Pattern Recognition Letters 60–61 (2015) 32–40

Contents lists available at ScienceDirect

Pattern Recognition Letters

journal homepage: www.elsevier.com/locate/patrec

An imaging approach for the automatic thresholding of photo defects ☆

Neelam Bhardwaj [a,*], Suneeta Agarwal [b], Vikash Bhardwaj [c]

[a] Research Scholar, Computer Science, MNNIT, Allahabad, UP, India
[b] Prof. Computer Science, MNNIT, Allahabad, UP, India
[c] ADRDE, Agra, UP, India

ARTICLE INFO

Article history:
Received 31 August 2014
Available online 20 April 2015

Keywords:
Thresholding
Photo defect detection
Imaging
Valley emphasis method

ABSTRACT

Automatic thresholding of photo defects means to accurately locate defect objects. The available approaches for automatic thresholding determine the optimal threshold values and segment the image into objects based on their gray level distribution. For defect object identification in images with multimodal distributions, these techniques also require knowledge of the defect object features, such as shape and size, which limits the applicability of these techniques because the defect object features may vary widely. Additionally, these methods result in extensive misclassification errors in the presence of photo objects similar to defect objects and unimodal distribution. We evaluated the limitations of the valley emphasis method and proposed a new approach that involves the imaging of a defected photo by sensing the light after it passes through photo and then applying the valley emphasis method for thresholding to identify defect objects. The obtained results are better even with the above discussed constraints of the available automatic thresholding approaches. Although the proposed technique is applicable only for physically available objects, it may contribute significantly towards the accuracy of machine vision based applications.

1. Introduction

Photo defect detection is the foremost essential requirement for the development of accurate images. Generally, photos are damaged by the occurrence of defects either by the addition of layers of substance (additive defects) or by the removal of layers of substance from their surfaces. The defect standard taxonomy is available [2]. Defects alter the intensity values of pixels at their locations and can be identified with the help of optimal intensity thresholding. Automatic thresholding of defects reduces the span of the histogram for analysis to locate defect objects. This enhances the effectiveness of vision-based industrial applications and may facilitate real-time corrective action in the manufacturing phase itself.

The basic idea of thresholding is to find an optimal gray-level by analyzing the gray-level distribution and extracting the objects of interest from an image. There are two types of automatic thresholding techniques, global thresholding and local thresholding. In global thresholding, a single threshold value is taken from the histogram of the entire image, and in local thresholding, the local gray-level distributions are explored to determine multiple threshold values. For defect detection applications, global thresholding is easier to implement, but its applicability is limited in photo images with distribution close to unimodal, whereas local thresholding methods work for both nearly unimodal and multimodal distributions, but they are complex.

Because of its scope, which includes other areas of image processing and machine vision based applications, much work on automatic thresholding has already been conducted. Recently, Sezgin and Sankur [18] conducted an exhaustive survey of non-parametric and statistical approaches for image thresholding, where they categorized the approaches according to the information used, such as the histogram shape, measurement space clustering, entropy, object attributes, spatial correlation, and local gray-level surfaces and compared their performance.

Among clustering-based methods, where the gray level samples are clustered in two parts as the background and foreground, the Otsu method [14] is the most popular method. This method selects threshold values that maximize the between class variances of the histogram. This technique works well but finds limitations in the case of unimodal or close to unimodal gray-level histograms. Many modifications have been added to the Otsu method to overcome its limitations. Ng [5] revised the Otsu method as the valley-emphasis method, in which the valley point information is considered in the objective function. In this method, the optimal threshold is decided by maximizing the between class variance and minimizing the within class variance. In this method, threshold values are located as close as

☆ This paper has been recommended for acceptance by G. Borgefors.

* Corresponding author. Tel.: +91 9411464637.
E-mail addresses: 8.bharadwaj@gmail.com (N. Bhardwaj), vikashbhardwaj01@gmail.com (V. Bhardwaj).

http://dx.doi.org/10.1016/j.patrec.2015.03.019
0167-8655/

possible to the valley points in the histogram. The modified valley emphasis method [7] covers the limitation for the case where the variance of the object is different from that of the background. They considered not only the valley-point information but also the neighborhood gray information around the valley-point and selected a threshold value that has small probabilities in its neighborhood area and also maximizes the between class variance in the gray-level histogram. Ng et al. [6] further improved the valley-emphasis method by introducing a Gaussian weighting scheme that efficiently uses the neighborhood information for inclusion in the objective function to enhance the effect of the weight factor. Hou et al. [4] proposed minimum class variance thresholding (MCVT) and compared it with the Otsu method. They found that in the Otsu method, the resulting threshold is biased towards the component with a larger class variance or larger class probability. Xu et al. [20] also described that when the within class variances of two classes are different, the Otsu threshold is biased toward the class with a larger variance. As a result, partial pixels belonging to this class will be misclassified into the other class with a smaller variance. To address this problem, they proposed an improved Otsu algorithm that constrains the search range of the gray levels. The minimum error thresholding (MET) method also assumes that the image can be characterized by a mixture distribution of foreground and background pixels [9].

The entropy-based techniques exploit the entropy of the distribution of the gray levels and interpret the maximization of the entropy of the thresholded image as indicative of maximum information transfer. The maximum cross entropy method [1,8] considers the foreground and background of an image as two different information sources, so that when the sum of these two class entropies reaches its maximum, the image is said to be optimally thresholded. The Tsallis entropy-based method [15], Renyi's entropy-based method [17], and supervised Lloyd algorithm [12] are also typical examples of this class.

In the spatial gray level distribution domain, Wanga et al. [19] attempted to explore a novel global image thresholding method based on the Parzen window estimate of an unknown gray value probability density function rather than the gray level histograms of an image. The Parzen window effectively integrates image histogram information with explicit spatial information about pixels of different gray levels. The MHUE thresholding method [16] utilizes the spatial information of an image. In this method, the spatial information is implicitly represented by region homogeneity. Maddalenaa et al. [11] used a fusion-based detection approach for scratches in corrupted image sequences. They fused algorithms utilizing Radon projection and then detected local maxima using Top Hat transformation and developed a scratch mask by assigning value 1 to all the pixels of columns that contain more than 70% pixels with value 1. Kokaram [10] presented his work on the restoration of defected motion pictures, where he also discussed the spike detection index (SDI), rank order detector (ROD), and image histogram based approaches and morphological approaches for defect detection.

Chang et al. [3] worked in a different way to threshold defects due to ink spray and scratches by thick colored pens. They used the low intensity variance property of ink spreading at defect locations and designed a thresholding filter to determine low varying and smooth portions of the histogram. Then, they tracked the decreasing rate of the area of thresholded objects. If the decreasing rate is high, then an object is not likely to be a defect object, and if the reduction in an object's size is less than half of the intensity value reduction of one, it is claimed as a defect object.

All the above discussed methods of automatic thresholding only produce the optimal segmentation of a defected input image into its constituent objects but cannot claim that a particular object is a defect object. Still, in the case of bimodal distributions, the defect objects can be filtered based on size. However, for defect detection in the case of a multimodal distribution, the entire image is scanned for comparison with available defect object properties for the best match, which makes these methods more complex and time consuming. The requirement of defect object features related to their shape and size limit the applicability of these techniques, as defect features are random in nature. These methods also generate high misclassification error in the case of similarity of defect objects to their background and undamaged image objects.

Automatic thresholding has been widely used in the industry for automated visual inspection of defects [13]. If a technique with less time complexity and independent to defect properties is available, it will enhance the effectiveness of vision-based applications and make them able to take real time corrective action at the manufacturing phase to reduce waste during inspection.

We have proposed a new technique of photo defect detection that images defected photos by sensing the light that passes through them instead of by sensing the reflection from their surfaces to applying the valley emphasis method to threshold defect objects. Imaging of a defected photo by the proposed technique enhances the contrast of defect objects with the image objects. In fact, a unimodal distribution becomes bimodal or multimodal, which makes them appropriate inputs to undergo automatic thresholding for accurate detection. We have experimented with approximately 20 input photos defected with various types of additive defects. We have also evaluated the limitations of the valley emphasis method and compared the result with the proposed method by taking two cases of suitably defected input photos. The results obtained are even better with above discussed constraints of currently available approaches. Due to the enhanced contrast of defect objects with image objects, this approach is able to distinguish the defect object from similar image objects. Although the proposed technique is only applicable to physically available photos, it may also contribute significantly towards the accuracy of machine vision based applications.

In this paper we have used the term "day image" for an image acquired by scanning the defected photo image by a conventional method i.e., by sensing the light reflection, "night image" for an image acquired by imaging the defected photo with the proposed method i.e., by sensing the light passed through the defected image, and "additive defect" for a defect caused by the addition of defect material.

In this paper, after an introduction about the problem and related work, Section 2 introduces the proposed imaging technique, Section 3 provides details about obtaining the threshold value, Section 4 describes the details of the experiments and the contribution made, and the report is finally concluded in Section 5.

2. Proposed approach

Generally, day images are used for thresholding in defect detection. However, in the proposed approach, the night images are explored primarily and used as inputs for the valley emphasis method for deciding the optimal threshold value. Due to the presence of additive defects, the image thickness at defect locations increases compared to the remaining undamaged regions. This keen observation led us to develop an entirely different approach than that found in the literature, where we have developed a new imaging setup for sensing the light passed through the defected photos instead of the usual way of scanning by sensing the reflected light from their surface. The proposed approach involves night image and day image acquisition followed by analysis and processing. The details about the proposed approach are given in the following subsections.

2.1. Proposed imaging and experimental setup

As the proposed imaging approach is based on sensing the light after passing through the input photos, light is projected from one side and sensed after passing through the subject photos by an image acquisition device placed on the opposite side, as shown in Fig. 1.