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Methods Of Identification Of Objects On Industrial Lines

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Abstract: *This paper examines modern methods of object identification in industrial production lines, focusing on quality control automation and production efficiency optimization. The research analyzes both classical computer vision approaches (including edge detection, contour analysis, Hough transformation, and template matching) and statistical methods for object identification and quality assessment. The study provides comprehensive comparison of various algorithms' effectiveness based on speed, noise tolerance, and accuracy criteria. Special attention is given to evaluating these methods' performance under different production conditions, considering factors such as lighting, surface characteristics, background environment, geometric parameters, and movement speed. Through systematic analysis of existing identification technologies, research establishes key implementation factors for industrial vision systems and provides structured recommendations for deploying identification systems in manufacturing environments. The paper offers valuable insights for industrial enterprises seeking to enhance their quality control processes through modern computer vision and object identification systems.*

Keywords— object identification, industrial automation, quality control, computer vision, edge detection, contour analysis, production efficiency

1. INTRODUCTION

The combination of automation, robotization, and informatization allows modern enterprises to remain competitive, ensure stable level of product quality, and respond quickly to changing market conditions [1-6]. Automation and informatization are especially important for quality control, where defects or deviations from standards need to be detected in timely and accurate manner.

Identification of objects on industrial lines is important component of modern production, where accuracy, speed, and reliability of quality control play crucial role. This process involves recognizing and classifying objects using various technologies, from classical methods to modern machine learning approaches.

In competitive environment, every part must meet high quality standards, and automating this process allows you to achieve consistent product quality, reducing reject rates and increasing production efficiency. Identification systems based on artificial intelligence and computer vision are able to automatically recognize and analyze characteristics of objects in real time, ensuring timely detection of defects or deviations.

Modern methods of object identification allow tracking both physical parameters of products (size, shape, color, texture) and their spatial location on conveyor. The use of high-resolution cameras and machine learning algorithms provides in-depth analysis that makes identification accurate, regardless of object complexity or lighting conditions. Object identification has become critical for automation and quality control in industries such as automotive, electronics, food, and many others where high product quality requirements do not allow even minimal errors.

The growing demand for high quality products and need to reduce costs require manufacturing companies to implement latest quality control and process optimization technologies. Traditional control methods based on manual inspection or standardized instrumental measurements are often unable to provide required level of accuracy and speed of inspection, especially in mass production. The high intensity of production lines, need for instant defect detection and reject rate reduction require implementation of automated solutions.

Therefore, important problem is to ensure identification and quality control of objects in real time. This task is complicated by need to process large amount of data with high accuracy and speed. Sometimes, lack of proper automated systems leads to problems such as increased rejects, inefficient use of resources, high dependence on human factor, and, as result, reduced productivity and product quality.

The purpose of this paper is to study and analyze modern methods of object identification on industrial lines, as well as to determine their effectiveness in ensuring high level of product quality control.

Therefore, to achieve this goal, following tasks are envisaged: analysis of modern methods of object identification on industrial lines; evaluation of effectiveness of object identification methods in different production conditions; development of recommendations for implementation of identification systems on industrial lines.

2. Related Work

Identification of objects on industrial lines is key step in automation of production processes, which contributes to increased accuracy, productivity and production safety. In recent years, number of methods and approaches have been proposed for object identification, ranging from traditional image processing methods to modern deep learning algorithms.

The paper [7] is devoted to methods of identification of industrial control objects based on amplitude-phase frequency characteristics. The main focus of study is aimed at development of mathematical models of control objects based on data of active experiment using overclocking characteristics. The authors chose statistical method.

Overview [8] of most popular and effective models for detecting objects in images, such as Faster R-CNN, R-FNC, and SSD. These models are among most used in computer vision due to their high accuracy and performance. The article discusses basic principles of these models, which are based on deep convolutional neural networks (ResNet, Inception, etc.) for primary image processing, as well as common stages of their algorithms, in particular proposal generation and classification.

In [9] comprehensive overview of machine learning (ML) methods for object recognition and analysis of manufacturing manufacturability is presented. The authors consider evolution of approaches from traditional methods to modern ML-based solutions. Analysis of conventional methods is carried out: graph-based approaches (AAG); volume decomposition; neural networks; heuristic methods; hybrid approaches.

A lot of scientific literature is devoted to latest standard of object detectors – YOLO (You Only Look Once) model. This approach has gained great popularity due to its high speed and accuracy, which allows it to be effectively applied in real-world conditions, in particular on industrial lines, in monitoring and security systems [10-12].

There are number of scientific papers on edge detection methods in manufacturing processes. These studies are aimed at developing and improving algorithms that allow accurate identification of object boundaries, increasing accuracy and efficiency of quality control and automation in production [13-15].

Hough Transformation is one of most common approaches for detecting lines, circles, and other simple geometric shapes in images, which is actively used in computer vision. Thanks to its ability to work efficiently even with noisy or incomplete data, Hough Transformation has found wide application in variety of industries, including manufacturing, where reliable identification of shapes and objects is required. Many researchers have worked to improve this method by adapting it to specific production conditions, improving its resistance and processing speed [16-18].

The pattern matching method is actively used to identify objects in images, especially when you need to recognize object by fixed pattern or reference. This method is widely popular due to its ease of implementation and accuracy in cases where shape and size of objects remain stable. There are number of studies aimed at improving this approach, improving its resistance to changes in lighting, noise, and other external factors [19-21].

Modern scientific literature presents wide range of methods for identifying objects on industrial lines – from classical approaches to advanced artificial intelligence technologies. Among them, following stand out: statistical methods using amplitude-phase characteristics; modern deep learning architectures (Faster R-CNN, R-FCN, SSD and YOLO), which provide high accuracy and speed of recognition; machine learning methods for analyzing CAD models, including graph-based approaches and volume decomposition; classic computer vision techniques such as edge detection, Hough transforms, and pattern matching that remain relevant for specific manufacturing tasks. Each of these methods has its own advantages and limitations, and their choice depends on specific production conditions, accuracy requirements and speed of identification system.

3. Methodology

The information base of study is based on analysis of scientific papers concerning methods and algorithms for identifying objects on industrial lines, as well as methods for automating quality control processes in industry. The included sources [6-21] provide data on modern methods and strategies for implementing automated defect identification and product quality assessment systems.

It is proposed to conduct review by dividing all methods into classical and statistical ones.

Classical object identification methods are usually based on computer vision algorithms that use geometric and statistical characteristics of objects. For example, edge detection methods, contour analysis, Hough transform for shape detection, and other image processing techniques can be used [22, 23].

3.1 Analysis of Existing Classical Methods of Object Identification

One of main approaches to identifying objects on industrial lines is edge detection. This method allows you to determine contours of objects in image. For this purpose, algorithms such as Robert, Canny, Sobel, Laplacian, or Prewitt can be used. These algorithms analyze changes in pixel intensity, which allows you to distinguish boundaries of objects.

Let's compare main edge detection algorithms (Table 1).

Table 1: Comparison of basic edge detection algorithms

#	*Algorithms*	*Advantages*	*Disadvantages*
1	Roberts is simple operator that detects edges based on difference between neighboring pixels.	Fast, easy to implement.	Sensitive to noise, does not detect weak edges.
2	Canny – multi-stage algorithm that includes Gaussian filtering, gradient calculation, and hysteresis.	Effectively detects sharp and blurred edges, low noise sensitivity.	More complex and slower compared to Sobel and Prewitt.
3	Sobel – uses kernel (mask) to calculate approximate brightness gradients.	Simple, fast, noise-resistant.	Can miss weak edges, not as accurate as Canny.
4	Laplacian – uses Laplacian to detect edges by searching for second-order change points.	Accurately detects edge centers, effective for detecting edges with high contrast.	Sensitive to noise, cannot distinguish weak edges from strong ones.
5	Prewitt is similar to Sobel operator, but uses simpler kernels to calculate gradients.	Simple, fast, noise-resistant.	Less accurate than Sobel, it can miss weak edges.

For clarity, diagram comparing different algorithms for object identification by three criteria is shown: speed, noise tolerance, and accuracy. Each algorithm is rated on scale from 1 to 5 for each of indicators (Figure 1).

Although Canny algorithm is considered one of most effective edge detection methods. It uses multi-step process to detect wide range of edges in image, but each algorithm has its own advantages and limitations depending on type of image and specific tasks.

When choosing method, it is necessary to take into account specifics of task, quality of input images, and requirements for speed and accuracy of edge detection. For example, Canny is more accurate but slower, while Sobel and Prewitt are faster but less accurate.

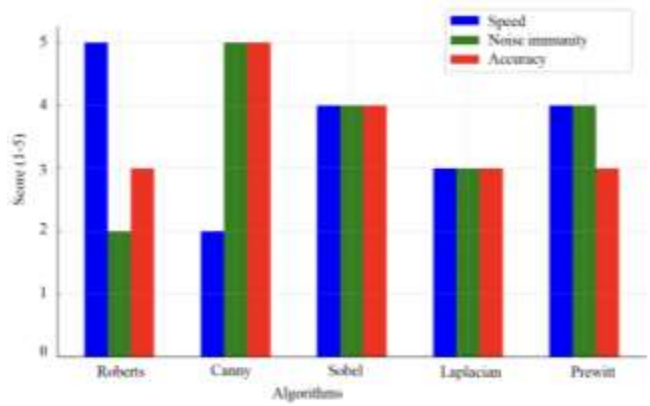
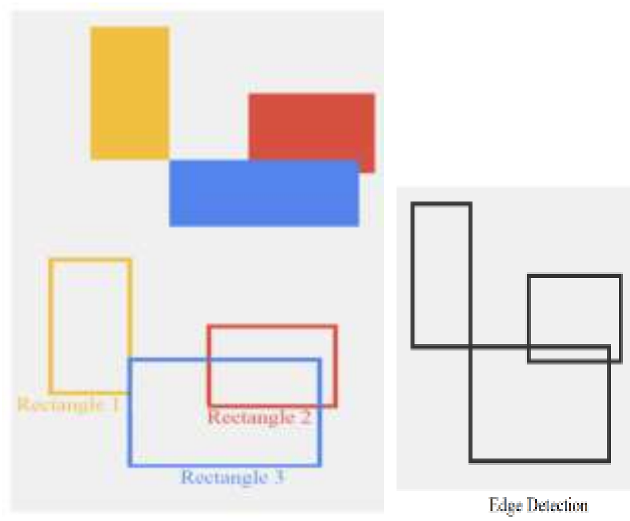


Fig. 1. *Comparison of different algorithms for object identification*

After edge detection, contour analysis is applied. This approach helps to determine shape of object, its size, orientation, and other geometric characteristics. Contour analysis also allows you to distinguish one object from another, even if they have similar properties.



a) b)

Fig. 2. *Example of using contour analysis to detect geometric shapes in image*

The input image (Fig. 2, a) shows three rectangular objects of different sizes and colors. Edge detection: After preprocessing image, clear outlines of objects are detected. This can be done using algorithms such as Canny, Sobel, or Prewitt. Contour analysis: Based on detected contours, shape, size, orientation, and other geometric characteristics of objects are analyzed. This information allows you to identify and classify objects.

Contour analysis allows you to distinguish objects of similar color by their geometric parameters. This is important for many industrial machine vision applications, such as sorting, quality control, motion tracking, and more.

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The advantages of contour analysis include:

1. Determination of geometric characteristics because contour analysis allows you to determine shape, size, orientation, and other geometric parameters of objects. This is important for classification, sorting and quality control of industrial products.

2. Distinguishing between similar objects Even if objects have similar properties (color, texture, etc.), they can be distinguished by geometric characteristics of their contours. This increases accuracy of identification.

3. Resistance to noise and partial overlap because contour analysis is less sensitive to noise in images and partial overlap of objects, unlike other segmentation methods.

4. Ability to track objects. The analysis of changes in contours allows you to track movement of objects in video streams, which is important for dynamic systems on assembly lines.

The disadvantages of contour analysis include:

1. Sensitivity to changes in lighting because contours can change with variations in lighting, which makes it difficult to identify objects consistently.

2. Complexity of algorithms. Contour analysis algorithms can be quite complex and computationally expensive, especially for large number of objects or complex shapes.

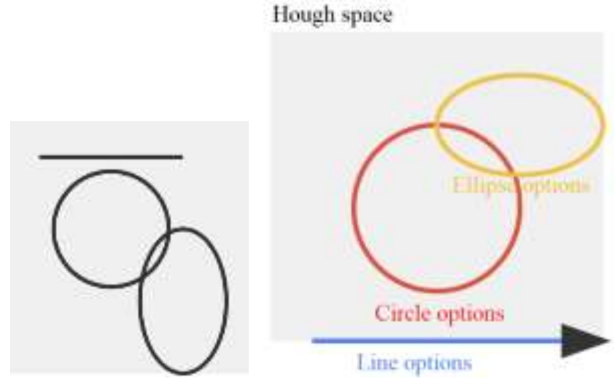
3. The effectiveness of contour analysis depends on quality of image preprocessing, in particular edge detection.

4. When objects significantly overlap, contour analysis may produce incorrect results.

Thus, contour analysis is powerful tool for object identification, but it has certain limitations that need to be taken into account when developing industrial vision systems.

Next, let's look at Hough transform. This is method used to detect simple geometric shapes such as lines, circles, or ellipses [24]. This method is especially useful for identifying objects with distinct geometric characteristics on conveyor line, as shown in Figure 3.

Figure 3, a shows input image containing line, circle, and ellipse. Figure 3, b shows "Hough space" in which each of these geometric shapes is represented by certain parameters (for example, for line, slope angle and distance to origin). The intersection points of curves in Hough space indicate presence of desired geometric shapes in input image. Thus, Hough transform allows you to effectively identify and localize simple geometric objects even in presence of noise or gaps at edges.



a) b)

Fig. 3. *Example of using Hough transformations to detect geometric shapes in image*

The advantages of Hough transformation include:

1. Resistance to noise and omissions at edges of objects.

2. Ability to detect continuous, open, partially overlapping objects.

3. Ability to detect objects of complex shape (not just straight lines).

The disadvantages of Hough transform are:

1. High computational costs, especially for complex shapes.

2. The need to pre-process image to extract edges.

3. Difficulty in choosing right thresholds for shape detection.

Hough transformation is widely used in industrial machine vision applications, such as part identification, quality control, object positioning, etc.

Template Matching is another classic method that compares image regions to predefined templates [25]. This approach is particularly effective for manufacturing in detecting objects with standardized sizes and shapes, such as printed circuit boards, their components, packaging, etc. The way template matching works is that moving "window" slides over entire image and compares its contents to template. When area that correlates most closely with template is found, it is identified as corresponding object.

The advantages of template matching are:

1. Template matching algorithms are relatively easy to implement and computationally efficient.

2. Method works well for identifying objects with clear, uniform characteristics, such as printed circuit boards, components, packages, etc.

3. Template matching can be robust to certain noise level and partial overlap of objects.

Disadvantages of template matching:

1. Method requires that template and object in image have same size and orientation. This limits its use for objects that can change scale and position.

2. Not suitable for identifying objects with significant variations in shape, color, or texture.

3. Difficulty finding optimal templates. Selecting representative templates that take into account all possible variations of objects can be difficult and time-consuming.

4. Method performs worse when there are many objects in image or significant overlaps.

In summary, template matching is simple and effective method for identifying objects on industrial lines, but it has certain limitations due to variability of object shapes, sizes, and positions. Therefore, it is often used in conjunction with other methods, such as contour analysis or deep neural networks, to improve overall performance of vision systems.

3.2 Analysis of Existing Statistical Methods of Object Identification

Statistical methods for object identification exist today, and they are widely used in computer vision, particularly for image analysis, object detection, and classification. Statistical methods are usually based on probability theory and statistical data analysis.

Statistical methods are another approach to identifying objects on industrial lines. Such methods are based on analysis of visual characteristics of objects, such as texture and color histograms.

The use of statistical methods can be useful for assessing product quality and identifying defects at early stages of production process. These approaches are based on image processing and statistical data analysis, which allows you to automate quality control process and increase overall production efficiency.

For example, texture analysis can help identify surface defects such as scratches, cracks, or uneven coating. In turn, color histograms can be used to detect color deviations that may indicate problems in process.

Table 2 shows comparison of statistical methods.

Table 2 summarizes main characteristics, advantages, and disadvantages of various statistical methods that can be useful for solving object identification problems in industrial vision systems.

The choice of particular method or combination of methods will depend on specifics of production process, characteristics of objects to be identified, and requirements for accuracy, speed, and flexibility of system.

Table 2: Comparison of statistical methods

#	*Methods*	*Advantages*	*Disadvantages*
1	Mass surveillance methods – collecting large amounts of data on characteristics of objects on production line.	- provide comprehensive information about objects; - identify general trends and deviations.	- require processing large amounts of data; - can be difficult to implement.
2	Methods of summarization and grouping – classification of objects by their measurable characteristics (e.g., size, shape, color, etc.).	- ease of implementation; - efficient grouping of similar objects.	- depend on choice of classification features; - may not detect subtle differences between objects.
3	Methods of analyzing distribution series – determining patterns in collected data, identifying deviations from norm.	- allow you to detect anomalies and defects; - identify general trends in data.	- require statistical analysis of large data sets; - difficulty in interpreting results.
4	Metric methods use measurements of similarity between objects to recognize and identify them.	- resistance to variations in shape, size, color; - ability to automate identification processes.	- require preliminary preparation of reference data; - difficulty in choosing right similarity metrics.

In general, statistical methods of image analysis are powerful tool for automated quality control and productivity improvement in industrial production. They allow you to quickly identify problems on line and take timely corrective action.

3.3 Evaluation of Effectiveness of Methods of Object Identification in Different Production Conditions

The choice of optimal method of object identification for particular industrial application depends on many factors, including specifics of production environment and requirements for vision system.

Let us consider main factors of production environment that influence choice of identification methods (Fig. 4):

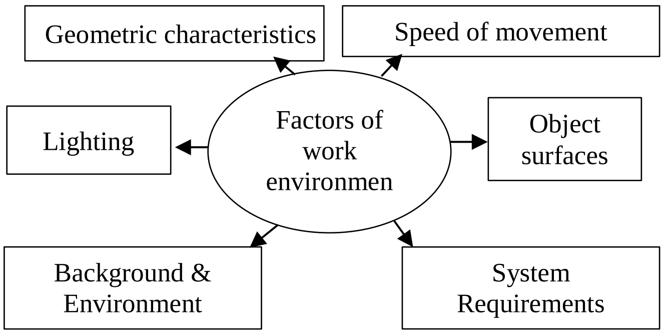


Fig. 4. *Main factors of work environment*

Let's take closer look at main factors of production environment.

1. Lighting: level of illumination (bright, dim, uneven); type of lighting sources (lamps, natural light, ultraviolet); stability of lighting (constant, variable).

2. Surfaces of objects: materials (metal, plastic, glass, fabric, etc.); color and texture of surfaces; gloss level (matte, glossy).

3. Background and environment: homogeneous or complex background; presence of foreign objects, obstacles; exposure to dust, smoke, vibrations.

4. Geometric characteristics of objects: sizes, shapes, orientation; similarity or diversity of objects; possibility of partial overlap.

5. Speed of objects movement: static or dynamic objects; high speed of conveyor line.

6. System requirements: required identification accuracy; system performance; flexibility to changes in production process.

These characteristics of production environment have significant impact on effectiveness of different object identification methods. For example, methods based on contour analysis can work more efficiently when lighting is stable and boundaries of objects are clear. Whereas statistical methods and deep neural networks can better cope with variations in shapes, textures, and backgrounds.

Therefore, when choosing identification methods for specific industrial application, it is necessary to carefully analyze features of production environment and requirements for vision system.

One of key criteria for evaluating performance is identification accuracy. It can depend on complexity of object shapes, variations in lighting, presence of noise or obstacles in images, etc. Methods such as contour analysis and pattern matching can be more accurate for standardized objects, while statistical and deep neural methods are better at dealing with variations in shapes and textures.

The speed of identification system is also important, especially on high-speed conveyor lines. Simple algorithms such as Sobel or Prewitt may be faster, but may be less accurate. In contrast, more complex methods such as Hough transform or deep neural networks may require more computing resources.

Flexibility and adaptability of methods are also important factors. Some industries may require identification of variety of objects, while others may only need to identify few standard products. Methods based on machine learning can be more flexible and adaptive, but require careful tuning and training.

In addition, aspects such as resistance to external influences (lighting, vibration, dust, etc.), ability to integrate with existing production systems, and ease of setup and maintenance must be evaluated.

3.4 Development of Recommendations for Implementation of Identification Systems on Industrial lines

Implementing effective identification systems on industrial production lines can bring significant benefits, including improved traceability, quality control, and operational efficiency. Here are some key recommendations to consider when introducing identification technologies in manufacturing environment:

1. Assess Current State and Requirements:

- thoroughly evaluate your existing production processes, data management systems, and pain points that identification systems could address;
- clearly define specific objectives and requirements for identification system, such as tracking individual parts/products, monitoring production status, or facilitating recall/warranty management;
- understand unique environmental conditions, material handling practices, and other constraints of your production lines.

2. Select appropriate identification technologies:

- evaluate various automatic identification technologies such as barcodes, RFID, visual identification (e.g. machine vision), or emerging technologies like blockchain-based digital twins;
- match capabilities of each technology to your specific requirements in terms of read range, speed, accuracy, environmental resilience, and cost;
- consider integration with your existing enterprise systems and software platforms to enable seamless data flow.

3. Design robust and scalable system architecture:

- implement layered architecture with reliable data capture hardware, secure connectivity, and centralized data management and analytics;

- ensure system can scale to handle increasing volumes of products, parts, and data as your operations grow;

- incorporate redundancy and fail-safe mechanisms to maintain system uptime and data integrity.

4. Ensure reliable data capture and management:

- strategically place data capture devices (e.g. barcode scanners, RFID readers) throughout production line to maximize coverage and minimize manual intervention;

- implement robust data validation, cleansing, and normalization processes to maintain data quality;

- integrate identification system with your ERP, MES, and other enterprise systems to enable data-driven decision making.

5. Emphasize change management and training:

- develop comprehensive change management plan to guide employees through transition to new identification system;

- provide thorough training for operators, maintenance staff, and other stakeholders on proper use and maintenance of identification technologies.

6. Continuously monitor and optimize performance:

- establish key performance indicators to measure effectiveness of identification system, such as read rates, product traceability, and impact on quality and productivity;

- regularly review system performance data and make adjustments to hardware, software, and processes to optimize identification system's efficiency and reliability.

4. Conclusions

In course of this work, research and analysis of modern methods of identifying objects on industrial lines were carried out. The main goal was to determine most effective solutions that are able to ensure stable product quality and optimize quality control costs.

Both classical methods of object identification (edge detection, contour analysis, Hough transformation, pattern mapping) and statistical approaches (analysis of textural characteristics, color histograms) were considered. For each method, its advantages, disadvantages and effectiveness in different production conditions were analyzed.

Thus, choice of particular method or combination of them will depend on characteristics of production process, characteristics of objects to be identified, and requirements for accuracy, speed and flexibility of system.

It is determined that main factors of production environment influencing choice of identification methods are: lighting, characteristics of surfaces of objects, background and environment, geometric parameters of objects, speed of movement, as well as requirements for accuracy, speed and flexibility of vision system.

Based on analysis, recommendations were developed for implementation of identification systems on industrial lines. These recommendations cover 6 key aspects.

The practical value of this work lies in fact that it provides integrated approach to implementation of effective systems for identifying objects in industrial production. The application of developed recommendations will allow enterprises to: improve accuracy and speed of product quality control; optimize production processes by automating identification; reduce costs associated with insufficient and inefficient use of resources; ensure better traceability and manageability of production.

Thus, this work can be useful for wide range of industrial enterprises that seek to implement modern systems of technical vision and object identification in order to increase efficiency and competitiveness of their products.

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