Barcode Detection Using a Hybrid Digital Image Processing and Convolutional Neural Network Framework

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***Abstract*—Auto-detection of barcodes has numerous applications these days. These include retail automation, inventory management, logistics, and document processing. The barcode recognition system faces challenges when dealing with naturally captured images, which contain illumination effects, noise, rotations, blur, and cluttered background scenes. This paper proposes an innovative barcode-detection system that can combine conventional Digital Image Processing techniques with an efficient Convolutional Neural Network (CNN) system. After preliminary image pre-processing techniques for emphasizing barcode-related patterns, edge detection and morphological processing techniques can be adopted for isolating barcodes. Next, a ROI (Region of Interest) generation stage relies on certain geometric properties. Further, a conventional CNN system is utilized to endorse these extracted regions. Experimental validation verifies that when using ROI regions with a conventional CNN system, accuracy and loss value can be significantly minimized when compared to processing entire images through conventional CNN models.**

Keywords—Barcode Detection, Digital Image Processing, Convolutional Neural Network, Region of Interest, Computer Vision

I. Introduction

Barcodes are widely used for encoding information in products, packages, and documents due to their simplicity, reliability, and low cost. They offer efficient and reliable recognition in several areas such as retail, medical, logistics, and industrial environments. As cameras are becoming common on portable devices, vision barcode recognition has emerged as an alternative to laser barcode scanners. Barcodes may look organized, but they are actually quite hard to detect in the wild. Issues such as uneven illumination, low contrast, blur, rotation, and background complexity may all impact such detection accuracy. Conventional barcode scanners cannot perform effectively under these conditions.

Techniques of Digital Image Processing (DIP) help in efficiently emphasizing lines and edges in the barcode. Nevertheless, DIP alone suffers from the drawback of generating false positives in cases when similar lines and edges are present in the background. Conversely, Deep Learning techniques and Convolutional Neural Networks specifically demand considerable data and computing power. To address these limitations, we propose a hybrid approach that leverages both the efficiency of localization through DIP-based localization and the discriminative capabilities of CNN-based classification. Additionally, performing CNN inference only on candidate regions helps to reduce the associated computations.

II. Related Work

Initially, feature-based barcode scanning techniques were primarily using handmade features such as gradient analysis, edge density, and morphological processing. These methods are computationally less intensive but are prone to illumination changes and noisy environments.

With the advent of deep learning, methods like Faster R-CNN, SSD, and YOLO have been employed for the target detection process within barcodes. Although the results are very impressive, the requirement for a lot of data and/or specialized hardware makes it unsuitable to be used in constrained environments.

Recently, research efforts have been made to combine the classical methods of image processing and machine learning techniques into a hybrid model. This approach is expected to limit the search area of the deep model to the ROI predefined by structural information. This proposed research is pertinent to the above-stated research and combines the use of DIP and CNNs to validate the ROI extracted.

III. Proposed System Architecture

The proposed system consists of a sequence of image preprocessing, feature enhancement, region extraction, and CNN-based validation stages. The overall architecture is designed to efficiently isolate barcode regions while minimizing false detections.

A. Dataset Preparation

The dataset is comprised of images that have barcodes and images that do not have barcodes. All images were resized to the same resolution and marked appropriately. A split in the dataset was performed in order to test the generalization of the models.

B. Image Preprocessing

To enhance barcode structures and suppress noise, the following preprocessing steps were applied:

1. Conversion of RGB images to grayscale
2. Gaussian filtering to reduce high-frequency noise
3. Histogram equalization to improve contrast between bars and background

These operations improve the visibility of barcode patterns and facilitate subsequent edge detection.

C. Edge Detection

Barcodes consist of dense, parallel edges. Thus, gradient-based edge detection methods such as Sobel and Canny were used to enhance this feature. Among them, the vertical edge responses showed especially great potential in distinguishing the barcode region out of other objects.

D. Morphological Operations

Morphological processing was applied to refine the edge maps:

- Dilation to connect fragmented bar edges
- Closing to fill small gaps between adjacent bars
- Opening to remove isolated noise components

These steps produce cleaner, more continuous regions suitable for contour analysis.

E. Region of Interest Extraction

After detecting contours, connected component analysis was applied in order to detect candidate regions. Geometric properties, including aspect ratio, rectangularity, and edge density, were analyzed for each region. Only those satisfying barcode-like constraints were chosen as ROIs.

F. CNN-Based Classification

A lightweight CNN model was implemented for binary classification on the region-of-interest (ROI) patches. The network model entailed convolutional layers responsible for feature extraction, pooling layers that achieved dimensionality reduction, dropout layers used as regularizers, and fully connected layers used for the classification process. Data augmentation methods were used to enable the network's robustness to rotation and scale variations.

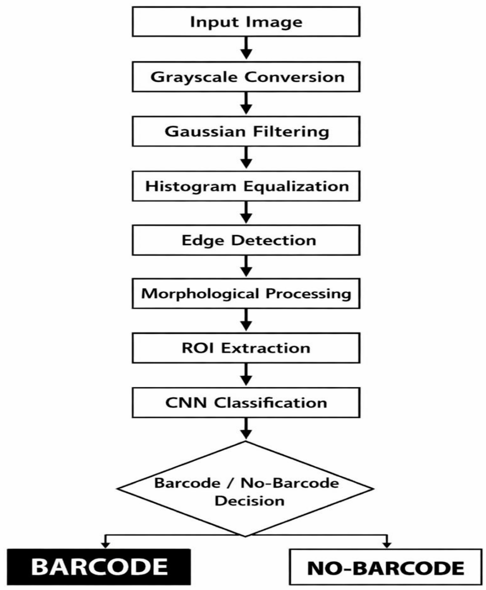
Two models were evaluated:

Model A: CNN trained on full images

Model B: CNN trained on extracted ROIs

IV. Flowchart of the Proposed Method

Figure 1 illustrates the processing pipeline of the proposed hybrid barcode detection system.



V. Experimental Results and Discussion

1. In this experiment
2. Both of the CNNs were trained with early stopping. They were trained with an adaptive learning rate. They were also trained based on the accuracy and loss functions on the validation set.

1. **Model A (Full Image CNN):**

- Validation Accuracy: 96.63%
- Validation Loss: 0.0888

3. **Model B (ROI-Based CNN):**

- Validation Accuracy: 99.52%
- Validation Loss: 0.0043

ROI-based model is significantly better than the full image model and achieved a higher accuracy of about 99.21%. Since the model considers only the areas where the barcode is expected to be located, the background interference is reduced. Although ROI extraction causes an overhead, it is justified by the higher accuracy of the model.

An ablation study revealed that the deletion of the ROI stage based on the DIP resulted in a degraded performance. This verified the effectiveness of the hybrid architecture.

VI. Conclusion

The paper discussed about the efficient hybrid method for barcode recognition based on Digital Image Processing and a lightweight Convolutional Neural Network. The classical image processing method was used to enhance the features of the barcode as well as to locate the regions of interest, where the Convolutional Neural Network was utilized for the validation process to improve the result in challenging image environments. The result shows that the ROI-based classification outperforms the full-image recognition using the Convolutional Neural Network. Future work will include the handling of class balance problems, the improvement of the execution speed, as well as the expansion of the system for barcode decoding and multiple formats.

References

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