

## **DEVELOPMENT OF ROBOTIC SYSTEMS FOR AUTONOMOUS CONTROL IN SMART CITIES AND INDUSTRY 4.0**

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Modern technological developments are aimed at creating smart cities and next-generation industries. Autonomous robotic systems play a key role in this transformation, ensuring increased efficiency, safety and sustainability of urban and industrial infrastructure.

Industry 4.0 is the integration of cyber-physical systems, the Internet of Things (IoT), and artificial intelligence to create smart manufacturing processes. Smart cities use these technologies to optimize various aspects of urban life, including transportation, energy supply, and resource management.

Autonomous Driving Technologies:

- Artificial Intelligence and Machine Learning: Allows robots to make decisions on their own and adapt to changing conditions.
- Internet of Things (IoT): Provides connectivity between devices and systems, allowing them to exchange data in real time.
- Cyber-Physical Systems: Combine physical objects and digital technologies to create intelligent control systems.

Artificial intelligence (AI) and machine learning are key technologies for creating autonomous systems. These technologies enable systems to analyze data, learn from it, and make decisions without human intervention. Examples of applications include:

Computer vision: Analyzing images and videos to recognize objects and situations.

Natural language processing (NLP): Understanding and generating human speech to interact with users.

Autonomous decision making: Using algorithms to optimize manufacturing processes and logistics.

IoT connects different devices and systems, enabling the exchange of data in real time. This enables the creation of integrated systems that can adapt to changes and provide more efficient resource management. Examples include:

Smart sensors: Collect data about the state of the environment and infrastructure.

Network protocols: Provide secure and efficient data exchange between devices.

Application Examples:

- Transportation and Logistics

Autonomous vehicles and drones play an important role in smart cities and Industry 4.0. These systems can significantly reduce delivery times and improve road safety. Examples include:

Driverless Cars: Using sensors and AI to control vehicles autonomously.

Delivery Drones: Autonomous delivery of goods over short distances.

- Energy

Smart cities are implementing intelligent energy management systems to optimize energy consumption and reduce costs. Examples include:

Smart Grids: Using sensors and AI to control power grids.

Energy-Efficient Buildings: Using IoT and automation to control heating, lighting, and other building systems.

- Infrastructure

Autonomous resource and infrastructure management systems help optimize city services and improve their quality. Examples include:

Water and sewerage management systems: Automatic regulation of water supply and management of treatment plants.

Building and bridge health monitoring: Using sensors to continuously monitor the health of infrastructure.

Challenges and Prospects:

- Cybersecurity

One of the main challenges in implementing autonomous systems is ensuring data security. It is necessary to develop reliable methods of protection against cyberattacks and unauthorized access.

- Ethical and legal aspects

The use of autonomous systems raises many ethical and legal issues. It is necessary to develop regulations and standards that will govern the use of these technologies and protect the rights of citizens.

- Technical challenges

Although autonomous control technologies are actively developing, they still face technical limitations. It is necessary to continue to improve algorithms and systems to ensure higher accuracy and reliability.

The development of robotic systems for autonomous control in smart cities and Industry 4.0 opens up new opportunities for improving the efficiency and safety of urban and industrial process management. However, successful implementation of these technologies requires addressing a number of challenges related to cybersecurity, ethical and legal aspects.

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