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Видання розраховане на науковців, викладачів, аспірантів, студентів, усіх, хто прагне отримати ґрунтовні знання теоретичного і прикладного характеру.

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«Грааль науки» є офіційно зареєстрованим мультидисциплінарним науковим виданням з міжнародною сферою поширення, що підтримує політику відкритого доступу. **Ідентифікатор медіа R30-02704** (рішення № 430 від 22.02.2024 Національної Ради України з питань телебачення і радіомовлення).

Наказом МОН України № 582 від 24.04.2024 виданню «Грааль науки» присвоєно Категорію Б фахових видань України з питань економіки (051 «Економіка»).

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Конференція зареєстрована УкрІНТЕІ (Посвідчення № 435 від 10.06.2025) та сертифікована Euro Science Certification Group (Сертифікат № 22924 від 14.07.2025).

За точність викладених фактів та правильність цитування відповідальність несе автор.

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The conference is approved by UKRISTEI (Certificate № 435 dated June 10th, 2025) and certified by Euro Science Certification Group (Certificate № 22924 dated July 14th, 2025).

The author is responsible for the accuracy of the facts presented and the correctness of citations.

ABSTRACT

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STUDY OF A HYBRID MOBILE MANIPULATING ROBOT CONTROL SYSTEM BASED ON MACHINE VISION AND SENSOR NETWORKS IN INDUSTRY 5.0 PRODUCTION SCENARIOS

Igor Nevliudov
Doctor of Engineering Science, Professor,
Head of Department of Computer-Integrated Technologies, Automation and Robotics
Kharkiv National University of Radio Electronics, Ukraine

Vladyslav Yevsieiev
Doctor of Engineering Science, Professor,
Professor of Department of Computer-Integrated Technologies, Automation and Robotics
Kharkiv National University of Radio Electronics, Ukraine

Elgun Jabrayilzade
Ph.D. student Department of Computer-Integrated Technologies, Automation and Robotics
Kharkiv National University of Radio Electronics, Ukraine

In the current conditions of transition to the Industry 5.0 paradigm, the key task is to ensure effective and safe interaction between humans and robots in a shared production environment. Mobile manipulator robots perform complex operations in a dynamically changing environment where numerous factors influence the control system's decisions: people's movement trajectories, the presence of obstacles, changes in the location of objects, etc. Traditional control systems based solely on sensor data or machine vision have limitations in response speed and recognition accuracy. The use of a hybrid control system that combines machine vision and sensor networks makes it possible to improve the accuracy of situation assessment, decision-making speed, and the safety of interaction with the operator.

In the context of mobile manipulator robots, a hybrid control system is understood as an integrated architecture that combines several methods of data perception and analysis to form control actions. In our case, hybridity consists in the simultaneous use of machine vision to determine the spatial location of objects, recognize operator gestures, and detect dynamic obstacles, and sensor networks to monitor distance, speed, position, tilt angle, grip force, and other physical parameters in real time. Combining these data sources into a single control model provides both a global understanding of the working environment and local high-precision adaptation of movements. A comparative analysis of the hybrid control system with existing systems is presented in Table 1.

Table 1

Comparative analysis of a hybrid control system with existing systems

Comparison criteria	Systems based only on machine vision	Systems based only on sensor networks	Hybrid control system
Accuracy of object detection	High in good lighting conditions, decreases in difficult conditions	Average, depends on the number of sensors	Very high, thanks to the combination of data sources
Resistance to interference	Poor in dust, fog, poor lighting	Average, problems with magnetic/electrical interference	High, data is mutually complementary
Response speed	Average, depends on computing power	High, processing of smaller amounts of data	High, thanks to data flow optimization
Cost of implementation	Relatively low (1-2 cameras)	Average or high (many sensors)	Higher than single systems, but justified by functionality
Flexibility of configuration	Average, limited by vision algorithms	High, easy to add/change sensors	Very high, both subsystems can be scaled
Safety of interaction with humans	Limited, depends on recognition algorithms	Average, possible error during rapid movements	High, thanks to multi-channel control
Adaptability to the environment	Average	High under certain conditions	Maximum, due to the combination of advantages

Advantages of the hybrid system: increased accuracy and speed of decision-making; ability to operate in difficult conditions (changes in lighting, noise, dust); enhanced situational awareness; increased level of safety in human-machine interaction.

Disadvantages of the hybrid system: higher implementation cost due to the need to integrate several technologies; complexity of configuration and synchronization of data from different sources; increased requirements for computing resources.

Conclusions: The study shows that a hybrid control system for a mobile manipulator robot based on machine vision and sensor networks is a promising direction for the development of robotics in Industry 5.0. It provides a high level of

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adaptability, accuracy, and safety when interacting with humans, which is especially important for collaborative scenarios. A comparative analysis confirms that, despite the increased cost and complexity of integration, such systems significantly outperform classical approaches, ensuring effective functioning in dynamic production environments. Further research should focus on optimizing data fusion algorithms, reducing decision-making delays, and lowering the energy consumption of computing modules.

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ДОСЛІДЖЕННЯ ГІБРИДНОЇ СИСТЕМИ КЕРУВАННЯ МОБІЛЬНИМ МАНІПУЛЯЦІЙНИМ РОБОТОМ НА БАЗІ МАШИННОГО ЗОРУ ТА СЕНСОРНИХ МЕРЕЖ У ВИРОБНИЧИХ СЦЕНАРІЯХ INDUSTRY 5.0