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Quality Inspection of Printed Texts

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***Abstract*—Inspecting the quality of printed texts has its own importance in many industrial applications. To do so, this paper proposes a grading system which evaluates the performance of the printing task using some quality measures for each character and symbols. The purpose of these grading system is two-folded: for costumers of the printing and verification system, the overall grade used to verify if the text is of sufficient quality, while for printer's manufacturer, the detailed character/symbols grades and quality measurements are used for the improvement and optimization of the printing task. The proposed system has been tested on images from a real industrial environment and the obtained results are promising.**

***Index Terms*—character recognition, quality assessment.**

I. Introduction

For decades, symbols and labels have been printed onto all sorts of items in order to provide information about the item. However, in some industries the quality is of high importance, as errors can have a vital influence, like in pharmaceutical packages. If these pharmaceutical packages are labelled with wrong or low quality symbols and text, it can have detrimental outcomes. This highlights the important aspect of inspecting the labels printed on pharmaceutical packages in order to verify the quality of the label.

To deal with this problem, we have developed an optical recognition (OCR) system that besides recognition of the characters and symbols, provides a kind of grading for the quality of the print of each symbol and character. The OCR technology is seen as a solved issue as most OCR modules are able to achieve above 99 % recognition rate for well formatted isolated characters [14]. However, grading quality of prints for each individual character can help improving the printer configuration. This is exactly the purpose of this paper to develop a system that can assess the quality of the prints and provide grading score reflecting the performance of the printers for each character.

The rest of this paper is structured as follows: Related work is presented in Section II. The proposed text grading system is presented in Section III. Experimental results are given in Section IV. Finally, the paper is concluded in Section V.

II. Related Work

The primary focus of a text grading system is recognition of the printed text in order to verify whether the correct text is printed. This section first provides related work within text recognition, then, within grade labeling.

A survey by Q. Ye and D. Doermann [14], analyses the field within text detection and recognition in imagery. A common text detection and recognition system is composed of multiple steps. Often, these steps are laid out as: acquisition, preprocessing, localization, verification, segmentation, and recognition. Image acquisition and preprocessing are the basic steps of an image processing system used to acquire the image and prepare it for the rest of the system. *Localization* is used to localize the text in image. Known methods for this are using Connected Component Analysis (CCA) methods or sliding window classification to find text candidates, often by determining regions as text or non-text. Different features can be used for text localization such as color, gradients, and texture. To find text with different characteristics, hybrid feature can be used. *Verification* is used to verify localized text region candidates as text or non-text. Methods for this can be prior knowledge or feature based. *Segmentation* is used to segment the text, which can be done on different levels, e.g. using binarization which separates text pixels from background pixels in order to create a binary text image. Another method is text line segmentation, which segments each line of text. An example of this is using a skeletonized image proposed by Shivakumara et al. [10]. Character segmentation works to segment isolated characters. A simple method is using projection histogram. Another method is proposed by Nomura et al. [8], which uses morphology operations. Roy et al. [9] uses convex hull for character segmentation. *Recogniton* is the step of recognizing the isolated character/text depending on the level of recognition. Recognition of isolated characters can be used by basic template matching to compare characters with known reference samples. Another use is extracting features and a classification method to find the best match. Proposed features for character representation are among many: Variations of projection histogram [3], border profile [12][4], crossing [2][3], zooning [11][2], and gradients [11]. Classification of characters could, e.g. be done using a nearest neighbor classifier or a trained SVM classifier [14].

Quality assessment is generally an important topic in image processing [6], [7]. In the context of OCR, quality grading is sometimes referred to as Optical Character Verification (OCV). OCV is used to confirm the legibility of OCR results [5] by measuring the print quality of characters using, e.g. sharpness and contrast of character images. Grading is more developed within other symbols such as barcodes and Data-Matrix. Measurements of barcode and datamatrix print quality are standardized by ISO and IEC. The ISO 15415 and ISO

15416 [13] have defined a standard measurement for barcodes and DataMatrix. These quality scores are calculated based on multiple parameters, like, symbol contrast, edge contrast, and other defined parameters. Such standards, however, do still not exist for character grading. This paper paves the way for such a standard.

III. Proposed System

The block diagram of the proposed system is shown in Figure 1. The steps of the system are explained in the following sub-sections.

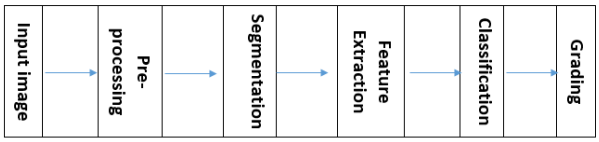
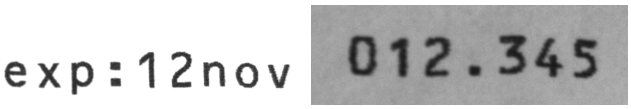


Figure 1: The block diagram of the proposed system

A. Input image

The input image to the system is acquired by an industrial printer that prints on small scales like visit cards or pharmaceutical packages. Examples of such images are shown in Figure 2.



(a) Figure B (b) Figure D

Figure 2: Examples of input images

B. Pre-processing

In order to prepare the image for the system, it is first rescaled to a height of 100 pixels and a width calculated based on the original aspect ratio. Furthermore, the image is converted to grayscale and normalized to the range of 0-255. At last, the image is filtered in order to remove noise, using a 7×7 Gaussian filter. Figure 3 shows the result of the applied pre-processing.

(a) Figure B (b) Figure D

Figure 3: Processed images.

C. Segmentation

The proposed system uses a character-based segmentation by applying local thresholding to obtain a binary image with text as foreground and non-text as background. Furthermore, morphology operations for closing small holes and removing small BLOBs are applied to remove noise and redundant information. The result of this is seen in Figure 4

(a) (b)

Figure 4: Binary images.

The binary image is used to segment isolated characters by calculating a vertical projection histogram. This is possible, as the text is horizontally aligned. With the use of the projection histogram, a splitting mask is generated in order to segment isolated characters. The splitting mask is generated by finding the centers between elements in the projection histogram. Figure 5(a) shows the results of the projection histogram and splitting mask generation of Figure 4(a). Figure 5(a) shows the calculated projection histogram and the marked center between elements. Figure 5(a) shows the generated mask. Each region of the mask corresponds on a character of the processed image.

(a) (b)

Figure 5: Projection histogram (a) and splitting mask (b) of Figure 4(b).

The binary image is masked with the generated splitting mask, and for each region the bounding boxes of all CCs are found. This way it is possible to extract characters with multiple CCs. From each region, an isolated character is extracted. This is shown in Figure 6.

(a) (b)

Figure 6: Isolated characters.

D. Feature Extraction

The isolated character images and the reference characters are normalized to be comparable. This is done by rescaling the binary character images to a size of 64×64 pixels and keeping the aspect ratio. The aspect ratio is kept by generating a black image of 64×64 pixels and rescale the character image to 64 pixels on the largest side and then placing it in the middle of the generated black image. This provides the results as shown in Figure 7.

(a) (b) (c) (d)

Figure 7: (a) and (c): Isolated characters ; (b) and (d) normalized characters.

Features are extracted in order to represent the normalized characters.This work proposes to use a combination of multiple features to represent characters. The used features are border profile, region projection, and zooming.

1) Border Profile: Border Profile [11] describes the outer contour of a character. The distance from bounding box to the first foreground (Non-zero) pixel is used to describe the character. The distance is calculated from four sides: two in horizontal direction from right and left, and two in vertical direction from top and bottom. The distance is found for each pixel row in horizontal direction and for each pixel column in vertical direction

2) Region Projection: By using ordinary projection histogram and a partitioned character image, Region projection histogram, also named Celled Projection, is obtained, as proposed by [3]. By calculating the horizontal projection histogram for each region in the partitioned character image, a combined region projection histogram feature vector can be constituted by concatenating the projection histogram for each region. In the proposed system, the character image is partitioned into 5 regions.

3) Zooning: In zooning [3] [11], the character image is divided into $N \times M$ zones. From each zone, features are extracted and then combined to constitute a feature vector for the whole character. For each zone, Histograms of Oriented Gradients (HOG) [1] are extracted.

E. Classification

To classify an unknown isolated character of the acquired input image, a nearest neighbor classifier is used by calculating a distance between the isolated character and each of the reference characters. This is done for each of the three features. The distance between two characters is calculated based on a histogram matching algorithm, which calculates the sum of pr. element error between the two feature vectors. The calculation of the histogram matching is shown in Equation 1

$$Distance = \sum_{n=0}^{N} |\hat{F}_1(n) - \hat{F}_2(n)| \quad (1)$$

where F_1 and F_2 are the two feature vectors and N = Size of F_1 and F_2 .

The calculated distance from the three features are then combined into a single combined distance, as shown in Equation 2.

$$CombinedDistance_i = w_1 * \hat{B}_i + w_2 * \hat{R}_i + w_3 * \hat{Z}_i \quad (2)$$

where $\hat{B}$, $\hat{R}$ and $\hat{Z}$ are the normalized distances of the three features.

F. Grading

The proposed system has used an adapted version of the ISO 15416 standard [13] for quality grading of printed text. The adapted version performs a scan line across the image for every 5th pixel row. For each scan line multiple parameter grades are calculated, and the lowest is used as scan line grade. An average of all scan line grades is then used as the final character grade. The used parameters are described in Table I.

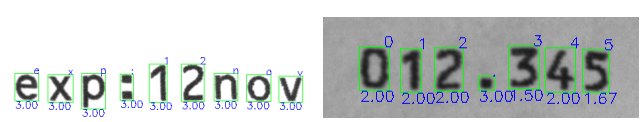
Parameter	***Description***
Decode	Based on the recognition of the character.
Symbol Contrast	The contrast between maximum and minimum value of the character image.
Min Edge Contrast	The min contrast of a transistion from foreground pixel to background or background to foreground.
Modulation	The ratio between Symbol Contrast and Min Edge Contrast.
Rmin	The min pixel value must be lower than 0.5 max pixel value.
Broken	Check if the characters have equal elements as their classified reference character.
Blur	Calculates the standard deviation of the image frequencies to check for blurry image.

Table I: Grading Parameters.

To calculate an overall grading score for the text image, the lowest individual character grade is used.

IV. Experimental Results

The proposed system is able to recognize characters of a text image and, in addition to this, calculate a quality grade for each character in the text image. The inspection results of the acquired input images from Figure 2 are shown in Figure 8, where the recognized character is written above the bounding box of isolated characters, and the calculated grade is written below.



(a) (b)

Figure 8: Inspection results of the proposed text grading system.

A. Recognition

The character recognition of the text grading system is tested with a dataset of 100 images with a total of 840 characters and another dataset containing known printing errors with 84 text images and a total of 1032 characters. The character recognition results are shown in Table II.

Dataset	*Recog. Rate*	*Precision*	*Sensitivity*
Border Profile			
Real Dataset	92.14 %	0.9203	1
Error Dataset	89.15 %	0.8770	0.9978
Region Projection			
Real Dataset	97.86 %	0.9774	1
Error Dataset	91.86 %	0.9054	0.9979
Zooning			
Real Dataset	97.62 %	0.9750	1
Error Dataset	91.76 %	0.9062	0.9979
Combined Features			
Real Dataset	98.69 %	0.9857	1
Error Dataset	92.93 %	0.9177	0.9978

Table II: Recognition Results.

The error dataset consists of subsets with known print errors, more specifically recognition results for the different error subsets are seen in Table III.

Dataset	*Border Profile*	*Region Projection*	*Zooning*	*Combined*
Blur	94.19 %	98.84 %	95.35 %	97.67 %,
Spray	85.47 %	87.21 %	88.95 %	84.88 %,
Cutted	95.93 %	92.44 %	97.67 %	97.09 %,
Tail	77.91 %	83.72 %	86.05 %	90.12 %
Smear	91.28 %	97.67 %	91.86 %	96.51 %
Missing Line	90.12 %	91.28 %	90.70 %	91.28 %
Error Dataset	89.15 %	91.86 %	91.76 %	92.93 %
Real Dataset	92.14 %	97.86 %	97.62 %	98.69 %

Table III: Recognition rates for the different features using different datasets.

B. Inspection

The result of an inspection using the text grading system is an inspection log holding all grading results for both individual isolated characters and the overall grading result.

V. Discussion and Conclusion

The recognition results showed high recognition rate as the system was able to perform a recognition rate of 98.69 % along with a precision of 0.9857 and a sensitivity of 1. The results show that the sensitivity is very high for the real dataset as the system achieves a sensitivity of 1. This means that the system is not missing any character in the system. At the same time, the system has a precision of 0.9857. This indicates that the system applies a strict segmentation in order not to classify noise as characters, and at the same time, without missing characters. The highest results are achieved using a combination of multiple features for representing and matching the characters. None of the single features are able to achieve the same high results alone. However, the use of the combination of multiple features has a downside, as the system has longer computation time. However, reducing the computation time by only using a single feature will also decrease the recognition rate. The log provides information about the recognition results, print quality, and grading scores of both the overall text image and the individual characters. The overall grading is valuable for costumers, as it is the actual purpose of the system, so it is possible to reject packages with bad prints. The individual character recognition and print quality results are valuable to printer manufacture, in order to troubleshoot the system. In this way, the system can be improved/optimized based on knowledge of system errors.

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