Proceedings of the 2nd International Conference on Machine Learning and Automation
DOI: 10.54254/2755-2721/101/20241010

# Research on automated defect detection system based on computer vision

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**Abstract.** With the intensification of market competition and consumer demand for product quality enhancement, people's development of industrialization is also more and more in-depth, the production scale and complexity of a variety of products is also increasing. However, in the process of automated production, product defects are unavoidable due to various factors such as equipment, environment, and human influence. The traditional human inspection method is inefficient, costly, and subjective, making it difficult to meet the needs of modern industrial production. Therefore, the need for an efficient, accurate and automated inspection system is urgent. Based on the current social situation, this paper will introduce the automated defect detection system based on computer vision, which is widely used in many fields, and has a great guarantee for people in the production of products with high quality and low cost, based on the needs in these areas, this paper will firstly introduce the relevant algorithms and their main contributions to the application scenarios of computer vision technology, and then introduce the key technologies of computer vision in defect detection in the key technology.

**Keywords:** Computer vision, automation, Defect detection.

## 1. Introduction

Enterprise development is also a key driving force for social development. Computer vision automated defect detection systems can help enterprises achieve this goal by improving product quality and market competitiveness. At the same time, the system can also reduce the cost of manual inspection and improve production efficiency and economic benefits, bringing significant economic and social benefits to enterprises. Defect detection of products mainly relies on computer vision systems. Computer vision is a science that studies how to make machines 'see', which uses cameras, sensors, and other equipment to obtain images or video data, and then uses computer algorithms to analyze and process the images to extract useful information or complete specific tasks. In recent years, with the rapid development of deep learning, image processing, and other technologies, computer vision has made significant progress in areas such as target detection, image classification, and image segmentation, providing a solid technical basis for the development of automated defect detection systems. With the continuous progress and development of technology and the expansion of application scenarios, the system will play a more important role in the future industrial development [1].

This paper will explore this disruptive technology in depth, revealing its potential and prospects in industry and various other scenarios. Firstly, it will review the current applications of computer vision

DOI: 10.54254/2755-2721/101/20241010

technology in defect detection, the many deep learning models and techniques and the results they have achieved. This will be followed by a description of the key techniques for the application of the technology in various areas of manufacturing in the era of industrialisation. Finally, the challenges and future directions of the technology will be discussed, and its important role in industrial production lines will be envisioned.

In addition to introducing the automated defect detection system based on computer vision, this paper also aims to stimulate thinking about the future application of computer technology. With the improvement of people's material needs, every aspect of society is ushering in a digital revolution, and automated defect detection based on computer vision is one of the leaders of this revolution. By combining industrialisation with technology, it breaks the traditional technology and provides people with a more convenient, efficient and intelligent computer system.

## 2. Models and algorithms for automated defect detection based on computer vision

In the progress of society, computer technology has taken root in various fields, and many researchers are using this technology to innovate and work on artificial intelligence products that can replace human activities. Among them, the field of computer vision is leading the way in terms of innovation and application of modification. This technology not only improves and guarantees the quality of the products, but also improves the efficiency of the business or company in the production of the products in one aspect and reduces the daily losses of the business. In a highly automated industrial production environment, the stability and consistency of product quality is directly related to the market competitiveness of enterprises. Traditional manual inspection methods are not only inefficient, but also vulnerable to subjective factors, it is difficult to adapt to the modern industrial production of high quality and high efficiency needs. Therefore, computer vision-based automated defect detection system was developed, which simulates human visual function and use advanced image processing technology and machine learning algorithms to achieve rapid and accurate detection of defects on the surface of the product [2].

The application of computer vision technology in defect detection mainly follows the framework of image acquisition, pre-processing, feature extraction, defect recognition and classification. This process ensures that defects are systematically and accurately identified. Firstly, the product surface image is acquired by a high-resolution camera; then, image pre-processing techniques are used to improve the image quality, such as noise removal and contrast enhancement; then, key features that can characterise the defects are extracted by a feature extraction algorithm; finally, the extracted features are classified using a classifier to achieve automatic recognition of defects. Some model frameworks, such as the defect detection model of convolutional neural network (CNN). The model automatically learns and extracts deep features in the image through multi-layer convolution and pooling operations, and finally achieves more than 95% detection accuracy on the test set, which is significantly better than traditional image processing methods. There is also a specific application of computer vision techniques in electronic component defect detection. The study used a combination of image segmentation and morphological processing to effectively identify scratches, cracks and other defects on the surface of electronic components, and the detection speed reached dozens of parts per second, greatly improving the detection efficiency [3].

With the rapid development of deep learning technology, its application in the field of computer vision has become increasingly widespread, especially in defect detection shows a strong potential. Deep learning models, such as CNNs and Generative Adversarial Networks (GANs), are able to automatically learn and extract complex features from images, significantly improving the accuracy and robustness of defect detection. For example, the YOLOv4 target detection algorithm, which can be applied in industrial product defect detection.YOLOv4 is known for its efficient speed and accuracy, and can achieve accurate recognition of multiple types of defects while ensuring real-time performance. Experimental results show that the system achieves an average detection accuracy (mAP) of more than 90% on the test set, and the detection speed can meet the needs of industrial production lines [4]. In the field of textile defect detection, the study uses deep learning models (e.g., U-Net) to segment textile

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images and achieve accurate extraction of defective regions. Experimental results show that the model performs well in a variety of textile defect detection tasks, with high levels of detection precision and recall [5].

In industrial production, real-time and robustness are important performance indicators for automated defect detection systems. To address these requirements, researchers usually adopt technical means such as optimising algorithm design, reducing the amount of computation, and utilising parallel computing. Meanwhile, in order to improve the robustness of the system, researchers have also introduced techniques such as adaptive algorithms and fault-tolerant mechanisms to cope with complex and changing industrial environments. For example, a real-time defect detection system based on lightweight convolutional neural network (MobileNetV2). The system achieves efficient operation on embedded devices by reducing network parameters and computational complexity. Meanwhile, the robustness of the system under different lighting conditions is improved by introducing adaptive threshold segmentation and noise suppression algorithms. Experimental results show that the system achieves a detection speed of tens of frames per second while maintaining high detection accuracy [6]. There are also innovative solutions that use augmented reality to provide inspectors with intuitive visual aids while combining computer vision algorithms for defect detection. This approach not only improves the detection efficiency, but also reduces the possibility of human misjudgment and further enhances the robustness of the system [7].

The automated defect detection system based on computer vision shows great potential in improving product quality, reducing production cost, and enhancing production efficiency. With the continuous development of deep learning technology and the continuous expansion of application areas, the detection accuracy, real-time and robustness of the system will be further improved. In the future, this paper can foresee that the automated defect detection system based on computer vision will be widely used in more fields and contribute to the development of intelligent manufacturing.

## 3. Key technologies and application scenarios of automated defect detection based on computer vision

### *3.1. Key technologies*

With the arrival of the industry 4.0 era, intelligent manufacturing has become an important direction for the transformation and upgrading of the global manufacturing industry. In this context, the importance of automated defect detection system as an important part of intelligent manufacturing, its importance is increasingly prominent. The automated defect detection system based on computer vision, with its advantages of high efficiency, accuracy and non-contact, has been widely used in various fields of manufacturing.

Image acquisition is the first step of automated defect detection system, and its quality directly affects the effect of subsequent processing. The development of modern industrial camera and sensor technology makes high-definition, high-speed image acquisition possible. The pre-processing stage mainly includes image denoising, contrast enhancement, image segmentation and other steps, aiming at improving image quality and laying a foundation for subsequent feature extraction and defect recognition.

Feature extraction is one of the core tasks in the field of computer vision, and its goal is to extract key information that can characterize defects from images. Traditional feature extraction methods include edge detection, texture analysis, and shape matching, and so on. In recent years, with the rise of deep learning technology, feature extraction methods based on deep learning models such as convolutional neural networks (CNN) have gradually become mainstream. These methods can automatically learn and extract complex features in images, significantly improving the accuracy and robustness of defect detection.

Defect recognition and classification is the ultimate goal of automated defect detection systems. Traditional methods are based on simple algorithms such as template matching and threshold segmentation, which are difficult to cope with complex and changing defect types. In contrast, classifiers based on machine learning and deep learning, such as support vector machine (SVM), random forest, neural network, etc., are able to achieve accurate recognition and classification of multiple types of defects. In particular, deep learning models, such as CNN, RNN, etc., with the support of large datasets, are able to learn finer and more complex feature representations, further improving classification performance.

### *3.2. Application scenarios and future development trends*

In this field, some model algorithms stand out, such as in CNN's surface defect detection model for industrial products, a migration learning strategy is used to fine-tune the pre-trained deep model to adapt to the defect detection task of specific industrial products. Experimental results show that the model performs well on a variety of industrial product surface defect detection tasks, with a detection accuracy of more than 95% and a detection speed that meets the real-time requirements of industrial production lines [8]. In addition, for detecting defects in electronic components, a detection method combining image segmentation and morphological processing is proposed. The method firstly uses image segmentation technology to separate the electronic components from the background, and then uses morphological processing technology to further process the segmented image in order to highlight the defective features. Experimental results show that the method can effectively identify defects such as scratches and cracks on the surface of electronic components, and the detection precision and recall rate reach a high level [9].

The application of this computer technology in modern society makes people's life very convenient. In the process of automobile manufacturing, the quality of painting is one of the important indicators for evaluating the quality of the whole vehicle. An automotive manufacturer introduced an automated computer vision-based painting defect detection system to achieve automatic detection of various defects such as scratches, orange peel, and flow hanging on the painted surface. The system uses a high-definition camera to collect images of the painted surface, and deep learning algorithms to identify and classify defects. Through practical application verification, the system significantly improves the coating quality and production efficiency, and reduces the defective product rate. In addition, defect detection in the semiconductor chip manufacturing process is critical to ensuring product quality. A chip manufacturer has adopted an automated defect detection system based on computer vision for high-precision detection of tiny defects on the chip surface. The system combines optical microscopy and deep learning techniques to identify defect features at the nanoscale. Experimental results show that the system performs well in the semiconductor chip defect detection task, with detection accuracy and efficiency reaching the international leading level. Also in the food packaging process, mixing foreign objects may lead to serious food safety problems. A food company introduced a computer vision-based foreign object detection system to automatically detect foreign objects in packaging. The system uses a high-resolution camera to scan the inside of the package, and analyses the image content through image processing techniques and machine learning algorithms to identify and flag any foreign objects that do not meet expectations. Experimental data shows that the system is able to efficiently and accurately detect a wide range of foreign objects, including metal fragments, glass slag, plastic particles, etc., effectively safeguarding the safety of food packaging and consumer health.

Of course, in the future, the automated defect detection computation of computer vision will also face many tests. With the continuous maturity of deep learning technology, the future automated defect detection system based on computer vision will be more dependent on the deep learning model. Therefore, it is necessary to have more efficient and accurate deep learning architectures, such as lightweight networks, attention mechanisms, etc., to adapt to the detection needs of different industrial scenarios. Meanwhile, new technologies such as cross-modal learning and self-supervised learning will also bring new breakthroughs in the field of defect detection. In order to further improve the accuracy and comprehensiveness of defect detection, future systems will tend to fuse multi-source data, such as images, sounds, vibration signals, etc., to obtain richer product information. In addition, combined with big data analysis and intelligent decision-making technology, the system is able to automatically adjust the inspection parameters and optimize the inspection strategy to achieve a more intelligent inspection

DOI: 10.54254/2755-2721/101/20241010

process. In industrial production lines, real-time and robustness are important indicators of the performance of defect detection systems. To address these challenges, future research will focus more on improving the real-time response speed and anti-interference ability of the system to ensure stable and reliable operation in the complex and changing industrial environment. With the popularity of defect detection technology and the expansion of the scope of application, the development of uniform technical standards and interface specifications has become an urgent task. In the future, more international organizations and enterprises will participate in the development and promotion of standards to promote compatibility and interoperability between different systems and reduce the cost of system integration and maintenance. In automated defect detection systems, a large amount of sensitive production data and user privacy information is involved. Therefore, future systems will pay more attention to data security and privacy protection issues. Measures such as encryption technology, access control, and data desensitization are used to ensure the legally compliant use and safe storage of data.

Automated defect detection systems based on computer vision play an increasingly important role in the field of intelligent manufacturing. Through continuous technological innovation and optimization in areas such as algorithm efficiency and hardware upgrades, the system has made significant progress in terms of detection accuracy, real-time performance and robustness. However, in the face of increasingly complex industrial environments and changing inspection needs, future research still needs to focus on key issues such as the integration of deep learning techniques, multi-source data fusion, real-time and robustness improvement, standardization and interoperability, and privacy protection and data security. It is believed that in the near future, the automated defect detection system based on computer vision will be widely used in more fields and contribute more to the development of intelligent manufacturing

## 4. Conclusion

This paper presents an automated defect detection system based on computer vision, which aims to improve the stability and consistency of industrialized product production quality. Through three key technologies: image acquisition and pre-processing, feature extraction and selection, and defect recognition and classification, the system can take advantage of its high efficiency, accuracy, non-contact, and other advantages to achieve the ultimate goal. That is, to achieve real-time monitoring and automatic detection of products on the production line, significantly increasing detection efficiency and accuracy while reducing human intervention and misjudgment. The key part of this system is computer vision and related deep learning algorithms. The key part is computer vision and deep learning algorithms. At present, many model algorithms in deep learning stand out, enabling detection accuracy and speed to meet the needs of industrial production lines, showing great potential, but the system is still facing great tests, such as privacy and security protection issues. I believe that in the future, these problems will be solved one by one, and with the emergence of a variety of efficient computer models, the detection accuracy, real-time performance and robustness of the system will be further improved, and its application areas and development prospects will be broader.

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