Міністерство освіти і науки України
Харківський національний університет радіоелектроніки
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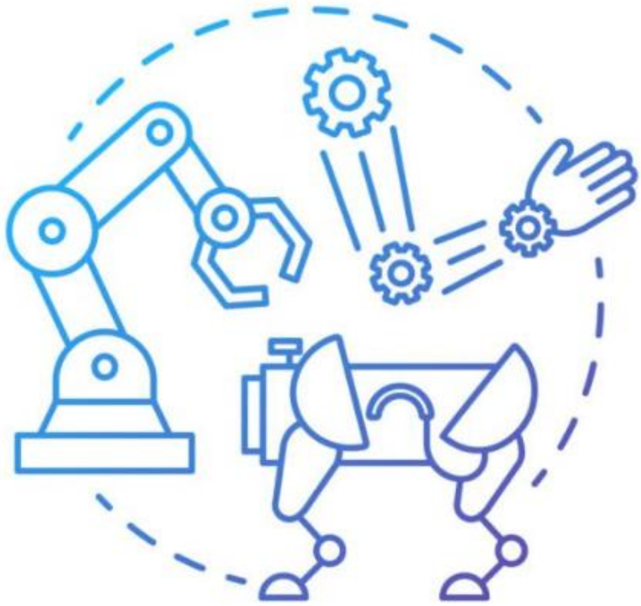

МАТЕРІАЛИ

III Всеукраїнської конференції
«Комп’ютерно-інтегрованих технологій, автоматизації та робототехніки»
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У збірник включені тези доповідей, які присвячені сучасним автоматизованим технологіям Industry 4.0 та їх впровадження; інформаційні управляючі системи технологічного призначення; математичні методи в системах автоматизації; розробка та програмування в робототехніці; штучний інтелект та машинне навчання в автоматизації; інтеграція технологій у виробництві та промисловості; сенсорні технології та взаємодія людини з роботами в Industry 5.0; ефективність використання роботизованих систем у виробництві; етика та правові аспекти в робототехніці; Інтернет речей та Інтегровані системи в комп’ютерно-інтегрованих технологіях, автоматизації та робототехніки; технологічні виклики та інновації у світі робототехніки.

Computer-integrated technologies, automation and robotics 2026: Proceedings of III st All-Ukrainian Conference, Kharkiv, May 14-15, 2026: Thesises of Reports / [Ed. I.Sh. Nevlyudov (chief editor).] .- Kharkiv .: [electronic version], 2026. - 97 p.

The collection includes abstracts devoted to modern automated technologies of Industry 4.0 and their implementation; information control systems for technological purposes; mathematical methods in automation systems; development and programming in robotics; artificial intelligence and machine learning in automation; integration of technologies in production and industry; sensor technologies and human interaction with robots in Industry 5.0; efficiency of using robotic systems in production; ethics and legal aspects in robotics; Internet of Things.

ЗМІСТ

COMPUTER VISION IN PRACTICE: FROM AUTOMATED QUALITY CONTROL IN MANUFACTURING TO AR APPLICATIONS

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Annotation: The paper examines the transformation of computer vision from an experimental technology into a critical tool for two mass-market industries: automated quality control in manufacturing and AR applications. It is shown that the success of implementation is determined not only by the choice of model (classification, detection, segmentation, SLAM) but primarily by the quality of data preparation and hardware configuration. A typical five-stage processing pipeline and critical differences in requirements are analyzed: manufacturing requires maximum accuracy under controlled conditions, while AR requires robustness and minimal latency in dynamic environments. Typical challenges are identified: unstable lighting, batch drift, and reflections in manufacturing; occlusions, tracking loss, and motion blur in AR applications.

Key words: computer vision, machine vision, quality control, defectoscopy, neural networks.

КОМП'ЮТЕРНИЙ ЗІР У ПРАКТИЦІ: ВІД АВТОМАТИЧНОГО КОНТРОЛЮ ЯКОСТІ НА ВИРОБНИЦТВІ ДО AR-ДОДАТКІВ

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Анотація: У роботі розглянуто трансформацію комп'ютерного зору з експериментальної технології в критичний інструмент для двох масових галузей: автоматичного контролю якості на виробництві та AR-додатків. Показано, що успіх впровадження визначається не лише вибором моделі (класифікація, детекція, сегментація, SLAM), а передусім якістю підготовки даних та налаштуванням апаратного забезпечення. Проаналізовано типовий п'ятиетапний конвеєр обробки та критичні відмінності у вимогах: виробництво потребує максимальної точності в контрольованих умовах, AR – стійкості та мінімальної затримки в динамічному середовищі. Виявлено типові виклики: нестабільне освітлення, дрейф партій та відблиски на виробництві; оклюзії, втрата трекінгу та розмиття в AR-додатках.

Ключові слова: комп'ютерний зір, машинний зір, контроль якості, дефектоскопія, нейронні мережі.

Relevance of the topic is driven by the rapid penetration of computer vision into key industries, where it is transforming from an experimental technology into a critical tool for solving specific business and engineering challenges.

In the realm of industry and automation, it is ceasing to be just a «useful feature». It is becoming the foundation for a new level of efficiency, accuracy, and continuity in manufacturing processes [1-10]. Simultaneously, in the field of interactive digital technologies, particularly augmented reality, computer vision serves as the foundation that enables stable, natural, and accurate interaction between the physical and virtual worlds [11-15]. These two, at first glance, different application domains demonstrate the universality of the methodology and the similarity of technical challenges: from choosing hardware and building reliable algorithms to integrating ready-made solutions into real workflows. Understanding these principles, architectures, and common practices allows not only for the effective implementation of ready-made systems but also for the correct formulation of tasks and evaluation of the technology's potential for new projects.

Computer vision today is about much more than just «recognizing a cat in a photo». In industry, it tackles critical challenges: consistently and quickly identifying defective parts, verifying labeling, tracking geometry, and assembly processes. In augmented reality, vision becomes the «eyes» of an application: it defines planes, anchors virtual objects in space, and understands gestures and occlusions. Despite the different contexts, the core remains similar: a camera, algorithms, a model, and a decision. Therefore, it is valuable to explore what a practical architecture looks like, where the bottlenecks occur, and which approaches truly work.

MATERIALS AND RESEARCH RESULTS. In applied systems, the most common tasks are: classification (what is in the frame), detection (where is the object), segmentation (which exact pixels belong to the object/defect), pose estimation (position of keypoints or 6DoF), and tracking. Classical methods (contours, thresholds, filters, Hough) are still useful for fast preprocessing, but the main improvement in quality in recent years has come from deep learning.

A typical pipeline looks like this: frame capture, normalization/filtering, model inference, post-processing (Non-Maximum Suppression, morphology, metrics), decision-making, and integration with equipment or an interface. In manufacturing, repeatability and the absence of "surprises" are crucial, while in Augmented Reality (AR), low latency and robustness to motion, scene changes, and lighting variations are key.

Let's outline the operational diagram (Fig. 1) of a Computer Vision system, which consists of five sequential stages:

- camera – image capture;
- preprocessing – image processing and preparation;
- CV model – a computer vision model for analysis;
- decision making – decision-making based on analysis;
- action/Integration – execution of actions or integration with other systems.

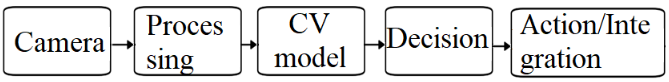

Figure 1 – Generalized diagram of the computer vision system operation

Examples of applications may include:

- Quality Control (QC) – quality control: detection of triggers, stable lighting, surface defects;
- Augmented Reality (AR) – augmented reality: SLAM/tracking, handling occlusions (object overlaps), low latency.

Depending on the specifics of the task, a computer vision system can solve various types of problems – from simple classification to complex spatial tracking. The main ones, along with characteristic model outputs and practical applications, are summarized in Table 1.

Table 1 – Tasks and typical outputs of computer vision models

Tasks	Output	Example in production	Example in AR
Classification	Class/Probability	OK/NG parts	Scene mode (indoor/outdoor)
Detection	BBox + class	Search for the missing element	Search for a marker/object for overlay
Segmentation	Pixel mask	Cracks, scratches, stains	Human mask for occlusions
Position assessment	Key points or 6DoF	Connector/hole position	Camera/Object Position
SLAM/tracking	Trajectory + map	Robot navigation in the workshop	Stable anchor in space

Table 1 shows that the choice of model type is determined more by the nature of the required information than by the field of application: for binary decisions (OK/NG), classification is sufficient; for defect localization, segmentation is needed; and for spatial orientation, pose estimation or SLAM is required.

Among the various applications of computer vision systems, automatic quality control in manufacturing occupies a special place, where the accuracy and speed of inspection directly affect economic efficiency.

The classic scenario is a conveyor and a camera above it. If the lighting is stable and the defects are typical, sometimes rules are sufficient: threshold + contours + geometric features. But as soon as variability appears (different material batches, reflections, small defects), detection and segmentation models that generalize better are preferred. A particular advantage is the ability to obtain not only the «bad» result but also the localization of the defect for rejection or repair.

In practice, most time is spent not on «choosing the neural network», but on data preparation: labeling, class balance, quality control of annotations, as well as on adjusting the optics (lens, focus, exposure) and lighting. In production systems, a trigger from the encoder is often used to capture the frame at the right moment, and hardware acceleration (GPU/TPU/Edge) is employed for stable inference.

In contrast to static production conditions, AR applications operate in a dynamic environment that requires specific approaches to tracking, SLAM, and scene «understanding».

In augmented reality, the key is to reliably anchor virtual content to the real world. To achieve this, visual or visual-inertial SLAM is used: estimating the camera position, building a feature/depth map, and continuously correcting the trajectory. Additionally, modern AR scenarios require semantics: human segmentation for occlusions, surface recognition, hand tracking, and sometimes object recognition.

The main difference from production is that the environment is uncontrolled. There is movement, changes in lighting, partial occlusions, and «blur» from rapid movement. Therefore, it is important to maintain low latency and stability: optimize the pipeline, limit resolution, apply quantization and hardware acceleration, and also have fallback strategies for when tracking is temporarily lost.

The main differences in the requirements for computer vision systems for production and AR are shown in Table 2.

Table 2 – Differences in requirements for computer vision systems for manufacturing and AR

Criterion	Production (QC)	AR apps
Stage	Controlled (light/background)	Uncontrolled (movement/occlusion)
Success metric	Sorting accuracy, minimal errors	Tracking stability, comfort
Delay	Important, but often serves as a buffer	Critical (interactivity)
Data	Few domains, but many parties	Very different domains/users
Typical risks	Reflections, drift of parties, dust	Tracking drift, occlusions, blurring

As can be seen from Table 2, production systems and AR applications have opposite priorities: while a controlled environment can be provided in production for maximum accuracy, in AR adaptability to unpredictable conditions with minimal latency is critical.

CONCLUSIONS. This work analyzes the practical application of computer vision in two key fields – automated quality control in manufacturing and AR applications, which demonstrate both the universality of the methodology and the specificity of requirements depending on the subject area. It is shown that a typical image processing pipeline consists of five sequential stages: frame capture, preprocessing, model inference, post-processing, and decision-making. The choice of model architecture (classification, detection, segmentation, pose estimation, SLAM) is determined not so much by the industry of application, but by the nature of the required information and the format of the output data.

Fundamental differences in the requirements for systems in different fields have been established. Manufacturing systems operate in a controlled environment with a priority on maximum accuracy and repeatability of results, whereas AR applications function in dynamic, unpredictable conditions where low latency and robustness to changes in lighting, motion, and occlusions are critical.

It has been revealed that in practice, the most time and effort are required not for choosing a neural network architecture, but for preparing high-quality data, configuring hardware (optics, lighting, triggers), and optimizing the entire pipeline to ensure stable operation in real-world conditions. The results of this work can be used to formulate technical requirements for computer vision systems, assess the feasibility of implementation, and select optimal architectural solutions according to the specifics of a particular task.

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