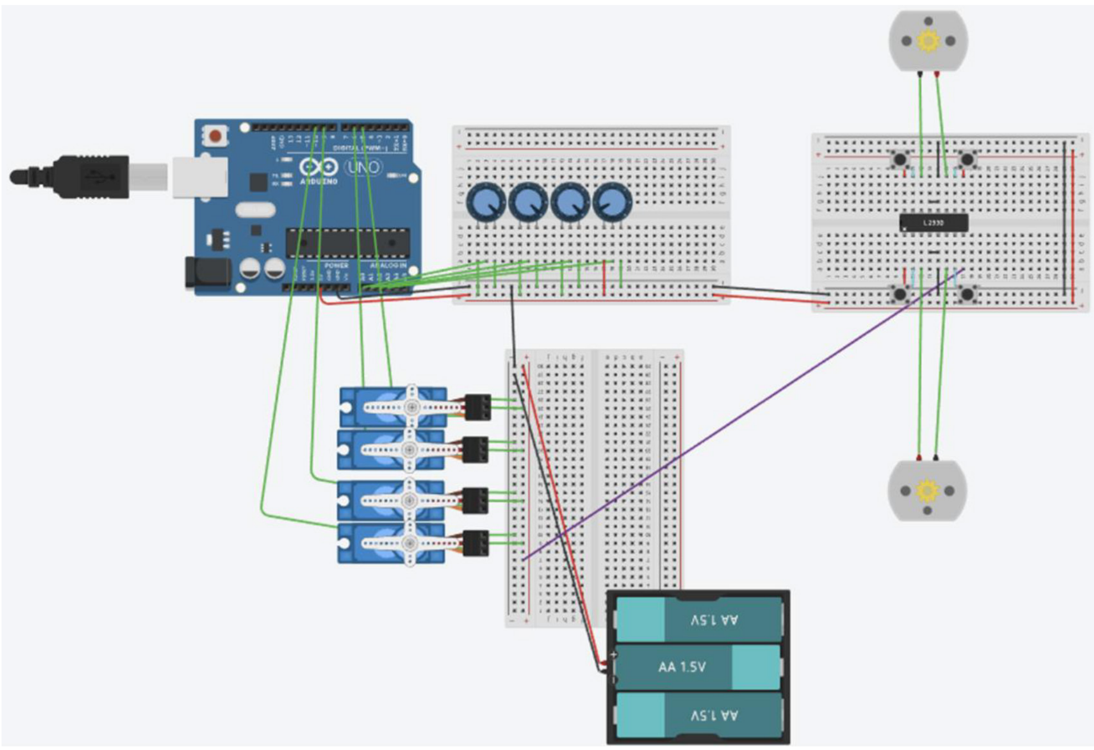

Fig. 3. Diagram of connecting Arduino project components in the Autodesk Tinkercad environment

choice of this platform is justified by its sufficient computational power, the availability of the required number of analog and digital inputs/outputs, as well as extensive library support for working with peripheral devices. Arduino UNO R3 provides the possibility to connect:

– micro Servo servos that mimic the movements of individual segments of the manipulator;

– DC motor through an L293D driver to simulate the operation of the gripping mechanism (claw);

– potentiometers for manually setting the position of each degree of freedom of the robot. The model's power supply is implemented from a 3 × AA battery pack with a nominal voltage of 1.5 V per cell, providing autonomy and portability of the prototype. The robot is controlled manually through analog controllers (potentiometers), allowing the operator to accurately control the position of each manipulator segment [18].

In the development of the program code, the standard Servo.h library was used, which provides functions for controlling pulse-width modulation (PWM) of servomotors. The program structure is built according to the classic Arduino project scheme and includes initialization, setup, and main execution loop blocks.

At the initial stage of the program, software objects are created to control the servomotors:

```
Servo servo1;
Servo servo2;
Servo servo3;
Servo servo4;
```

Each object of the Servo type corresponds to a separate servo in the manipulator design and provides an interface for controlling its position. Next, the analog input pins for connecting potentiometers are defined:

```
int pin0 = A0;
int pin1 = A1;
int pin2 = A2;
int pin3 = A3;
```

These variables indicate the analog inputs of the controller, through which voltage values are read from the potentiometers corresponding to the desired position of each segment.

Thus, the main functional blocks of the program include:

1. Library inclusion. The program starts with the directive to include the Servo.h library, which provides specialized functions for working with servomotors.

2. Creation of control objects. Four objects of the Servo class are declared for independent control of the four servomotors of the manipulator.

3. Configuration of input-output ports. Analog input pins are defined for reading signals from potentiometers, and variables are also declared for storing the current angular positions and analog-to-digital converter (ADC) values.

4. Setting limit values. Restrictions are set for the movement ranges of the servomotors and threshold values for controlling their rotation speed, which ensures smooth movements and prevents mechanical damage.

5. The initialization function setup(). This function performs the initial system setup:

– configuring pins as inputs or outputs;

– attaching servo software objects to the appropriate digital pins of the controller;

– establishment of the initial positions of the executive mechanisms.

6. The main execution loop loop(). This function runs cyclically and implements the main control logic:

– reading analog values. Using the function analogRead(), voltage values from

potentiometers are read (range 0–1023) and scaled to the control range 1–29 using the map() function;

– center correction. Software correction of values is performed to compensate for possible inaccuracies in the mechanical centering of the potentiometers;

– calculation of increments. The difference between the current analog input value and the central position determines the direction and speed of change of the servo position;

– conversion to angles. The internal values of the servos are converted to rotation angles in the range from 10° to 180° using the map() function;

– command transmission. The calculated angular values are sent to the corresponding servos via the write() method, which directly controls the PWM signal;

– gripping mechanism control. When the button is pressed (reading HIGH on pin 3), a digital output is activated (pin 4 is set to HIGH), simulating the activation of an electromagnet or the gripping system.

Such software architecture provides flexible and precise control of all degrees of freedom of the manipulator, allowing the operator to intuitively control the robot's position and perform basic manipulation operations. The modular code structure facilitates further system improvements, including the implementation of automatic operating modes, integration of additional sensors, or the realization of wireless control.

Conclusions. During the course of the work, a comprehensive design of a stationary construction manipulator robot was carried out, encompassing both the structural and software components of the system. The study was based on an analysis of current trends in the automation of the construction industry and the need to improve productivity, accuracy, and safety in performing technological operations on construction sites. A structural scheme of the automated control system was developed, defining the interaction of the robot's main components, including the controller, feedback sensors, actuators, and a database for storing and processing operational parameters. This scheme became the conceptual basis for further modeling of the design and development of the control system. Based on a comparative analysis of software environments for three-dimensional modeling, the Blender platform was chosen, which provided an optimal combination of accessibility, visualization functionality, and the capability for robot kinematics animation. In the Blender environment, a detailed three-dimensional model of a stationary palletizing robot manipulator was created using a sequence of stages, from planning and constructing basic geometric primitives to applying modifiers and implementing a skeletal rig for motion simulation. The resulting model reflects the robot's design features, its spatial geometry, and possible movement trajectories of individual manipulator segments. For the development of the software and hardware parts of the control system, the Autodesk Tinkercad platform was used, allowing the virtual modeling of the electronic circuit connections of components and preliminary testing of the operational logic without the need for physical devices. The created scheme includes an Arduino UNO R3 microcontroller as the central control element, four potentiometers for manual position setting, three servomotors to simulate the movements of the manipulator's joints, an L293D motor driver, and an autonomous power supply. This configuration provides sufficient functionality to demonstrate the basic principles of controlling a multi-link manipulator. Software has been developed based on the Arduino microcontroller using the Servo.h library to control the servomotors via pulse-width modulation. The program code implements cyclic reading of analog signals from the potentiometers, their mathematical conversion into angular values for the servomotors, taking into account limit constraints and centering correction, as well as control of the gripping mechanism through a digital output.

The modular architecture of the program allows the operator to intuitively control the position of each degree of freedom of the manipulator and perform basic manipulation operations in manual mode. The practical value of the completed work lies in the creation of a functional prototype of a stationary robot control system, which can be used for educational purposes, demonstrating the principles of robotics in construction, and further improvement for practical implementation. The obtained results provide a foundation for expanding the system's functionality by integrating additional sensors for automatic object position detection, implementing autonomous trajectory control algorithms, developing wireless control interfaces, and adapting the design for specific construction operations. The developed design methodology can be applied to create other types of construction robots, taking into account the specifics of particular technological tasks.

Bibliography

1. Sotnik S., Lyashenko V. Prospects for Introduction of Robotics in Service. *International Journal of Academic Engineering Research*. 2022. № 6(5). С. 4–9.
2. Bielik M. S., et al. Analysis of the structures of mobile platforms for promoter robots. *The 5th International scientific and practical conference "Global trends in science and education" (June 2–4, 2025) SPC "Sci-conf.com.ua", Kyiv, Ukraine*. 2025. С. 319–325.
3. Saad S., et al. AI in Material Science. Boca Raton : CRC Press, 2024. 288 p.
4. Chang S., et al. Evolution pathways of robotic technologies and applications in construction. *Advanced Engineering Informatics*. 2022. № 51. P. 101529. https://doi.org/10.1016/j.aei.2022.101529
5. 王璐. Research on construction performance evaluation of stationary and mobile robots in wooden block stacking method. WANG LU, 2022. 359 p.
6. Asadi K., et al. Automated object manipulation using vision-based mobile robotic system for construction applications. *Journal of Computing in Civil Engineering*. 2021. 35.1, С. 1–8.
7. Wei H. H., et al. Intelligent robots and human-robot collaboration in the construction industry: A review. *Journal of Intelligent Construction*. 2023. Vol. 1, no. 1. С. 1–12. https://doi.org/10.26599/JIC.2023.9180002

8. Faheem M. A., et al. AI and robotic: About the transformation of construction industry automation as well as labor productivity. *Remittances Review*. 2024. № 9. P. 871–888. https://doi.org/10.33282/rr.vx9i2.42
9. Dong Z., et al. Computer vision to recognize construction waste compositions: A novel boundary-aware transformer (BAT) model. *Journal of environmental management*. 2022. № 305. P. 114405. https://doi.org/10.1016/j.jenvman.2021.114405
10. Ghosh A., et al. Patterns and trends in Internet of Things (IoT) research: future applications in the construction industry. *Engineering, construction and architectural management*. 2021. Vol. 28, no 2. P. 457–481. https://doi.org/10.1108/ECAM-04-2020-0271
11. Onososen A. O., Musonda I. Research focus for construction robotics and human-robot teams towards resilience in construction: scientometric review. *Journal of engineering, design and technology*. 2023. Vol. 21, no 2. P. 50–526. https://doi.org/10.1108/JEDT-10-2021-0590
12. Liang C. J., et al. Human–robot collaboration in construction: Classification and research trends. *Journal of Construction Engineering and Management*. 2021. Vol. 147, no 10. P. 03121006. https://doi.org/10.1061/(ASCE)CO.1943-7862.0002154
13. Vasylchenko Y., et al. Development of Security and Fire Alarm Integrated Automation System at Enterprise. *WSEAS Transactions on Systems*. 2025. № 24. C. 642–664. https://doi.org/0.37394/23202.2025.24.56
14. Sotnik S. Development of a range measurement module on an ultrasonic sensor with a GSM module. *Radio Electronics, Computer Science, Control*. 2025. P. 32–44. https://doi.org/10.15588/1607-3274-2025-2-3
15. Yechevskyi A. D., et al. Research of orientation methods of autonomous mobile robots in industrial conditions. "*Computer-integrated technologies, automation and robotics*" *CITAR-2025*. 2025. P. 115–119.
16. Sotnik S. V. Development of automated control system and registration of metal in continuous casting. *Radio Electronics, Computer Science, Control*. 2024. P. 197–211. https://doi.org/10.15588/1607-3274-2024-3-17
17. Zhao X., Cheah C. C. BIM-based indoor mobile robot initialization for construction automation using object detection. *Automation in Construction*. 2023. № 146. P. 104647. https://doi.org/10.1016/j.autcon.2022.104647
18. Sukhomlinova D.A., et al. Aerial robot in urban environments. *Sustainable smart cities and communities: business and innovation solutions 2025: Proceedings of I st I International Conference, Kharkiv, April 21, 2025: Thesises of Reports*. 2025. P. 45–46.

References

1. Sotnik, S., & Lyashenko, V. (2022). Prospects for Introduction of Robotics in Service. *International Journal of Academic Engineering Research*, 6(5), 4–9.
2. Bielik, M.S., et al. (2025). Analysis of the structures of mobile platforms for promoter robots. *The 5th International scientific and practical conference "Global trends in science and education" (June 2–4, 2025) SPC "Sci-conf.com.ua", Kyiv, Ukraine*, 319–325.
3. Saad, S., et al. (2024). AI in Material Science. Boca Raton: CRC Press. – 288 p.
4. Chang, S., et al. (2022). Evolution pathways of robotic technologies and applications in construction. *Advanced Engineering Informatics*, 51, 101529. DOI: 10.1016/j.aei.2022.101529
5. 王璐. (2022). Research on construction performance evaluation of stationary and mobile robots in wooden block stacking method. WANG LU. – 359 p.
6. Asadi, K., et al. (2021). Automated object manipulation using vision-based mobile robotic system for construction applications. *Journal of Computing in Civil Engineering*, 35.1, 1–8.
7. Wei, H. H., et al. (2023). Intelligent robots and human-robot collaboration in the construction industry: A review. *Journal of Intelligent Construction*, 1(1), 1–12. DOI: 10.26599/JIC.2023.9180002
8. Faheem, M. A., et al. (2024). AI and robotic: About the transformation of construction industry automation as well as labor productivity. *Remittances Review*, 9, 871–888. DOI: 10.33282/rr.vx9i2.42
9. Dong, Z., et al. (2022). Computer vision to recognize construction waste compositions: A novel boundary-aware transformer (BAT) model. *Journal of environmental management*, 305, 114405. DOI: 10.1016/j.jenvman.2021.114405
10. Ghosh, A., et al. (2021). Patterns and trends in Internet of Things (IoT) research: future applications in the construction industry. *Engineering, construction and architectural management*, 28(2), 45–481. DOI: 10.1108/ECAM-04-2020-0271
11. Onososen, A. O., & Musonda, I. (2023). Research focus for construction robotics and human-robot teams towards resilience in construction: scientometric review. *Journal of engineering, design and technology*, 21(2), 502–526. DOI: 10.1108/JEDT-10-2021-0590
12. Liang, C. J., et al. (2021). Human–robot collaboration in construction: Classification and research trends. *Journal of Construction Engineering and Management*, 147(10), 03121006. DOI: 10.1061/(ASCE)CO.1943-7862.0002154
13. Vasylchenko, Y., et al. (2025). Development of Security and Fire Alarm Integrated Automation System at Enterprise. *WSEAS Transactions on Systems*, 24, 642–664. DOI: 10.37394/23202.2025.24.56
14. Sotnik, S. (2025). Development of a range measurement module on an ultrasonic sensor with a GSM module. *Radio Electronics, Computer Science, Control*, 32–44. DOI: 10.15588/1607-3274-2025-2-3
15. Yechevskyi, A. D., et al. (2025). Research of orientation methods of autonomous mobile robots in industrial conditions. "*Computer-integrated technologies, automation and robotics*" *CITAR-2025*, 115–119.
16. Sotnik, S. V. (2024). Development of automated control system and registration of metal in continuous casting. *Radio Electronics, Computer Science, Control*, 197–211. DOI: 10.15588/1607-3274-2024-3-17
17. Zhao, X., & Cheah, C. C. (2023). BIM-based indoor mobile robot initialization for construction automation using object detection. *Automation in Construction*, 146, 104647. DOI: 10.1016/j.autcon.2022.104647
18. Sukhomlinova, D. A., et al. (2025). Aerial robot in urban environments. *Sustainable smart cities and communities: business and innovation solutions 2025: Proceedings of I st I International Conference, Kharkiv, April 21, 2025: Thesises of Reports*, 45–46.

ПРОЕКТУВАННЯ КОНСТРУКЦІЇ ТА СИСТЕМА КЕРУВАННЯ РУХАМИ СТАЦІОНАРНОГО РОБОТА-МАНІПУЛЯТОРА ДЛЯ БУДІВЕЛЬНИХ РОБІТ

Анотація. *У статті представлено результати комплексного дослідження, присвяченого створенню стаціонарного робота-маніпулятора (палетайзера) для виконання технологічних операцій у будівельній галузі. У роботі представлено комплексний підхід до проєктування стаціонарного робота-маніпулятора, який охоплює конструктивні, апаратні та програмні аспекти системи. Розроблено структурну схему автоматизованої системи управління, яка встановлює функціональні зв'язки між контролером, датчиками зворотного зв'язку, виконавчими механізмами та базою даних для зберігання операційних параметрів. Ця схема визначає архітектуру взаємодії ключових компонентів робота та забезпечує концептуальну основу для реалізації системи. Проведено порівняльний аналіз сучасних програмних середовищ для тривимірного моделювання, зокрема Blender, SolidWorks та Autodesk 3ds Max, за критеріями доступності, функціональності, можливості проведення випробувань, легкості освоєння та підтримки інженерних форматів. За результатами аналізу обґрунтовано вибір платформи Blender як оптимального інструменту, що забезпечує найкращий баланс між доступністю, можливостями візуалізації та анімації кінематики маніпулятора. Детально описано методологію моделювання, що включає етапи планування, створення базових геометричних примітивів, детального моделювання з використанням різноманітних інструментів та модифікаторів Mirror, Subdivision Surface і Boolean для оптимізації геометрії, а також створення скелетної арматури для імітації рухів робота. Створено повнофункціональну тривимірну модель стаціонарного робота-маніпулятора палетайзера, яка відтворює його конструктивні особливості, просторове розташування компонентів та кінематичні можливості. Модель дозволяє візуалізувати траєкторії переміщення окремих сегментів маніпулятора та перевірити працездатність конструкції у віртуальному середовищі до етапу фізичного виготовлення. Для реалізації апаратної частини системи використано платформу Autodesk Tinkercad, що дозволила віртуально змоделювати електронну схему підключення компонентів без потреби у фізичних пристроях. Реалізовано програмне забезпечення на базі мікроконтролера Arduino з використанням бібліотеки Servo.h для управління сервоприводами через широтно-імпульсну модуляцію. Практичне значення отриманих результатів полягає у створенні функціонального прототипу системи управління стаціонарним роботом-палетайзером, який може використовуватися для навчальних цілей, демонстрації принципів робототехніки у будівництві та подальшої модернізації. Отримані результати формують основу для розширення функціональності системи шляхом інтеграції додаткових датчиків для автоматичного визначення положення об'єктів, впровадження алгоритмів автономного керування траєкторіями руху, реалізації бездротових інтерфейсів управління та адаптації конструкції під специфічні будівельні операції палетизації матеріалів на будмайданчиках.*
Ключові слова: конструкція, стаціонарний, робот-маніпулятор, робототехніка в будівництві, система керування рухами, 3D модель, Blender, Tinkercad.

Невлюдов І. Ш.
доктор технічних наук, професор, завідувач кафедри комп'ютерно-інтегрованих технологій, автоматизації та робототехніки
Харківський національний університет радіоелектроніки, м. Харків

Сотник С. В.
Ph.D., доцент кафедри комп'ютерно-інтегрованих технологій, автоматизації та робототехніки
Харківський національний університет радіоелектроніки, м. Харків

Дата надходження статті: 23.10.2025
Прийнято: 07.11.2025
Опубліковано: 30.12.2025