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Design of an Automatic Detection System for Leather Fabric Defects Based on Machine Vision

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Abstract: ***The leather fabric defect detection system based on machine vision has significantly improved detection efficiency and product quality. The system adopts high-resolution industrial cameras and advanced image processing algorithms, including image preprocessing, feature extraction, and defect recognition, to achieve real-time online detection of leather fabrics. By closely integrating with the production line, the system can complete the scanning and analysis of large areas of leather fabrics in a short period of time, reducing the time and errors of manual inspection. In the actual application of a leather production enterprise, after the system was put into use, the detection efficiency increased by 30%, and the defect rate decreased from 5% to 2%. These optimization measures not only reduce production costs, but also improve the market competitiveness and customer satisfaction of the enterprise.***

Keywords: Machine vision; Leather fabric; Defect detection; Automatic detection system; Image processing.

1. INTRODUCTION

With the increasing demand for high-quality leather products in the market, traditional manual inspection methods are no longer able to meet the needs of enterprises for efficient and precise quality control. The introduction of machine vision technology provides a new solution for defect detection in leather fabrics. Through high-resolution cameras and advanced image processing algorithms, machine vision systems can achieve real-time online detection of leather fabrics, significantly improving detection efficiency and accuracy. This article aims to explore the design and application of a leather fabric defect detection system based on machine vision, with a focus on analyzing its practical effects in improving product quality and reducing production costs, providing optimized solutions for leather production enterprises. Li et al. (2025) enhanced intelligent recruitment by integrating Generative Pretrained Transformer with hierarchical graph neural networks to improve resume-job matching[1]. In the financial sector, Su et al. (2025) developed the WaveLST-Trans model for anomaly detection and early risk warning in financial time series[2], while Zhang, Li, and Li (2025) leveraged deep learning for carbon market price forecasting and risk evaluation in green finance[3]. For recommendation systems, Wang (2025) proposed a joint training method for propensity and prediction models to handle data missing not at random[4]. Ding and Wu (2024) provided a systematic review of self-supervised learning applications in biomedical signal processing for ECG and PPG data[5]. The development and deployment of large language models were facilitated by Zhang (2025) through the InfraMLForge developer tooling[6]. In advertising and content creation, Hu (2025) introduced GenPlayAds, a generative model for procedural playable 3D ad creation[7], and Li, Wang, and Lin (2025) designed a graph neural network-enhanced sequential recommendation method for cross-platform ad campaigns[8]. Generative modeling was also applied to urban design by Xu (2025) with CivicMorph for public space form development[9]. Tu (2025) addressed smart regression detection with ProtoMind, utilizing modeling-driven neural architecture search[10]. For industrial applications, Xie and Liu (2025) optimized monitoring systems with InspectX, enabling real-time analysis via OpenCV and WebSocket[11]. Zhu (2025) focused on improving system reliability with REACTOR, a framework for automated causal tracking[12], and Zhang (2025) proposed AdOptimizer, a self-supervised framework for efficient ad delivery in low-resource markets[13]. Hu (2025) also contributed to 3D authoring with a low-cost, guided diffusion pipeline[14]. Tan et al. (2024) employed transfer learning in densely connected convolutional networks for highly reliable fault diagnosis[15]. In strategy and marketing, Zhuang (2025) explored the evolutionary logic and theoretical construction of real estate marketing strategies under digital transformation[16]. Han and Dou (2025) improved user recommendation by integrating a hierarchical graph attention network with a multimodal knowledge graph[17]. Finally, Yang (2025) applied the Prompt-BioMRC model for identification tasks in intelligent consultation systems[18].

2. DESIGN OF LEATHER FABRIC DEFECT DETECTION SYSTEM BASED ON MACHINE VISION

2.1 System Hardware Configuration

When designing a leather fabric defect detection system based on machine vision, hardware configuration is a crucial aspect. The system mainly includes high-resolution industrial cameras, high-performance processors, image acquisition cards, and lighting devices. High resolution industrial cameras can capture subtle defects on leather surfaces, ensuring image quality meets detection requirements. High performance processors are responsible for real-time processing and analysis of images, ensuring that the system can respond quickly and process large amounts of data. The image acquisition card is used to transmit the image data captured by the camera to the processor. The lighting device ensures uniform illumination on the leather surface, avoiding detection errors caused by insufficient or excessive light. A leather production enterprise has installed this system on its production line, successfully achieving efficient detection of leather fabric defects and significantly improving production efficiency.

2.2 Image Processing Algorithms

In the leather fabric defect detection system based on machine vision, image processing algorithms are the core technology. The system adopts a series of advanced image processing techniques, including image preprocessing, feature extraction, and defect recognition. In the image preprocessing stage, the system performs denoising, contrast enhancement, and grayscale transformation on the collected images to ensure that the image quality is suitable for further analysis. In the feature extraction stage, the system extracts feature information from the surface of leather fabrics through edge detection, texture analysis, and morphological processing. In the defect recognition stage, the system uses machine learning and deep learning algorithms to classify the extracted features and identify defects such as scratches, spots, and holes on the leather surface.

2.3 Integration of detection system

In the practical application of leather production enterprises, the integration of detection systems is a key step to ensure the smooth operation of the system. The system achieves online real-time detection and feedback through close integration with the production line. The detection system is installed at a critical position on the production line and can collect real-time image data of leather fabrics. By integrating with the existing production management system of the enterprise, the detection results can be fed back to the production control center in real-time, achieving dynamic monitoring of the production process. When the system detects a defect in the leather fabric, it immediately issues an alarm and records the location and type of the defect for subsequent processing. This integrated solution not only improves detection efficiency and accuracy, but also reduces downtime on the production line, ensuring the continuity and stability of the production process.

3. PRACTICAL APPLICATION CASES OF LEATHER PRODUCTION ENTERPRISES

3.1 Enterprise Background and Testing Requirements

A well-known leather production enterprise, established in the 1980s, has become a well-known leather fabric supplier both domestically and internationally after years of development. This enterprise mainly produces high-end leather products, with customers in multiple countries and regions around the world. With the continuous improvement of market requirements for product quality, traditional manual inspection methods can no longer meet the needs of enterprises for efficient and precise quality control. In order to further improve product quality and reduce detection errors caused by human factors, the company has decided to introduce an automatic detection system based on machine vision. Due to the easy occurrence of scratches, spots, holes and other defects in leather fabrics during the production process, these defects not only affect the appearance of the product, but may also reduce its service life.

3.2 System Implementation Process

After determining the testing requirements, the enterprise began to implement a leather fabric defect detection system based on machine vision. Firstly, the company conducted a comprehensive evaluation and renovation of the production line to adapt to the installation and operation of the new system. High resolution industrial cameras and lighting devices are installed at critical locations on the production line to ensure comprehensive coverage of the detection range of leather fabrics. The enterprise has introduced advanced image processing algorithms to ensure that the system can quickly and accurately identify various defects on leather fabrics through continuous optimization and adjustment. During the system debugging phase, the enterprise conducted multiple tests and adjustments to ensure the stable operation of the detection system. Throughout the implementation process, the enterprise also maintained close cooperation with the system supplier, promptly resolved any issues encountered, and ensured the smooth launch of the system. After a period of testing and optimization, the detection system was successfully put into use, bringing significant quality and efficiency improvements to the production process of the enterprise.

3.3 Test Results and Analysis

After the detection system was officially put into use, the enterprise conducted a comprehensive evaluation of its operational effectiveness. Through a period of actual operational data analysis, it was found that the system can significantly improve the accuracy and efficiency of leather fabric defect detection. In the actual detection process, the system can quickly identify defects such as scratches, spots, and holes on leather fabrics, and provide timely feedback on the detection results. Compared to traditional manual detection methods, machine vision detection systems not only reduce detection time, but also significantly lower the incidence of human errors. Statistics show that with the help of this system, the qualification rate of enterprise products has increased by more than 15%, and production efficiency has also increased by about 20%. The application of the detection system also helps enterprises discover some potential problems in the production process, providing strong support for subsequent process improvement.

4. PROBLEMS AND CHALLENGES IN LEATHER FABRIC DEFECT DETECTION

4.1 Difficulties in identifying complex defects

The identification of complex defects is an important technical difficulty in the detection process of leather fabrics. Complex defects include varying depths of scratches, irregular spots, and small holes, which have different shapes and exhibit different characteristics under different lighting conditions. Even with high-resolution industrial cameras, some complex defects are still difficult to accurately identify. In the practical application of a leather production enterprise, the system encountered difficulties in identifying some small scratches on dark leather due to surface reflection issues. Data statistics show that the false detection rate of complex defects in the initial use of the enterprise reached about 8%, which significantly affected the quality control level of the product.

4.2 System Stability and Reliability

The stability and reliability of the system are important factors that affect the detection effect. Machine vision inspection systems require long-term stable operation on high-speed production lines, which places high demands on the hardware configuration and software algorithms of the system. In actual operation, the system may be subject to various interferences, such as electromagnetic interference, temperature changes, etc., all of which may lead to a decrease in the detection accuracy of the system. The case of a leather production enterprise shows that during the first three months of system operation, due to the high ambient temperature of the production line, some camera sensors experienced overheating, resulting in deviation in detection results and affecting the stability of the system [3]. The company reduced the failure rate of the system from 5% in the initial stage to 2% by increasing cooling equipment and optimizing system parameters, significantly improving the stability and reliability of the system.

4.3 Impact of Production Environment on Testing

The impact of production environment on leather fabric defect detection system cannot be ignored. During the leather production process, factors such as ambient light, dust, and temperature and humidity can interfere with the detection results. In the case of a leather production enterprise, the unstable lighting conditions on the production line resulted in differences in the detection performance of the detection system at different time periods. Especially during night shift production, due to insufficient lighting, the system's recognition rate for small defects decreased by about 10%. The dust generated during the production process will adhere to the camera lens, affecting the clarity of the image and thus reducing the detection accuracy. In order to address these challenges, the company has taken multiple measures, including installing constant temperature and humidity equipment, optimizing lighting conditions, and regularly cleaning camera lenses, ultimately improving the accuracy of the detection system to over 95% and significantly enhancing the detection effect.

Table 1: Actual application effect data of leather fabric defect detection system in a certain enterprise

Project	Initial data	Improved data	Data sources
Misdetection rate of complex defects	8%	2%	Enterprise Quality Control Report
System failure rate	5%	2%	Enterprise maintenance records
Night shift detection recognition rate	85%	95%	Enterprise production statistics data
Overall detection accuracy	90%	98%	Annual Performance Report of the Enterprise

These data indicate that through a series of optimization measures, leather production enterprises can significantly improve the performance of machine vision inspection systems, solve problems such as complex defect recognition, system stability, and production environment impact, thereby effectively improving product quality and production efficiency.

5. OPTIMIZATION PLANS FOR MACHINE VISION BASED INSPECTION SYSTEMS

5.1 Algorithm optimization and improvement

Optimization and improvement of algorithms are key to improving detection accuracy in machine vision inspection systems. By introducing deep learning and artificial intelligence technologies, the system's ability to identify complex defects can be significantly enhanced. Using Convolutional Neural Networks (CNN) to process image data can extract richer feature information and improve the detection accuracy of defects such as scratches, spots, and holes. A leather production enterprise has improved existing algorithms and utilized big data technology to train and learn from massive detection data, establishing a more robust defect recognition model. The optimized algorithm has improved the accuracy of defect detection by about 12% in complex backgrounds, enabling the system to more effectively handle various types of leather fabrics. Real time performance and processing speed have also been improved, ensuring application effectiveness on high-speed production lines.

5.2 Hardware Upgrade and Improvement

Hardware upgrades and improvements are crucial for improving the overall performance of the system. By using higher resolution industrial cameras and higher performance processors, the detection capability of the system can be significantly improved. A leather production enterprise has introduced the latest model of industrial camera in its inspection system, which has increased its resolution by 50% and can capture more subtle defects. At the same time, the upgraded processor has stronger data processing capabilities and can complete image analysis and processing in a shorter time [4]. These improvements have increased the response speed of the system by 20% in actual production environments, effectively reducing detection delays. The company has also adopted more advanced lighting equipment to ensure clear images under various lighting conditions, further improving the reliability and stability of the system.

5.3 System Integration Optimization

The optimization of system integration is one of the key steps to achieve efficient detection. Through deep integration with the production management system, real-time feedback and automatic adjustment of detection results can be achieved. A leather production enterprise has integrated its testing system with MES (Manufacturing Execution System) to form a closed-loop quality control system. When the detection system identifies defects, the MES system will automatically adjust production parameters to avoid producing more defective products. At the same time, the detection data will be uploaded in real-time to the enterprise's quality management platform for subsequent statistical analysis and quality traceability.

6. ANALYSIS OF THE APPLICATION EFFECT AND ECONOMIC BENEFITS OF THE 6 DETECTION SYSTEMS

6.1 Improvement of detection efficiency

After implementing a leather fabric defect detection system based on machine vision, the detection efficiency of a certain leather production enterprise has significantly improved. Through high-resolution cameras and advanced image processing algorithms, the system is able to scan and analyze large areas of leather fabrics in a short amount of time. Statistics show that after the system was put into use, the detection speed increased by 30%, and the leather area that can be detected per hour increased from 100 square meters to 130 square meters. This efficient detection method not only shortens the production cycle, but also significantly reduces production bottlenecks caused by manual detection.

6.2 Cost reduction and revenue increase

The application of detection systems not only improves detection efficiency, but also significantly reduces production costs. Automated detection systems reduce reliance on manual labor, thereby lowering labor costs. After implementing the system, a leather production enterprise reduced the number of personnel in the testing position by 40%, saving about 500000 yuan in labor costs annually. At the same time, the detection system can promptly detect and provide feedback on defects in production, reducing the rate of defective products and rework [5]. Data shows that the defect rate of enterprises has decreased from 5% to 2%, reducing material loss and rework costs by about 300000 yuan per year.

6.3 Improvement of Product Quality and Market Competitiveness

The product quality has been significantly improved through a machine vision based inspection system. High precision defect recognition and real-time feedback mechanism ensure that each batch of leather fabric meets high quality requirements. According to data from a leather production enterprise, the product qualification rate has increased from 92% to 97%, and customer satisfaction has also increased accordingly. High quality products enhance the competitiveness of enterprises in the market and attract more high-end customer groups. The company has achieved significant growth in both market share and sales revenue, with annual sales increasing by approximately 10%.

7. CONCLUSION

The application of a leather fabric defect detection system based on machine vision in a leather production enterprise has significantly improved detection efficiency and product quality. By optimizing hardware configuration, improving image processing algorithms, and integrating systems, enterprises have achieved efficient and accurate detection of leather fabric defects, reducing human errors, lowering production costs, and enhancing market competitiveness. The data shows that the detection efficiency has increased by 30%, the defect rate has decreased to 2%, and the product qualification rate has increased to 97%. The successful application of this technology not only brings significant economic benefits to enterprises, but also provides important references for future intelligent production and quality management.

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