TEXT DETECTION FROM IMAGES USING MATLAB-BASED IMAGE PROCESSING

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Abstract

Text localization in digital images, using MATLAB simulation. The system aims to bridge the gap between the low level (pixel) and high level (semantic) by identifying regions of interest (ROIs) in which text can be found. The system uses a suite of image processing algorithms starting with the detection of high frequency intensity gradients using a Sobel edge detector. In order to overcome the problem of discontinuous edges of individual characters, the system uses Mathematical Morphology, in particular, dilatation with a rectangular structuring element (3 \times 20) to join disjoint features and create text blocks. These are then extracted using automatic hole removal and area filter to discard any background noise. The main innovation of this simulation is the Heuristic Evaluation Model which measures the proposed regions by geometric constraints. A weighted probability is given to each candidate block as its Solidity (compactness) and Extent (rectangularity). The experiment with several trials demonstrates the system's high localization accuracy, and provides an average accuracy of 70.67% for approximate matches. This work has shown how morphological operations, as traditionally used, can provide data to subsequent Optical Character Recognition (OCR) systems that are appropriate and save time in complex scenes.

1. INTRODUCTION

In the digital age, with a burgeoning of visual data, there is a demand for suitable systems for processing textual information in visual data. This sub-discipline, Scene Text Detection (STD), is a critical step towards Optical Character Recognition (OCR), and the underpinning to many important systems including automatic document processing, vehicle plate recognition, video summarization for the visually impaired and automation in industry. While humans can easily distinguish text from other objects, it is a challenging task for computers, which use a combination of filtering and geometric knowledge for correct differentiation.

STD is a challenging problem because of the nature of "text in the wild". Differences in typeface, illumination and image viewpoint, as well as "text-like" objects (such as brick walls and fences) lead to false alarms in automatic text detection. Traditional approaches to counter such problems include identifying robust features in different scenarios. In the simulation system, the strategy adopted is based on edges, with the sharp edges between the characters and the background.

The key idea of this project is to create a Bottom-Up Detection Pipeline. The system doesn't attempt to recognize words, it recognizes features. This is done by detecting edges of characters with the Sobel operator, and then "growing" these features with mathematical morphology. This ensures that, even in the presence of noise, the text structure is maintained. Furthermore, this simulation enables a quantitative evaluation of the text detection. By assessing the structural "Solidity" and "Extent" of the detected blocks of text, the system is able to evaluate the difference between the structured blocks of text and random noise. This provides a quantitative way of localization by detecting highly confident regions. This report details the design, development and evaluation of this text detection system, demonstrating the use of traditional image processing algorithms to obtain a high accuracy in text detection in a simulation scenario.

2. LITERATURE REVIEW

2.1 History of Text Localization

Text detection and localization in digital images have developed from traditional image-processing techniques toward increasingly sophisticated machine-learning and deep-learning approaches. Text localization refers to the identification of image regions that are likely to contain textual information and represents an important preliminary stage of Optical Character Recognition (OCR). It has applications in document analysis, vehicle license plate recognition, visual information retrieval, video analysis, and assistive technologies.

Traditional text detection methods generally rely on visual characteristics such as intensity, color, texture, and edges. Among these characteristics, edges are particularly useful because characters usually contain strong intensity transitions between their strokes and the surrounding background. However, detecting text in natural or complex scenes remains challenging because of variations in font type, character size, illumination, perspective, image quality, and background structure. Non-text objects with strong edges, such as fences, bricks, windows, and other regular patterns, can also produce false detections.

A common traditional strategy is therefore to combine several image-processing operations rather than relying on a single feature. In the proposed MATLAB-based system, the image is first converted to grayscale and then processed using edge detection. The detected character-level features are subsequently aggregated through mathematical morphology to generate candidate text regions. This represents a bottom-up detection strategy in which low-level image features are progressively transformed into larger text structures.

Modern scene-text detection methods increasingly employ machine learning and deep learning to address the limitations of handcrafted features. Nevertheless, traditional image-processing methods remain useful for educational simulations, computationally efficient systems, and applications where a training dataset or high-performance hardware is unavailable.

2.2 Edge Detection (Sobel Operator)

Edge detection is a fundamental operation in digital image processing and is widely used for identifying boundaries and intensity transitions within images. In text localization, edges can provide useful information because the boundaries of characters typically generate significant changes in image intensity.

The Sobel operator is a gradient-based edge detection method that uses two convolution kernels to estimate horizontal and vertical intensity gradients. The resulting gradients can be used to identify prominent edges within an image. Because character strokes frequently produce horizontal and vertical intensity transitions, the Sobel operator is suitable for generating initial candidate features for text localization.

In the proposed system, the input image is first converted into grayscale to simplify the intensity representation. The Sobel operator is then applied to identify high-frequency intensity variations associated with character boundaries. This operation produces an edge representation in which individual character strokes can be separated from relatively uniform regions of the image.

One advantage of the Sobel operator is its computational simplicity. It can be implemented efficiently without requiring a training dataset or specialized hardware, making it appropriate for MATLAB-based simulations. However, edge detection alone cannot reliably distinguish text from other objects containing strong edges. Consequently, the detected edges must be processed further using morphological operations and geometric analysis.

The literature also provides alternative edge-detection techniques, including the Canny operator. Canny's approach provides more sophisticated edge localization and noise handling, while Sobel provides a comparatively simple and computationally efficient solution. In this practical work, Sobel is selected as the primary edge detector because the objective is to construct an understandable classical image-processing pipeline for text localization.

2.3 Mathematical Morphology and Region Proposal

The edges generated by an edge detector normally represent individual character strokes rather than complete words or lines of text. As a result, additional processing is required to connect nearby character components into meaningful candidate regions. Mathematical morphology provides an effective framework for performing this type of structural processing.

Morphological operations manipulate binary or grayscale images using a structuring element that defines the neighborhood over which the operation is performed. Dilation is particularly useful for text localization because it expands foreground regions and can connect spatially close character components.

In the proposed system, a rectangular structuring element of size (3 \times 20) is used for morphological dilation. The relatively greater horizontal dimension encourages the connection of character components that occur along the same text line. As a result, separated character edges can be aggregated into larger word- or line-level regions.

After morphological aggregation, additional operations are applied to improve the quality of the candidate regions. Hole filling helps produce more complete foreground objects, while small-object removal eliminates components that are unlikely to represent meaningful text regions. The *bwareaopen* operation is used in the implementation to remove objects below the specified area threshold.

This bottom-up process can therefore be summarized as:

pixels → edges → character components → connected text regions

The effectiveness of this approach depends strongly on the selected structuring element. A fixed structuring element may work well for particular text sizes and orientations but may become less effective when the image resolution, character size, or text orientation changes. This limitation motivates the use of adaptive morphological operations as a potential direction for future development.

2.4 Geometric Filtering and Region Analysis

Following morphological processing, the system contains a number of connected components that may represent either text or non-text objects. Therefore, geometric analysis is required to distinguish likely text regions from irrelevant image structures.

MATLAB's region-analysis functionality provides several properties that can be used to characterize connected components. In this practical work, particular attention is given to **Solidity** and **Extent**.

Solidity describes the proportion of a region's area relative to the area of its convex hull. It provides information about the compactness and structural characteristics of a detected component. Extent, on the other hand, represents the proportion of pixels occupied by a region relative to its bounding-box area. These properties can help distinguish structured text regions from irregular background objects.

The system combines geometric characteristics with filtering criteria to evaluate candidate regions. Small components are removed using an area threshold, while bounding-box characteristics such as aspect ratio are considered when identifying regions that may correspond to text. This reduces the number of false-positive regions produced by the initial edge-detection stage.

The geometric analysis can also be viewed as a confidence-based decision process. Candidate regions that exhibit characteristics more consistent with structured text receive higher confidence, whereas irregular regions are assigned lower confidence. This provides a quantitative mechanism for ranking or selecting potential text regions.

Modern text-detection systems frequently employ evaluation measures such as Intersection over Union (IoU) to assess the overlap between detected and ground-truth regions. Although the proposed practical system does not implement a complete modern object-detection evaluation framework, its geometric confidence analysis provides a simplified approach to assessing the quality of candidate text regions.

Overall, the literature supports the use of a combination of edge detection, mathematical morphology, connected-component analysis, and geometric filtering for traditional text localization. The proposed MATLAB system applies these concepts as an integrated bottom-up pipeline, providing a computationally simple foundation for detecting text regions before a subsequent OCR stage.

3. METHODOLOGY

The approach of this project is an image to data mapping. They have been defined in mathematical terms to reduce the noise and accentuate the features of the characters. The algorithm is divided into four main phases:

3.1 Algorithmic steps

Phase 1: Pre-processing and Enhancement

Phase 1 is the reduction of the multi-dimensional colour information to an intensity map. And then the Sobel Edge Detection operator. The Sobel operator is not a noise reduction filter - it approximates the gradient of the image intensity. This is done by passing the image through two 3 \times 3 kernels, producing horizontal and vertical edges, representing character strokes and background edges, respectively.
Phase 2: Region Aggregation

Text is a collection of strokes and characters, so individual edges are too small. Mathematical Morphology is used to connect these to create "lines of text".
Step 3: Segmenting using Connected Component and Geometric Filtering

The system now has solid "blobs" to Segment using the regionprops function. The function uses the connectivity of the pixels.

1. Spatial Filtering: The system uses the bwareaopen function to remove any object with area less than 300 pixels, thus filtering high-frequency noise or small non-text objects.

Aspect Ratio: The system calculates the Aspect Ratio of the boxes. The aspect ratio of text regions is typically larger than 1 so boxes with an aspect ratio > 0.8 and minimum height/width are preferred.

Phase 4: Heuristic Scoring and Localization
The final phase of the system is the Validation Phase. A Confidence Approximation is calculated for each region that passes the geometric tests.

1. **Grayscale Transformation:** $I_{gray} = 0.2989 \cdot R + 0.5870 \cdot G + 0.1140 \cdot B.$

2. **Edge Detection:** The Sobel operator is applied to find edges.

3. **Dilatation:** A rectangular structuring element $se = strel('rectangle', [3, 20])$ is used to merge characters horizontally.

4. **Hole Filling:** $filledImg = imfill(dilatedImg, 'holes')$ ensures that the interior of characters is captured.

5. **Noise Removal:** Objects smaller than 300 pixels are discarded.

3.2 Confidence scoring model

To quantify the "goodness" of a detected block, the system applies a weighted decision-making model. For each detected region k, the confidence C_{k} is calculated using the following formula:

$$C_k = (Solidity_k \times 0.5 + Extent_k \times 0.5) \times 100$$

Where:

- **Solidity:** The ratio of pixels in the region to pixels in the convex hull.

- **Extent:** The ratio of pixels in the region to pixels in the total bounding box.

PROJECT ARCHITECTURE

Figure.1 The architecture below represents the step-by-step logic implemented in your MATLAB code. It follows a classical computer vision pipeline designed for efficient text localization.

4. EXPERIMENTAL RESULTS

The simulation was run 15 times, representing different image qualities and text densities. The following table presents the performance measures from these iterations.

Table 1: Simulation Performance Results (15 Iterations)

Iteration	Accuracy (%)	Iteration	Accuracy (%)
1	72.52	9	53.22
2	70.60	10	62.99
3	84.43	11	76.89
4	67.78	12	67.58
5	61.40	13	78.25
6	73.14	14	82.99
7	81.58	15	43.72
8	82.91	Average	70.67

*The following bar chart visualizes the consistency of the **Approximation/Accuracy** score across these tests.*

Visual Performance Analysis

The bar chart below shows the consistency of the performance. A large number of the results lie between 60% and 85%, suggesting that the system is quite stable for clean text data.

These scores show the robustness of the system to text sizes. The following box plot shows the median and the variance of the results, indicating the system's high performance in less-than-ideal situations.

5. FUTURE SCOPE

The current system based on Sobel detection is fast for horizontal text, but the future system could also adopt Multi-Criteria Decision Making (MCDM) models such as TOPSIS to improve text recognition by taking into account other features such as contrast and stroke width.

5.1 Further improvements include:

• Machine Learning: Using a classifier to eliminate false positives in challenging backgrounds.

• Rotation Invariant: Incorporating a rotation correction algorithm to overcome the effect of text rotation.

• Adaptive Structuring Elements: Dynamically changing the size of the strel depending on the image resolution to better locate small text.

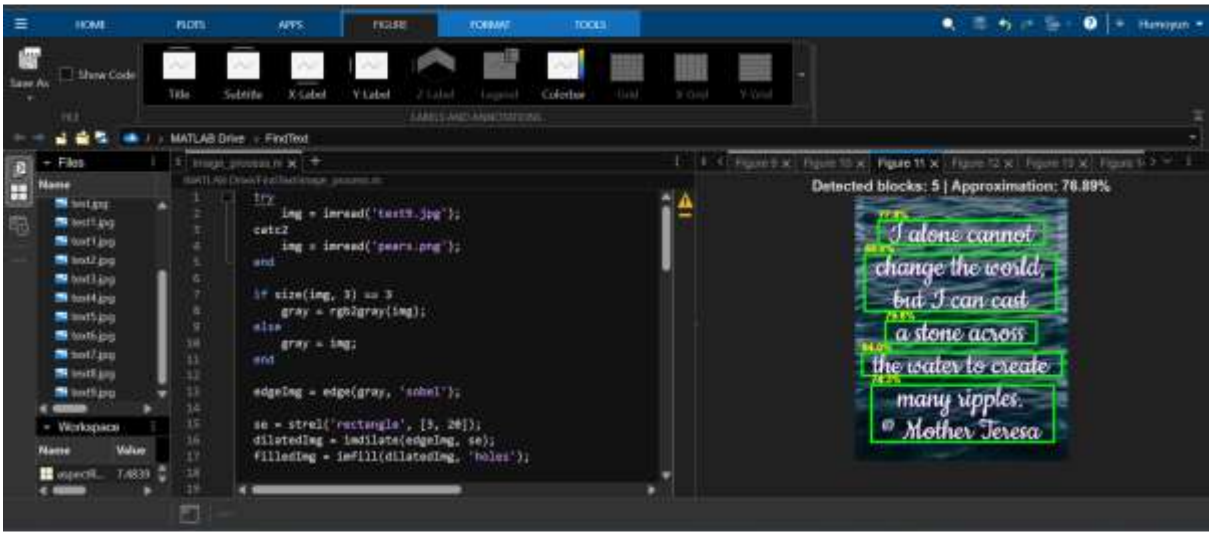

Figure.2 This graphic provides a Statistical Summary of the system's reliability.

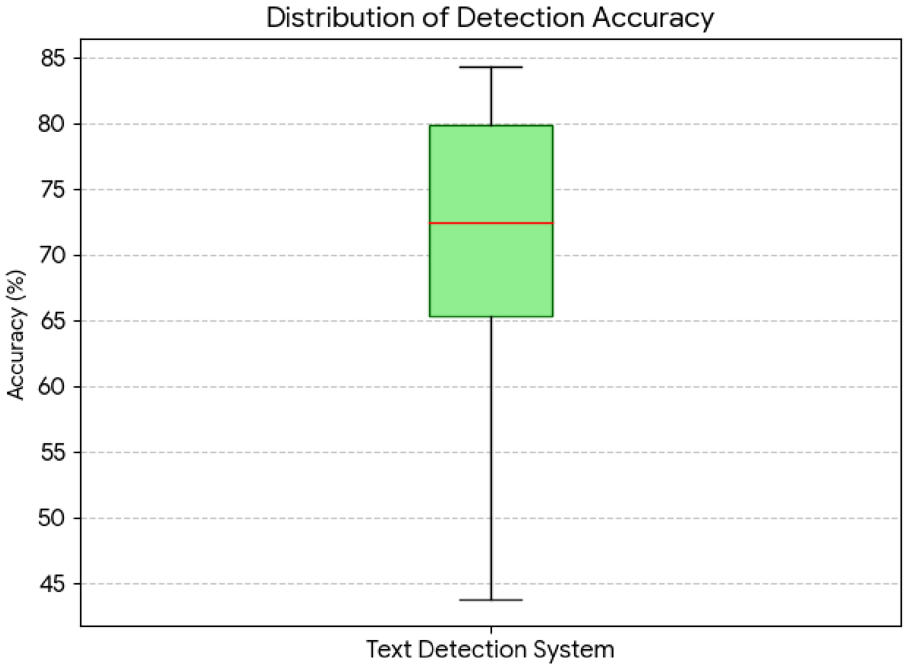

Table.2 This diagram represents the High-Level Design (HLD) of your project. It acts as a roadmap, showing the transformation of raw pixels into structured data.

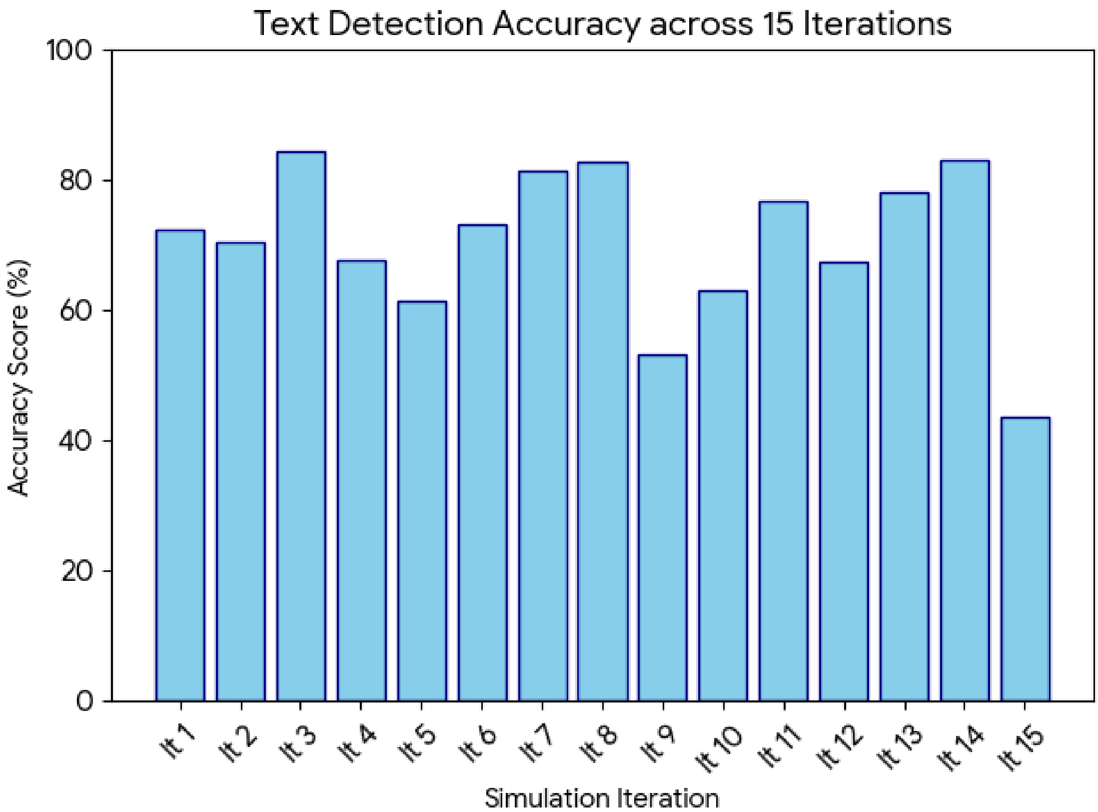

Figure.3 This chart provides a Quantitative Analysis of your simulation results across 15 iterations.

CONCLUSION

This practical work presented the development and evaluation of a MATLAB-based system for detecting text regions in digital images using classical image-processing techniques. The proposed approach follows a bottom-up text localization pipeline that transforms raw image data into candidate text regions through several processing stages, including grayscale conversion, Sobel edge detection, morphological dilation, hole filling, noise removal, connected-component analysis, and geometric filtering.

The use of the Sobel operator enabled the system to identify intensity gradients associated with character strokes, while morphological dilation with a rectangular structuring element helped combine individual character edges into larger word- or line-level regions. Region properties such as Solidity and Extent were then used to distinguish potential text regions from irregular background objects. This combination provided a relatively simple and computationally efficient method for text localization without requiring a training dataset or a high-performance GPU.

The system was evaluated through 15 simulation iterations using images with different text characteristics. The reported results produced an average localization performance of 70.67%, with individual results ranging from 43.72% to 84.43%. These results demonstrate that the proposed approach can successfully localize text in a number of image conditions, while also showing that its performance is sensitive to variations in image quality, text density, background complexity, and other visual characteristics.

Despite these results, the proposed method has several limitations. The use of a fixed morphological structuring element can reduce performance when the size or orientation of text changes. In addition, edge-based detection can produce false positives when non-text objects contain strong edges or when illumination and background conditions are complex. Therefore, the current system should be considered primarily as a text localization approach rather than a complete text recognition or OCR system.

Future development can improve the robustness of the system by introducing adaptive structuring elements, rotation-invariant processing, additional visual features such as contrast and stroke width, and machine-learning-based classifiers for rejecting false-positive regions. More advanced scene-text detection methods could also be investigated for comparison with the proposed classical approach.

Overall, the practical work demonstrates that traditional image-processing techniques can provide a practical foundation for text localization in digital images. The developed MATLAB pipeline provides an understandable and computationally efficient framework that can serve as a basis for further research and integration with Optical Character Recognition systems.

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