Implementation of Barcode Localization Technique using Morphological Operations

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ABSTRACT
Barcode Localization is an extremely important task in Barcode Reading system which depends highly on imaging conditions and methods used for barcode localization. In this paper, we have presented a method for barcode localization which is based on basic morphological operations. The method introduced is implemented in MATLAB 2012 and is then examined for different types of test images such as images with skewed, blurry or multiple barcodes in an image. The method is then compared with some existing methods of literature on the basis of these test images. It has been found that the performance of the algorithm depends upon the proper choice of the switching element.

Keywords
Barcode Localization, Morphology, Bottom- Hat Filter, Directional Image Opening.

1. INTRODUCTION
Barcodes are 1- dimensional group of parallel lines that carry alphanumeric information which can be read using computers, smart phones etc [7]. The main principle behind barcodes is to encode information in bars and spaces of varying widths along with redundant information for error correction. These are a very convenient and an efficient method of data representation and can be of very big help in today's world where amount of information is increasing exponentially. In order to fully utilize the power of barcodes, we need the process of Barcode Localization.

Barcode Localization means locating or finding barcodes in simple or complex images. It is mainly based on two main properties of barcodes. First property of barcode is that it contains black bars against a white background. Second property of barcodes states that it has a strong directional continuity. It means that barcodes have very strong continuity at one particular orientation and very low in all other orientations [4].

Many methods for Barcode Localization exist such as Tuinstra's method based on basic morphology [2] and Juett and Qi's method based on Bottom- Hat filtering [4]. In this paper, we have implemented a Barcode Localization method. It is based on both Bottom- Hat filtering and basic morphology. Our main aim was to devise a method for barcode localization which works well for most of the imaging conditions and different types of test images.

This paper is organized as follows: In Section- 2, we will discuss some Related Work to our research work which has been done previously. In Section- 3, we will discuss our improved method using various steps of implementation. Section- 4 covers the Results and Discussion part of the implementation using qualitative and quantitative analysis of the resultant images. Finally, Section- 5 covers the conclusion part.

2. RELATED WORK
Many methods for Barcode Localization exist; some of which come under Spatial Domain Methods while others come under Frequency Domain Methods. In the following paragraphs we will discuss both these categories of Barcode Localization.

Spatial Domain Methods are those which search for group of dark lines on white background and which also have very strong directional continuity at a particular angle so as to locate barcodes [4][8]. For example, Tuinstra's method uses basic morphological operations to localize barcodes. It basically relies on the fact that due to high intensity difference between bars and the background, gradient calculation using sobel kernel highlights the bars [2].

Juett and Qi's method is based on Bottom- Hat filtering instead of edge detection so as to highlight bars. Although, it takes more time than the previous method but its results are more accurate [4]. Telkin and Coughlan's method is based on scanning the image in four directions (0°, 90°, 180° and 270°) so as to localize barcodes. It was designed mainly for visually impaired and blind people so as to` help them in their routine tasks [3].

Other methods also exist for barcode localization which are based on Frequency Domain Methods. For example, methods based on wavelet transformation look at images for barcode like appearance by a cascaded set of weak classifiers. Each classifier works in wavelet domain by searching for areas in the image that may contain barcodes [7].

A. K. Jain and Yao Chen's method is based on multi channel Gabor filtering technique which can locate barcodes at any orientation and can also locate them on both planar and curved surfaces. Other methods also exist which use other types of transformations such as Hough Transformation and Fourier Transform.

In this research work, our goal is to implement a barcode localization method which works well under different imaging conditions and for different test images.

3. IMPLEMENTATION OF BARCODE LOCALIZATION METHOD
In this section we will discuss the implementation of Barcode Localization. This method based on Tuinstra's method based on basic morphological operations and Juett and Qi's Barcode Localization method based on Bottom- Hat Filtering. Various steps in this method are given as under:

ALGORITHM
(i) Initial Pre- processing of Input Image
(ii) Bottom- Hat Filtering
(iii) Binarizing the resultant image
(iv) Dilation using Square Structuring element
(v) Erosion using Square Structuring element

(vi) Removing Small area objects
(vii) Obtaining true shape of the barcodes
(viii)Finding Barcode Orientation

Each of the above steps can be explained as under:

Step 1-Initial Pre- processing of Input Image

In this method, the input image is first converted to greyscale intensity image. After this contrast stretching is performed to highlight the difference between light and dark areas.

Fig. 1: Original Image from which barcodes are to be localized [7]

Fig. 2: Image after conversion to gray scale and Contrast Stretching

Step 2-Bottom- Hat Filtering

This method uses two important properties of barcodes i.e. they contain black bars against white background and that they have strong directional continuity, so as to highlight barcodes. In this initially, close of image is taken which expands the white areas in the image, by expanding areas around black bars but does not affect the areas which are already white. So, when we subtract the obtained image from the original image, the resultant image shows highlighted bars of the barcodes.

Close of image is performed by using a square structuring element whose side needs to be at least as wide as widest bar in the barcodes.

Fig. 3: Image after performing Bottom- Hat filtering to highlight bars.

Step 3-Binarizing the resultant image

After this the resultant image is converted to binary using Otsu's global thresholding method.

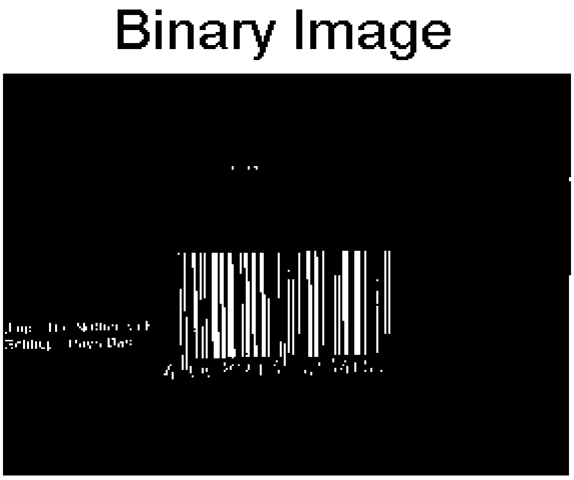


Fig. 4: Image after binarizing the resultant of Bottom- Hat filtering using Otsu's Threshold method

Step 4-Dilation using Square Structuring element

After this dilation is performed so as to merge the nearby areas so that the barcodes form a region.

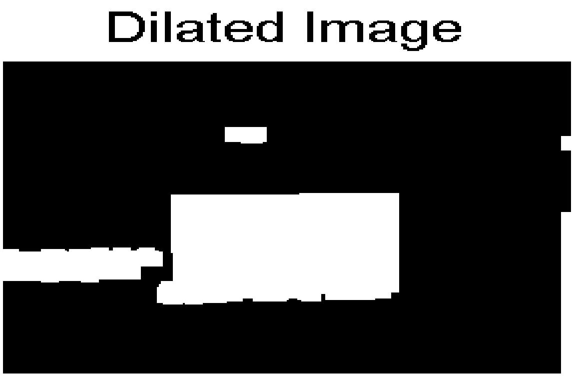


Fig. 5: Image after Dilation of the Binary Image

Step 5-Erosion using Square Structuring element

After this erosion is performed using square structuring element having side greater than the square using which dilation was performed so as to discard thin objects.

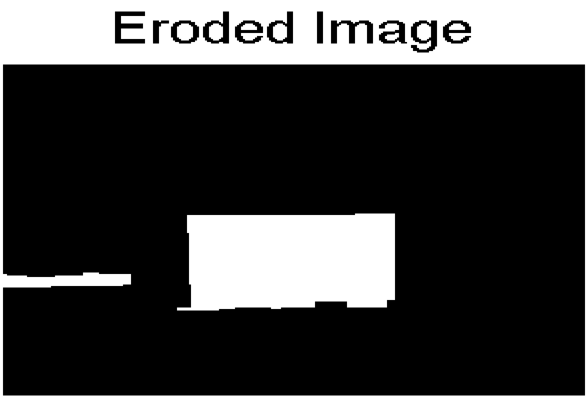


Fig. 6: Image after eroding the resultant so as to eliminate thin objects

Step 6-Removing Small area objects

After this small area objects, which is mostly noise are removed so that the resultant image contains only barcodes.

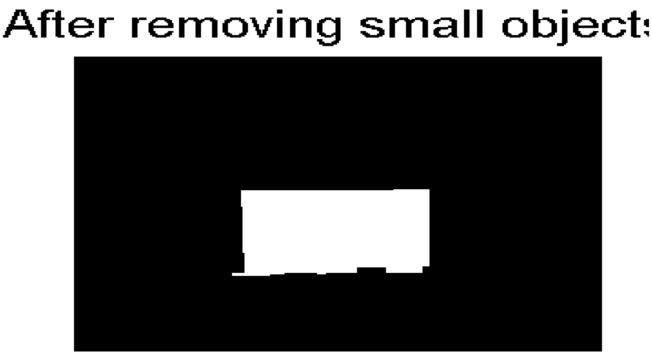


Fig. 7: Image after removing small area objects

Step 7-Obtaining true shape of the barcodes

After this the resultant image is subtracted from original image to obtain true shape of the barcode.

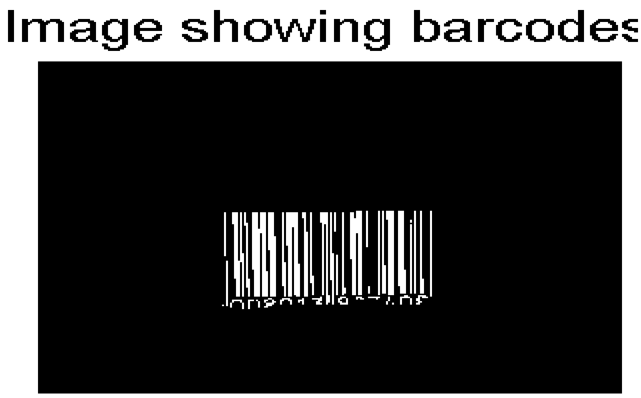


Fig.8: Image after subtracting the resultant from the original image to obtain true shape of the barcodes

Step 8-Finding Barcode Orientation

After this directional opening is performed using linear structuring element in 20 different directions so as to find the orientation of barcodes.

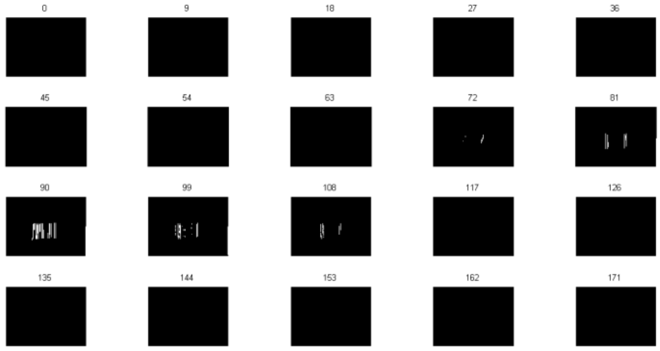


Fig. 9: Image showing the orientation of the barcodes (90°)

4. RESULTS AND DISCUSSION

4.1 Test suite, Test Environment and Implementation

Experiments were conducted on test images having dimensions as 720 x 480 or 640 x 480 and in PNG format taken from [1] and [4]. Test images included images having multiple barcodes, skewed barcodes, images with complex background and images having noise.

We implemented the algorithm given in previous section using MATLAB 2012 with the help of the Image Processing Toolbox. Evaluation was performed on a computer with Intel ® Core ™ i3 2.40 GHz CPU, 3 GB RAM and Windows 7 (64- bit) operating system.

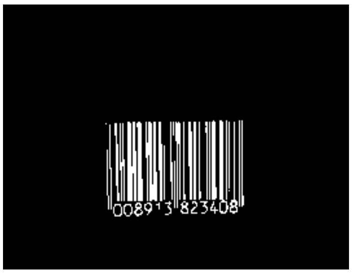
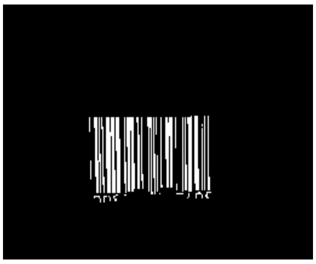
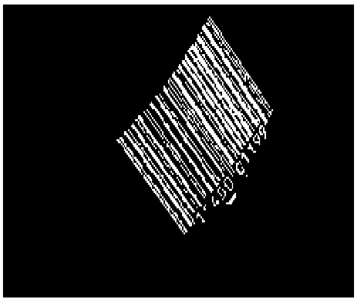
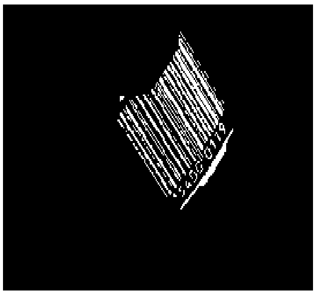
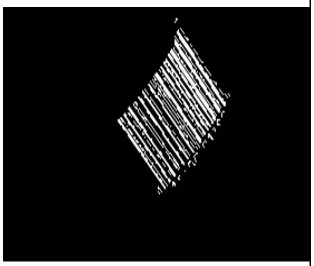
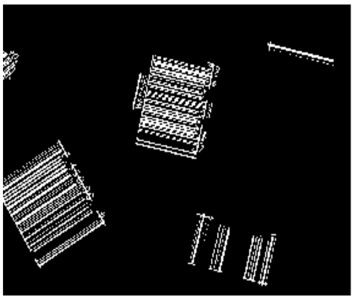
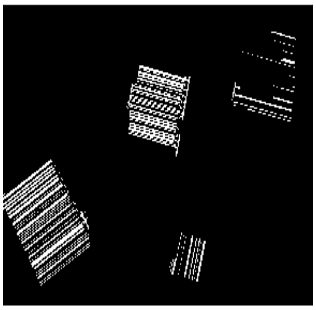
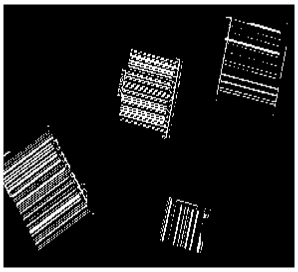
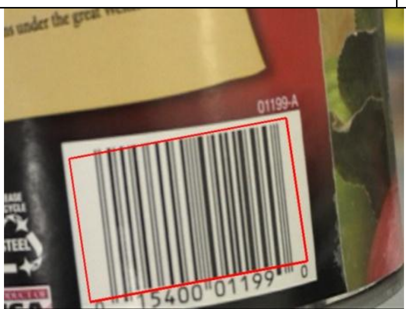
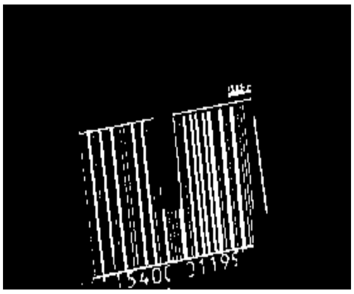
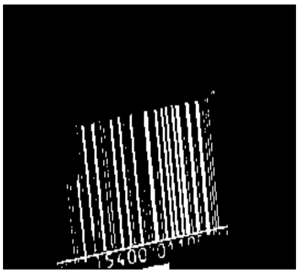
4.2 Results

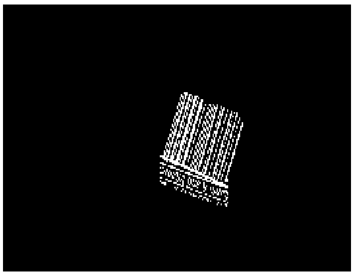
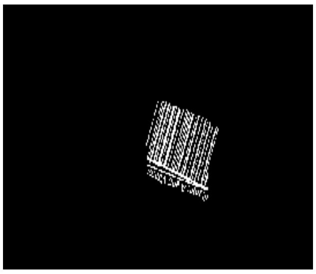
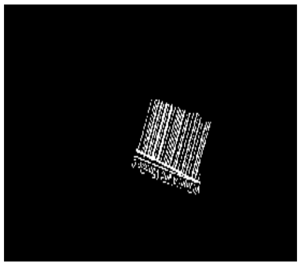
Proposed method is analyzed both qualitatively and quantitatively so as to find its advantages over existing methods. So, in this section we are comparing the proposed method with existing methods both quantitatively and qualitatively.

Qualitative Analysis:

In this section we will evaluate the method presented in above section for different types of images such as skewed, blurred, and complex and when there are multiple barcodes in an image as shown in the table below:

Table I: Table showing Qualitative analysis of different test images using existing methods and method implemented

Original Image	Results*		
	Tuinstra's Method	Juett and Qi's Method	Implemented Method
 **Normal Barcodes [7]**			
 **Skewed Barcodes**			
 **Multiple Barcodes [4]**			
 **Blurred Barcodes [4]**			

 Complex Image [4]			

***Images obtained through implementation in MATLAB**

Quantitative Analysis

Method is analyzed quantitatively on the basis of following parameters:

(i) Orientation:

The Barcode Localization method discussed gives the orientation of the barcodes in the input image using directional opening in 20 different directions starting from 0° and incrementing successively by 9°.

(ii) Structural Similarity Index (SSIM)

Structural Similarity Index is an image quality metric that assesses the visual impact of three characteristics of an image: luminance, contrast and structure. In other words, the Structural Similarity (SSIM) index is a method for measuring the similarity between two images. The SSIM is used as a quality measure in which one image is compared to another, assuming that the other image is of very good quality [10].

$$\mathrm{SSIM}(x, y)=[l(x,y)]^{\alpha} \,.\, [c(x, y)]^{\beta} \,.\, [s(x, y)]^{\gamma}.$$

Where,

$$l(x, y) = \frac{2\mu_x\mu_y + C_1}{\mu_x^2 + \mu_y^2 + C_1}$$

$$c(x, y) = \frac{2\sigma_x\sigma_y + C_2}{\sigma_x^2 + \sigma_y^2 + C_2}$$

$$s(x, y) = \frac{\sigma_{xy} + C_3}{\sigma_x\sigma_y + C_3}$$

where,

μ_x, μ_y = local means

σ_x,σ_y = standard deviations

σ_{xy} = cross- covariance for images x, y

If $\alpha = \beta = \gamma = 1$ and $C_3 = C_2/2$ (default selection of C_3) the index simplifies to:

$$\mathrm{SSIM}(x, y) = \frac{(2\mu_x\mu_y + C_1)\,(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)}$$

(iii) Coefficient of Correlation (COC)

The quantity *r*, called the *linear coefficient of correlation* measures the strength and the direction of a linear relationship between two images or variables. The linear correlation coefficient is also called *Pearson Product Moment Correlation Coefficient.* The mathematical formula for Coefficient of Correlation is [12]:

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{n(\sum x^2) - (\sum x)^2}\,\sqrt{n(\sum y^2) - (\sum y)^2}}$$

where *n* is the number of pairs of data. Value of r can be positive, negative or zero.

Positive Correlation: In case two variables or images have strong positive relationship then value of r is near +1. Value of r exactly +1 indicates a perfect positive fit. Positive correlation means that with increase in one variable the other variable also increases proportionally [12].

Negative Correlation: In case two variables or images have strong negative relationship then value of r is near -1. An *r* value of exactly -1 indicates a perfect negative fit. Negative correlation means that with increase in one variable the other variable will decrease proportionally [12].

Table II: Table showing parameter value for Normal Barcodes

Parameter	Results for Normal Barcodes		
	Tuinstra's Method	Juett and Qi's Method	Method Implemented
Orientation	NA	90°	90°
SSIM	0.5649	0.7324	0.7339
COC	-0.8280	-0.8654	-0.8579

Table III: Table showing parameter value for Skewed Barcodes

Parameter	Results for Skewed Barcodes		
	Tuinstra's Method	Juett and Qi's Method	Method Implemented
Orientation	NA	135°	135°
SSIM	0.6308	0.7742	0.7746
COC	-0.8195	-0.85	-0.8534

Table IV: Table showing parameter value for Multiple Barcodes in an image

Parameter	Results for Multiple Barcodes in an image		
	Tuinstra's Method	Juett and Qi's Method	Method Implemented
Orientation	NA	33.75°, 78.75°, 168.75°	36°, 72°, 171°
SSIM	0.7221	0.8352	0.8627
COC	-0.7662	-0.7855	-0.6644

Table V: Table showing parameter value for Blurred Barcodes

Parameter	Results for Blurred Barcodes		
	Tuinstra's Method	Juett and Qi's Method	Method Implemented
Orientation	NA	101.25°	99°
SSIM	0.7299	0.8312	0.8406
COC	-0.6822	-0.7067	-0.6713

Table VI: Table showing parameter value for Complex Image

Parameter	Results for Complex Image		
	Tuinstra's Method	Juett and Qi's Method	Method Implemented
Orientation	NA	67.5°	72°
SSIM	0.8230	0.8980	0.8991
COC	-0.8745	-0.8834	-0.8718

5. CONCLUSION

In this paper, we have implemented a Barcode Localization algorithm which is based on basic morphological operations. The performance of this algorithm depends upon the proper choice of switching element. It works well for different categories of test images such as images with skewed, blurry, multiple barcodes as well as complex images containing barcodes. Thus, it can be used effectively under different kind of imaging conditions such as industrial set ups as well as using portable devices like mobile phones, laptops etc.

Future work includes improving the timing results of the procedure and working on collared images as well as maximizing recall of barcodes in industrial environment and embedding Barcode Localization in camera software of portable mobile phones.

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