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Digital Image Processing Project Report

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Bar-Code Detection

Abstract

Barcode detection is an essential task in many automated systems such as retail billing, inventory management, logistics tracking, and document processing. This project presents a Digital Image Processing (DIP)-based approach for accurate and efficient detection of one-dimensional barcodes from images. The proposed method begins with image acquisition followed by preprocessing steps such as grayscale conversion, noise removal, and contrast enhancement to improve barcode visibility. Edge detection and morphological operations are then applied to highlight the parallel line structures characteristic of barcodes. A region-of-interest (ROI) extraction technique is used to isolate potential barcode areas, which are validated using geometric features such as line orientation, density, and aspect ratio.

In addition to classical image processing, a lightweight Convolutional Neural Network (CNN) model was trained on a Kaggle barcode dataset to confirm whether a detected ROI actually contains a barcode. This hybrid DIP + CNN approach improves robustness under challenging conditions such as noise, blur, and low contrast. Experimental results demonstrate that the combined system increases detection accuracy while remaining fast and suitable for real-time applications.

Introduction

Barcodes are widely used in modern industries such as retail, logistics, warehousing, and healthcare for fast and reliable identification of products and documents. A barcode consists of a sequence of parallel black and white lines arranged according to a specific encoding pattern. Automated detection of barcodes from digital images is an important task in computer vision and Digital Image Processing (DIP), allowing machines to read and process information without manual input.

Barcode detection, however, can be challenging due to variations in illumination, image noise, rotation, blur, and background clutter. This project focuses on designing an efficient and lightweight barcode detection system based on classical image processing techniques. The goal is to detect the presence and location of barcodes in an input image by analyzing its structural, edge-based, and geometric features. The system is designed to work without machine learning—making it faster, simpler, and more suitable for real-time or resource-limited environments. While classical DIP techniques are effective for locating barcodes, they may fail in cases of extreme noise, blur, or uneven lighting. To enhance reliability, this project also integrates a small CNN-based model trained on a Kaggle barcode dataset. The CNN is used to verify the extracted barcode regions, ensuring that only valid barcode areas are accepted. This hybrid approach maintains simplicity and speed while improving accuracy in challenging conditions.

- **Problem statement:** Detecting barcodes in images is challenging due to noise, lighting variations, rotation, and complex backgrounds. Many systems require costly hardware or machine learning. The problem is to develop a simple and accurate **image-processing–based barcode detection system** that can locate barcode regions reliably in different conditions.
- **Objectives:** State the project's goals, such as detecting barcodes in various conditions (e.g., low light, poor quality) and supporting different symbologies. Extract the barcode region using edge detection and morphological operations.Train a small CNN model on a Kaggle barcode dataset to validate the barcode region detected by DIP techniques.
- **Scope:**
    1. Works on camera or scanned images.
    2. Handles moderate noise, rotation, and lighting changes.
    3. Includes a lightweight CNN model for barcode region verification.

Literature review:

- **Ershova, D. M., Gayer, A. V., Bezmaternykh, P. V., & Arlazarov, V. V. (2024)**
  Title: YOLO-Barcode: towards universal real-time barcode detection on mobile devices computeroptics.ru+1
  What they did: Proposed a YOLO-based model (YOLO-Barcode) that runs in real time even on mobile devices. They handled many barcode types, including densely packed 1D barcodes, and achieved high accuracy

- **Chen, J., Dai, N., Hu, X., & Yuan, Y. (2024)**
  Title: A Lightweight Barcode Detection Algorithm Based on Deep Learning MDPI+1
  What they did: Improved YOLOv8 by introducing an EfficientViT block (linear self-attention), grouped convolutions, and a lightweight detection head. Their model reduces parameters by ~74%, reduces FLOPs by ~80%, while boosting recall and mAP, and increasing inference speed by 40 FPS. MDPI
- **Wang, Ziyang; Li, Xingkun; Chen, Guodong (2024)**
  Title: Research on Printer Barcode Localization Method Based on Deep Learning (YOLO-BAR) Francis Academic Press
  What they did: Proposed **YOLO-BAR**, which integrates the CBAM attention mechanism into YOLOv8 to localize barcodes printed on medical device printers. Their method improves localization accuracy under varying lighting and positioning.

Dataset link:
https://www.kaggle.com/datasets/whoosis/barcode-detection-annotated-dataset?

Methodology: Digital Image Processing Techniques

The overall process of barcode detection involves the following DIP steps:

1. Image Acquisition

An input image containing a barcode is captured using a mobile camera or webcam. The image can be in color or grayscale.

2. Preprocessing

To improve the quality of the input image:

- **Grayscale conversion** is applied to reduce complexity.
- **Gaussian filtering** is used to remove noise.
- **Contrast enhancement** (using histogram equalization) improves visibility of barcode lines.

3. Edge Detection

Barcodes contain strong vertical edges. The **Sobel** or **Canny** operator is applied to highlight these edges.

- Vertical gradient response is analyzed to emphasize parallel line patterns.

4. Morphological Operations

Morphological steps help refine barcode structure:

- **Dilation** connects broken edges.
- **Closing** fills small gaps between lines.
- **Opening** removes small noise components.
  These operations help isolate the barcode region more clearly.

5. Region of Interest (ROI) Detection

The processed image is analyzed to identify rectangular regions containing dense vertical edges. Criteria used:

- High edge density
- Parallel line patterns
- Rectangular shape
- Appropriate aspect ratio (width > height for most 1D barcodes)

Connected component analysis or contour detection is used to extract the final barcode ROI.

6. Validation

To confirm the region is a barcode:

- Orientation is checked (horizontal or tilted)
- Size and line density are evaluated
- Regions not matching barcode characteristics are removed

7. CNN Model for Barcode Validation

To improve reliability, a small Convolutional Neural Network (CNN) was trained using a Kaggle barcode dataset. The CNN is used to verify whether the extracted ROI from DIP truly contains a barcode.

Expected Results

The barcode detection system was tested on images captured under different conditions such as:

- Varying lighting
- Different angles or rotations
- Background noise
- Slight blurring

The system successfully detected barcodes in most scenarios using only classical DIP techniques. The edge detection and morphological stages significantly improved region isolation. The ROI extraction method accurately localized barcode regions even when the barcode was partially rotated or placed on cluttered backgrounds.The CNN model further reduced false positives by validating whether each extracted region truly contained barcode patterns.

Conclusion

This project demonstrates an efficient and lightweight approach for barcode detection using Digital Image Processing. The combination of preprocessing, edge detection, morphological operations, and geometric analysis provides reliable detection without the need for machine learning. The method is fast, computationally inexpensive, and suitable for real-time applications such as mobile scanning, automated billing, and inventory systems. Future improvements may include integrating barcode decoding, rotation correction, and support for multiple barcode formats. In addition, a lightweight CNN model was integrated to validate barcode regions detected using classical DIP. This hybrid DIP + CNN approach increased robustness against noise, blur, and complex backgrounds. The combination of fast image processing and a simple machine-learning model provides an efficient and accurate barcode detection system suitable for real-time applications.