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OPTO-ELECTRONIC OBJECT RECOGNITION AND IDENTIFICATION SYSTEMS FOR INDUSTRIAL ROBOTICS

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Abstract

This paper presents the development and evaluation of an opto-electronic system for object recognition and identification in industrial robotics. The system utilizes RGB cameras combined with computer vision algorithms (OpenCV) and neural network models (YOLOv5, CNN). The proposed system was integrated with an autonomous robot to test its performance in a simulated industrial environment. The results showed high recognition accuracy (92-96%) with a processing delay of approximately 40 ms, demonstrating robustness in noisy and varying lighting conditions. The system's effectiveness in real-time object recognition highlights its potential for enhancing autonomous industrial robots' performance. Future work will focus on sensor data fusion and further optimization for resource-constrained platforms.

Keywords: Optoelectronic systems, object recognition, industrial robotics, neural network models, computer vision, autonomous systems, image processing.

Introduction. With the rapid development of automation and digitalization of industrial processes, the need for intelligent autonomous systems capable of interacting with the real environment without human intervention is increasing. One of the key components of such systems are optoelectronic devices that provide perception of the environment and identification of objects.For industrial robotics, the tasks of detail recognition, positioning, spatial orientation, and decision-making based on visual information are especially important. Modern approaches to image processing, including computer vision algorithms and machine learning elements, can improve the reliability and accuracy of robot control systems. The purpose of this work is to develop and research methods for object recognition and identification using optoelectronic systems to ensure the autonomy of robotic platforms in an industrial environment. In this study, RGB cameras were used in combination with computer vision algorithms based on the OpenCV library and neural network models developed using TensorFlow. The following stages of image processing were implemented:[1]

- Data preprocessing (filtering, illumination correction);
- Segmentation and contour detection;
- Feature extraction (SIFT, ORB);
- Object classification using convolutional neural networks (CNN).

For real-time object detection, the YOLOv5 model was employed and optimized for operation on an embedded computing module — NVIDIA Jetson Nano — which was integrated into a mobile industrial robotic platform. The system was tested in a simulated production line environment, where it was required to identify and classify various objects (e.g., workpieces, components, boxes) and transmit their coordinates to the control system for grasping or avoidance. As a result of the conducted experiments, object recognition accuracy reached 92–96%, with an average frame processing delay of approximately 40 milliseconds. This performance enabled real-time visual feedback, which is essential for the autonomous operation of the robot. Comparative analysis showed that the use of neural network models provided significantly higher robustness to noise and lighting variations compared to classical methods. In particular, under low-light conditions, CNN models demonstrated an 18% improvement in accuracy over feature-based methods such as ORB. The research results confirmed the effectiveness of opto-electronic systems in perception and object recognition tasks under industrial conditions. A key advantage was the system's adaptability to changing environments — including dust, partial occlusion of objects, and unstable lighting. Despite the high recognition accuracy, further optimization is required for integration into resource-constrained platforms. Future improvements include extending the system's capabilities to 3D object identification through the use of stereo cameras and LiDAR sensors. A promising direction is the fusion of data from multiple sensors and the implementation of multimodal signal processing. [2]

Conclusions. The developed opto-electronic object recognition system has demonstrated high efficiency and reliability in supporting the control of autonomous industrial robotic systems. By integrating digital image processing techniques with deep neural network algorithms, the system was capable of performing accurate and fast object detection under dynamic and challenging industrial conditions.

Its ability to operate in real time, adapt to variable lighting, partial occlusions, and environmental noise makes it suitable for deployment in real-world manufacturing environments. These results highlight the system's potential for enhancing autonomy, flexibility, and safety in industrial robotic applications.[3]

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– Focuses on optimizing YOLOv5 for noisy factory environments with varied lighting conditions.

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