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Design and Development of a Fastener Identification and Location System Based on YOLOv8

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Abstract

Small and medium - sized auto and motorcycle parts enterprises still use traditional manual sorting methods for sorting small - sized fasteners, which are characterized by high sorting error rates, slow sorting speeds, and high labor costs. This paper designs and develops a fastener identification and location system based on YOLOv8. By building an image acquisition platform and designing a visual operation interface, it can real - time identify camera video streams, dynamic videos, and static photos. Methods such as histogram equalization are used for image enhancement and pre - processing, and the optimized YOLOv8 algorithm is adopted as the core detection method. 500 images are collected, and 4000 images of fasteners of different batches and models are obtained through image enhancement to train the model. The results show that the detection accuracy of this algorithm reaches 92%, the recall rate is 88%, and the detection speed is 60FPS. This system can meet the accuracy and real - time requirements of fastener detection in industrial production, optimize and replace traditional sorting operations, and has economic and practical value.

Keywords

Machine Vision; Fastener Detection; YOLOv8 Algorithm; Image Acquisition; Algorithm Optimization.

1. Introduction

In the wave of Industry 4.0, the intelligent transformation of the manufacturing industry is accelerating. As basic components, the quality inspection and precise identification of fasteners are crucial for production efficiency and product quality. In fields such as automotive and aerospace, the confusion of fasteners with different specifications can seriously affect assembly accuracy and product performance. Traditional manual sorting is inefficient, error - prone, and costly. Traditional sorting devices have complex structures and high misdetection rates, making it difficult to meet the requirements of modern production.Machine vision technology integrates multi - disciplinary theories and has the advantages of high precision, high speed, and non - contact detection. Combining it with industrial robots for fastener sorting can improve the automation level and reduce labor costs, which is an effective way to solve the fastener detection problem. This research was commissioned by Ruian Yihang Auto Parts Co., Ltd., aiming to develop a fastener detection and location system that meets the requirements of its production line.

2. Research Status

With the development of vision technology, there has been an increasing focus on its application and research in society. Yao Jiaqi applied vision inspection to maintain the fasteners at the bottom of subway cars, solving the defects of traditional inspection robots and providing a new solution for subway bottom - inspection robots. Chen Xizhaoimproved the YOLOv8 model

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and made improvements to the defects in identification and detection based on deep learning. Liu Xianghe used the YOLOv5 algorithm to extract the ROI area of copper plates and designed a robot vision positioning system. Xin Lang achieved high - precision detection of target workpieces by improving YOLOv3 - tiny and using deep - learning methods. Fu Chenfu, Ren Lisheng, and Wang Fang mentioned in the paper "FABF - YOLOv8s: A Lightweight Beef Cattle Behavior Recognition Method in Automated Scenic Areas" that the detection head of YOLOv8s adopts a decoupled head structure, changing from Anchor - Based to Anchor - Free, directly predicting the center of the target, which improves the detection accuracy. It abandons the Anchor - Base mode, adopts Anchor - Free detection, directly predicts the center of the object, reduces the number of bounding - box predictions, accelerates the non - maximum suppression inference step, and improves the detection speed. Liu Mingrui, Che Ben, Dong Hongbo, etc. compared the performances of algorithms such as Faster - RCNN and the YOLO series in small - target detection of UAV remote - sensing images in open - pit coal mines. They pointed out that although the original Faster - RCNN network performed well, its computational inference speed was slow and required more computing power resources. While YOLOv5, YOLOv6, and YOLOv8 had fast detection speeds, they were not precise enough in detecting small objects and were prone to missed detections. However, YOLOv8 has improved its small - target detection ability in subsequent improvements, and its overall performance is better than that of Faster R - CNN. The Faster R - CNN algorithm has a large amount of computation and a slow detection speed. Shen Yang, Wang Chongyu, Zhao Jiayi, etc. conducted research on the fry counting method based on improved YOLOv8 and multi - target tracking and compared the performances of YOLOv5 and YOLOv8 in the fry counting task. This research shows that YOLOv8 outperforms YOLOv5 in detection results, especially in complex scenarios with small targets, such as fry overlapping and motion blur, where YOLOv8 shows better recognition results.

3. Research Methods

3.1. Building the Image Acquisition Platform

The image acquisition platform is a key part of the system. In this study, an overall architecture covering image acquisition and processing was designed.In terms of hardware selection, the selection of industrial cameras is particularly important. Considering the comprehensive requirements for image quality and cost in fastener detection, and based on the size of the fasteners to be detected, the detection field of view was determined to be 130×130mm. The pixel accuracy of the selected camera meets the detection accuracy requirement of 0.2mm. The lens selection is based on the pinhole imaging principle:

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$$

Where u is the object distance, v is the image distance, and f is the focal length. Combining the performance parameters of the lens and the size of the fasteners, and considering the need for convenient loading and unloading, a 2k high - definition external camera was selected. Its parameters are suitable for the working distance and the size of the camera sensor, which can ensure that multiple fasteners are completely imaged.The camera is installed in the Eye - to - hand mode. In this mode, the camera is fixed, not affected by the movement of the manipulator, and its parameters are stable, which is suitable for the sorting scenario. LED lights are selected as the light source because of their long lifespan, low power consumption, small heat generation, and high luminous efficiency. The lighting method uses a Feishite ring - shaped light source to illuminate from top to bottom, which can eliminate shadows and highlight the characteristics of fasteners.

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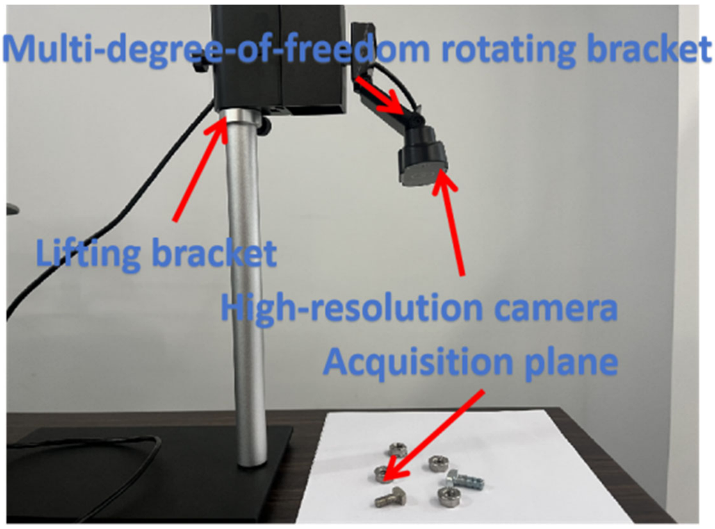

Figure 1. Image Acquisition Platform

3.2. Operation Interface Design

A visual interface is designed to display the detection results. It can display the images collected by the camera in real - time, frame the detected fasteners with different - colored borders, and mark the category, confidence level, and position in the image, facilitating operators to quickly understand the detection situation. The software design includes buttons for opening and closing the camera, opening and playing videos, opening images, starting and stopping recognition, clearing the screen, and exiting the software. The image - acquisition module realizes image acquisition and monitoring; the target - detection module trains and detects fasteners based on the YOLOv8 framework.

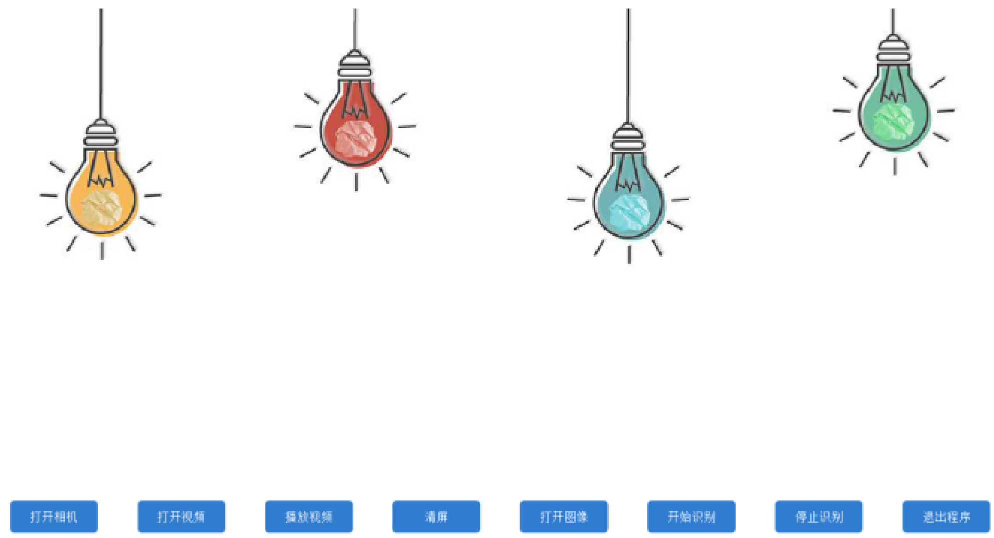

Figure 2. Operation Interface of the Detection and Recognition System

3.3. Image Enhancement and Pre - processing

Since YOLOv8 may be inaccurate in complex situations, image enhancement and pre - processing are required. In view of the image problems caused by the complex and changeable lighting conditions in the industrial environment, methods such as histogram equalization and contrast stretching are used to enhance the collected fastener images, improving image clarity and contrast for better model learning.After image enhancement of the collected images, some of the obtained images are shown as follows.

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Figure 4. Images Before Image Enhancement

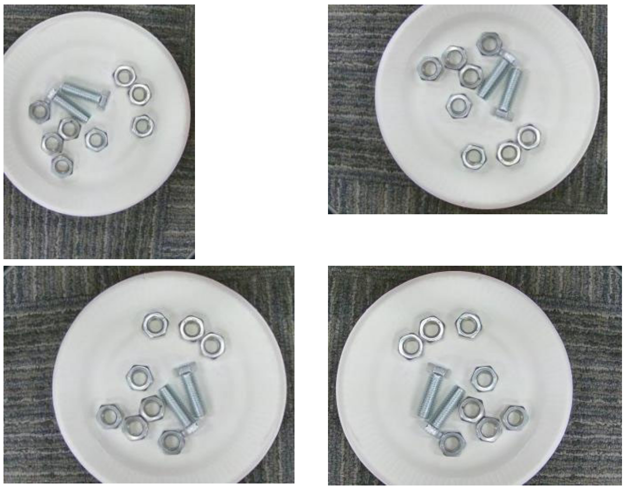

Figure 5. Images After Image Enhancement

3.4. YOLOv8 Model Recognition

YOLOv8 is adopted as the core detection algorithm. The network architecture is shown in the following figure.

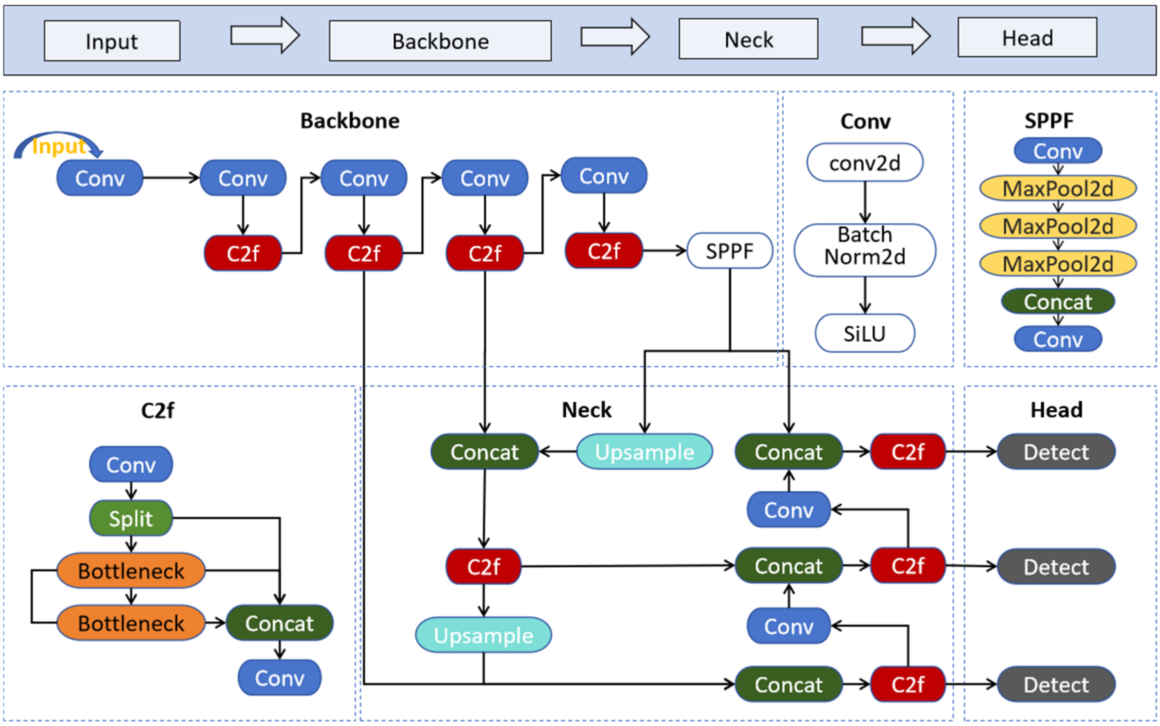

Figure 6. YOLOv8 Network Structure

4. Analysis and Discussion

4.1. Experimental Setup

The experiment was carried out on a computer equipped with an Intel Core i7 - 12700K processor and an NVIDIA GeForce RTX 3060Ti graphics card. A dataset consisting of 500 images of fasteners of different batches and models was used. Through image enhancement, 4000 images were obtained and divided into a training set, a validation set, and a test set in a ratio of 8:1:1.

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4.2. Data Training and Experimental Results

During the model training process, various indicators were monitored. In terms of training loss, the bounding - box loss, class loss, and distribution - free loss were high in the initial stage of training, and then decreased rapidly and tended to be stable, indicating that the model's ability to predict the bounding box of fastener targets accurately, recognize the category, and predict the distribution characteristics of the targets was continuously improving. Although the validation loss fluctuated, it showed an overall downward trend, reflecting the continuous enhancement of the model's adaptability to fastener images in different scenarios. In terms of performance indicators, the precision, recall rate, average precision at IoU = 0.5, and average precision at IoU = 0.5 - 0.95 all showed a good trend. They increased rapidly in the initial stage of training and tended to be stable and remained at a high level in the later stage, verifying the effectiveness and superiority of the YOLOv8 algorithm in the fastener - detection task. The experimental results show that the detection accuracy of the YOLOv8 algorithm reaches 92%, the recall rate is 88%, and the detection speed is as high as 60FPS.

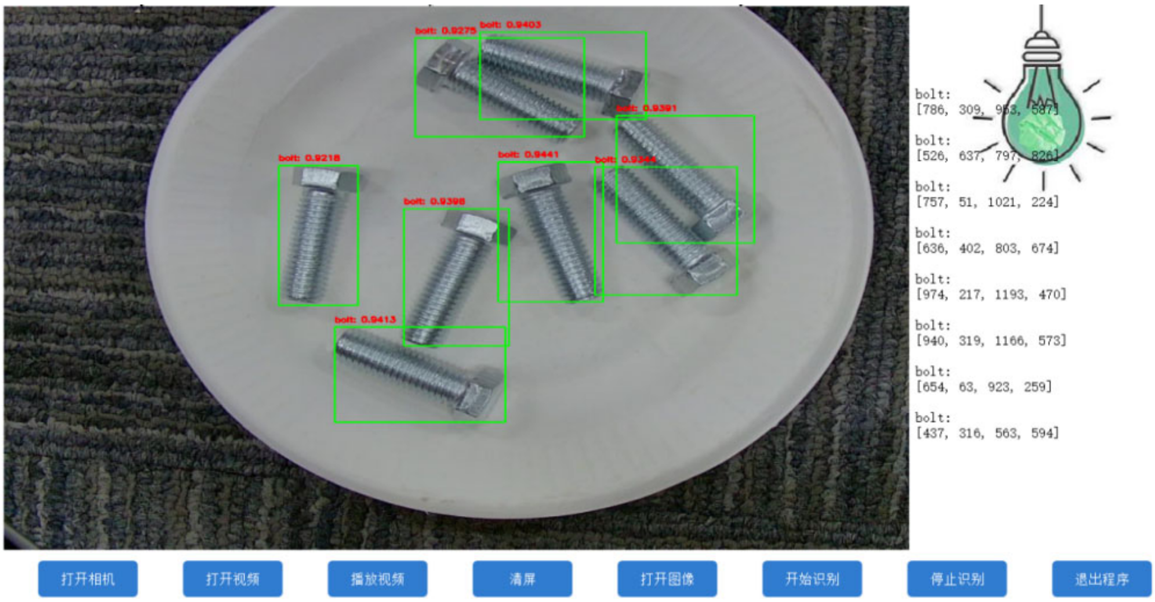

Figure 7. Identification Photos of the Fastener Detection and Recognition System

4.3. Result Analysis

The YOLOv8 algorithm performs excellently in fastener detection. The reason lies in its new network architecture and module design, which enhance the feature - extraction and expression capabilities. Traditional algorithms are limited by manual features and simple classifiers and are difficult to adapt to complex industrial environments and diverse fastener samples.

5. Summary

In small and medium - sized auto and motorcycle parts enterprises, a considerable number of them still use manual sorting methods for sorting small - sized fasteners such as bolts and nuts, which increases the labor costs of enterprises. This research has successfully constructed a fastener identification and location system based on machine vision and achieved important results in system construction and algorithm application. This system can meet the high - precision and real - time requirements of fastener detection on the industrial production line, realize the optimization and replacement of traditional sorting operations, and has significant economic value and practical significance. However, in complex industrial environments such

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as extreme lighting and severe occlusion, the system's detection performance is affected, and the scale and diversity of the dataset need to be expanded. In the future, the system's robustness and generalization ability can be further improved by introducing multi - modal data - fusion technology and optimizing the model structure.

Acknowledgements

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