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Comparative Study of Counting Algorithms and Its Performance Analysis

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Abstract: This paper presents comparative analysis of counting algorithms based on image processing in LabVIEW platform. Four different algorithms are tested with cigarette packet images. A total of 100 images are chosen for comparison. Different qualities of images are considered like good image, low light image, out of focus image, and extra bright image. An 80% matching with the template is considered as success. A comparison table is formed and Otsu method is found to be the best one with mean accuracy of counting as 97.5%. The mean accuracy is lowered due to 10% of raw images are out of focus. This paper contributes on the choice of counting algorithms.

Keywords: Cigarette; Counting; CLAHE; Image processing; LabVIEW; Template.

1. INTRODUCTION

In this era of computing, all problems can be solved efficiently if the technique is best chosen. The problem of detecting cigarettes in digital images and counting them automatically can be solved by a number of techniques. So to ensure the best outcome from this automatic fault detection, diagnosis and control system, use of the best suitable technique needs to be confirmed.

Various techniques for automation of product inspection in varied application domains are proposed by many researchers in recent past. Speaking about vision based applications in particular, Malamus *et al.* [1] surveyed the modern applications, state of art tools and techniques related to vision based industrial inspection systems. Kumar [2] in his survey paper presented the inspection techniques for fabric defect detection. Application related to Automatic inspection of thermal fuses for detection of commonly seen defects such as black-dot, small-head, bur, and flake during production is proposed by Te-Hsiu Sun *et al.* [3].These applications of machine vision rely solely on object detection. The problem of detecting objects and counting them in digital images can be solved using many techniques. Barbedo in his paper [4] surveyed the domain of automatic object detection and counting in digital images. Mehmet Sezgin *et al.* [5] performed a quantitative assessment after a rigorous study of image thresholding techniques.

Some researchers have reported works on Cigarette packet inspection too. A number of techniques are available in the literature that can be adopted for fault detection in cigarettes packets. The domain of automated inspection for industrial products is found to be populated mostly by vision based applications. Many researchers have reported on Cigarette packet inspection in particular, such as HU Fang-xia *et al.* [6] proposed vision based inspection system for flaw detection in external packaging of cigarette packets using fast Hough transformation based on support vector machines. Yue Cui *et al.* [7] proposed a vision based inspection scheme to detect incorrect number of cigarettes; improper placing and paper handle defects for cigarettes on in an open tin container using K means clustering. Zhou Ping *et al.* [8] designed a capacitance based technique for detection of improper number of cigarette packets in box utilizing back

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propagation neural networks. A. Sarkar *et al.* [9] demonstrated a procedure to detect the defects regarding cigarette packet label using image processing in LabVIEW platform. M. Park *et al.* [10]-[11] reported identification of individual cigarette and paper spoon in the tin packing using morphological operations of image processing. Automatic off line counting of cigarettes in cigarette packets using image processing in LabVIEW is discussed [12]. He Wenping *et al.* [13] proposed a method for detection of faults in external packaging of cigarettes utilizing machine vision and implemented that it in FPGA. Abahan *et al.* [14] proposed a technique for an automated process for fault diagnosis in cigarette packets.

Apart from all these machine vision based applications, Zhou Ping *et al.* designed a capacitance measurement based technique for detection of improper number of cigarette packets in cartons utilizing back propagation neural networks [8]. An automated egg crack detection system using LabVIEW is reported [15].

From survey of reported work, it is clear that although automated inspection is a research trend but relatively less work has been reported in the area of automated inspection on cigarette packet industry. In this paper an image processing based algorithms on LabVIEW [31]-[35] and Matlab is designed to estimate the cigarettes per packet. Existing algorithms are also used to estimate the cigarettes with an exhaustive comparison.

The paper is organised as follows: After Introduction in Section 1, Section 2 discusses the associated problem. Section 3 deals with different object detection algorithms. Results and Discussion are given in Section 4. Finally, Section 5 concludes the paper.

2. PROBLEM DESCRIPTION

Main objective of this paper is to count the number of cigarettes per packet using different existing algorithms. Comparative analyses also take place in account. The cigarette images are captured using NI smart camera 1744 [30] considering all probable disturbances. The following section explains the proposed solution.

3. OBJECT DETECTION ALGORITHMS

The four different object detection techniques are identified from literature for counting the numbers of cigarettes are: Template matching based, Circular Hough transform based, CLAHE based and Otsu's thresholding technique [27]. All four of these are having the potential to solve the said objective. These four techniques are then translated into algorithms and tested with different quality of cigarette images, i. e. good image, low light image, out of focus image, and extra bright image. A comparison table is formed and this paper enlightens the best suitable technique for counting of cigarette images.

3.1 Template Matching Based Object Detection

Template matching is a scheme is used to find the small part of an image after calculating the matching score a predefined template image. The object of interest is embed in the template either in the form of a feature or an image. The algorithm then searches the input image extensively for finding a match. For counting purposes, the number of matches of the template gives the count of interest in the input image. Feature and template based approach are used to achieve the template matching.

The use of pattern matching technique for counting of bounded bar steel in a stack is reported by Wang Jingzhong *et al.* [17]. Phawis Thammasorn *et al.* [18] used template matching technique for counting of varieties of stacked objects. Tian Juan *et al.* [19] discussed application of template matching to the fields of face recognition, fingerprint recognition, character recognition and license plate recognition. An application

of template matching in electron microscopy images for particle detection is reported by Z. Huang *et al.* [20].

Template based approach is considered in this work. A template image consists a single cigarette bud is used to search the incoming images for presence of cigarettes. An 80% similarity score with the template leads the number of cigarettes in the digital image.

3.2 Circular Hough Transform Based Object Detection

It is an object detection technique which finds circles in a specified radius range in an image. It searches an image extensively for arrangements of points which satisfy the parametric equation of a circle,

$$(x-a)^2+(y-b)^2=r^2 \tag{1}$$

It is a specialisation of the generalised Hough Transform which detects straight lines. The circle candidates are produced by "voting" in the Hough parameter space and then the local maxima is selected in a so-called accumulator matrix. This technique is computation intensive but gives directly the location of centers of the circles in the image.

An application of Hough transform for circular object detection in medical images is found in the works of B. Solaiman *et al.* [21]. Hough transform is very popular in detection of circular objects like iris of eye as reported by Qi-Chuan Tjan *et al.* [22], in counting of RBC in blood cell images [23] by M. Maitra *et al.* and many more.

3.3 CLAHE Based Enhancement and Object Detection

Contrast limited adaptive histogram equalization (CLAHE) [24] is essentially a powerful image enhancement technique which can take care of lighting variations in the image and thus helping in better segmentation. CLAHE processing of images containing several disturbances demonstrate improved object detection.

To improve the contrast quality of an image, adaptive histogram equalization (AHE) is used. It computes several histograms considering each distinct section of the image and reallocates the lightness values of the image which is not possible in ordinary histogram equalization. Therefore it is appropriate for refining the local contrast and used for cigarette detection. But it suffers to over-amplify noise in relatively identical regions of an image. Thus, contrast limited adaptive histogram equalization is used to prevent this said problem.

The CLAHE technique of image enhancement for successful counting of clustered soyabean seeds is demonstrated by Barbedo [24]. An application of CLAHE and thresholding for underwater image segmentation is found by R. Kumar *et al.* [25]. Realization of CLAHE for real time image enhancement and understanding is reported by Ali M. Reza [26].

3.4 Otsu's Thresholding Based Object Detection

Otsu's thresholding [27] is a revolutionary technique in the field of image segmentation, leading to detection and counting. The algorithm adopts that the image contains two classes of pixels following bi-modal histogram. The optimum threshold value is determined separating the two classes for minimal intra class variance. It is used to convert the input image into required binary image. An erosion operation is used to the binary image to eliminate clustering between adjacent cigarettes.

N obuyuki Otsu [27] in his revolutionary paper presented the popular method for automatic threshold selection for picture segmentation knows as Otsu's Method. Hui-Fuang Ng reported an application of

this Otsu's method for defect detection, incorporating minor modifications [28]. Yan Wenzhong *et al.* demonstrated a thresholding based technique for counting chromosomes [29] and Barbedo reported an algorithm for counting microorganisms in digital images [30].

4. RESULTS AND DISCUSSION

For testing and comparing the capabilities of these said techniques, algorithms are designed in LabVIEW. These four techniques for object detection and for counting are tested using a sample set of 100 cigarette images which contains 70 good images, 10 out of focus images, 10 low light images, and 10 extra bright images.

The algorithm for Template matching based technique is developed in LabVIEW using NI VBAI. Fig. 1 shows the inspection window view for a sample template matching based counting. The inspection status shows pass because 10 cigarettes are counted successfully.

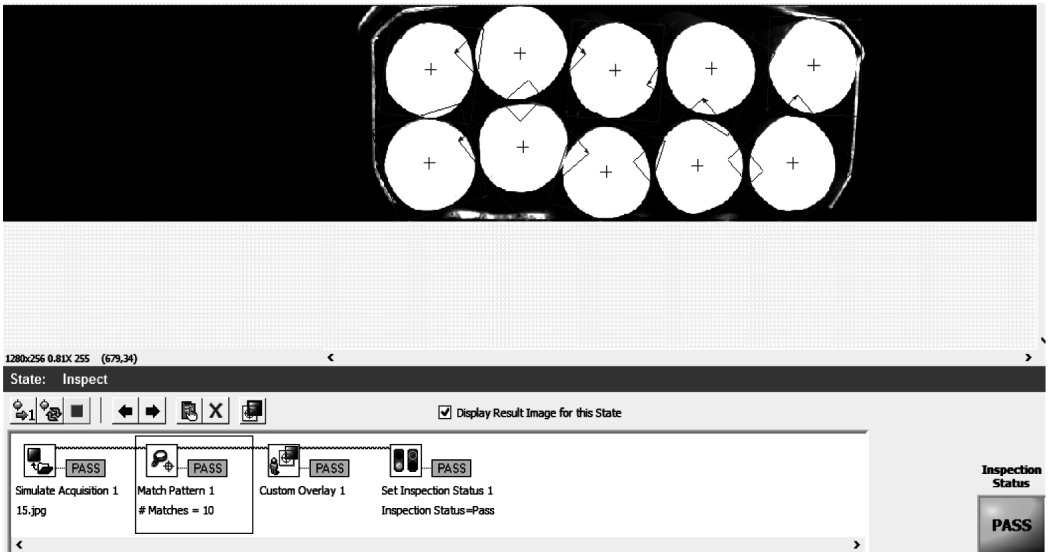

Figure 1: Template matching based detection and counting

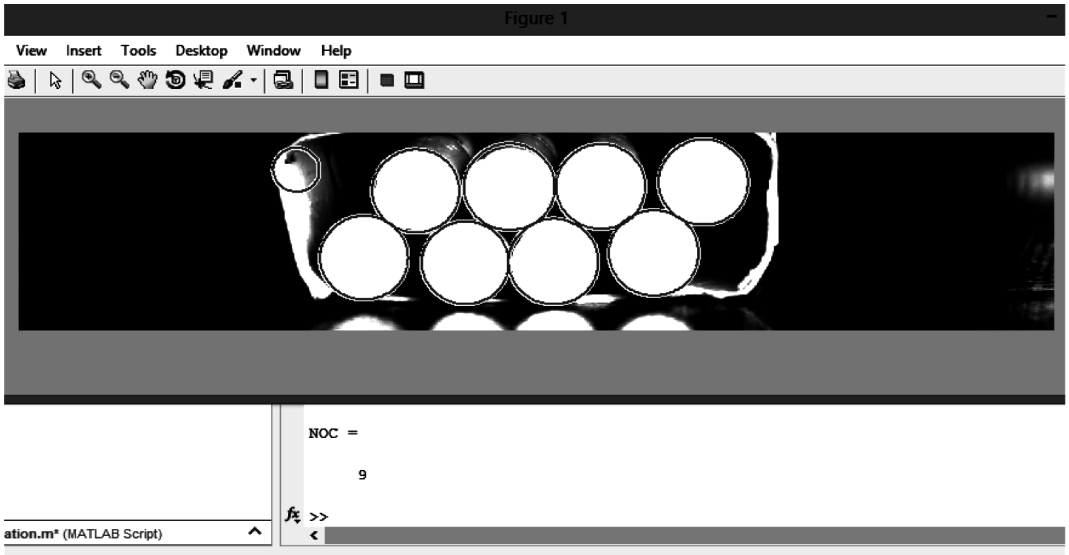

Figure 2: Circular Hough Transform algorithms for detecting and counting cigarettes

The Circular Hough transform based object detection and counting technique is tested in Matlab because it offers a function '***imfindcircles***' in the image processing toolbox. This function uses Circular Hough transform to find the circles in a given image and returns their respective centres. Thus the number of circles can be found out easily. An interesting feature of this function is the presence of an argument with which the amount of circularity can be controlled and thus the algorithm can be made to detect almost circular shapes like cigarettes. Fig. 2 shows a detection being done using this algorithm. It is also noted that 9 cigarettes are reported (NOC=9) in place of 8.

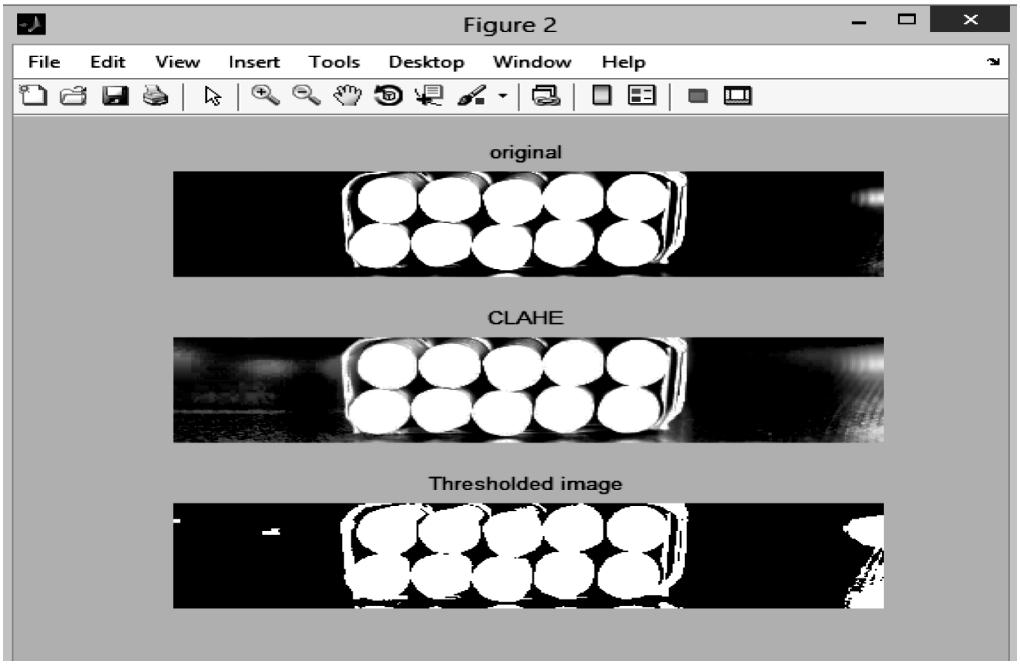

Figure 3: The CLAHE processed image and the thresholded image in Matlab

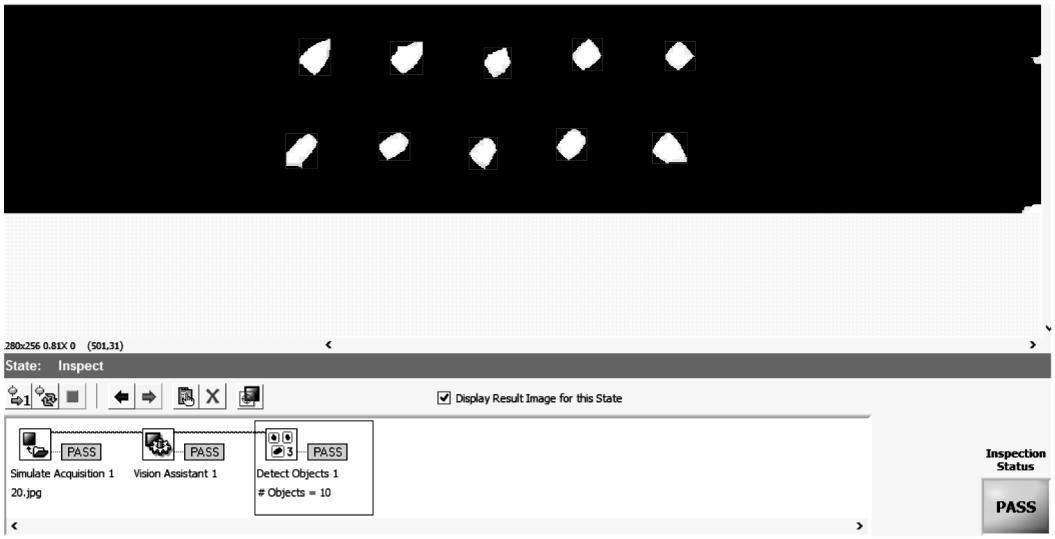

Figure 4: Detection of cigarettes using CLAHE processed images from Matlab

The CLAHE enhancement technique is applied to the images in Matlab and the enhanced images are used in NI VBAI for detection and analysis. Matlab is used in this step because the image processing toolbox presents a powerful function called '***adapthisteq***' which performs CLAHE enhancement in the

image. The '***cliplimit***' and the '***numtiles***' arguments of the function are set to 0.05 and [3, 3] by trial method searching for acceptable detection. Then this enhanced image is thresholded in Matlab before detection in NI VBAI. Fig. 3 shows the CLAHE processed image and its corresponding thresholded image in Matlab. Fig. 4 shows the successful counting of cigarettes in the same image in NI VBAI.

The Otsu's thresholding based object detection technique is tested in the NI VBAI environment. The '***NI Vision assistant***' VI is used to implement the technique in LabVIEW. The Otsu's threshold level finding algorithm is already incorporated in this powerful VI and is named as '***Inter Variance***' technique. Once the threshold level is available, the input gray image is converted to binary image and is passed on to the '***Detect object***' VI which takes care of the further object detection steps.

Figure 5: Binary image showing foreground and background using Otsu's algorithm

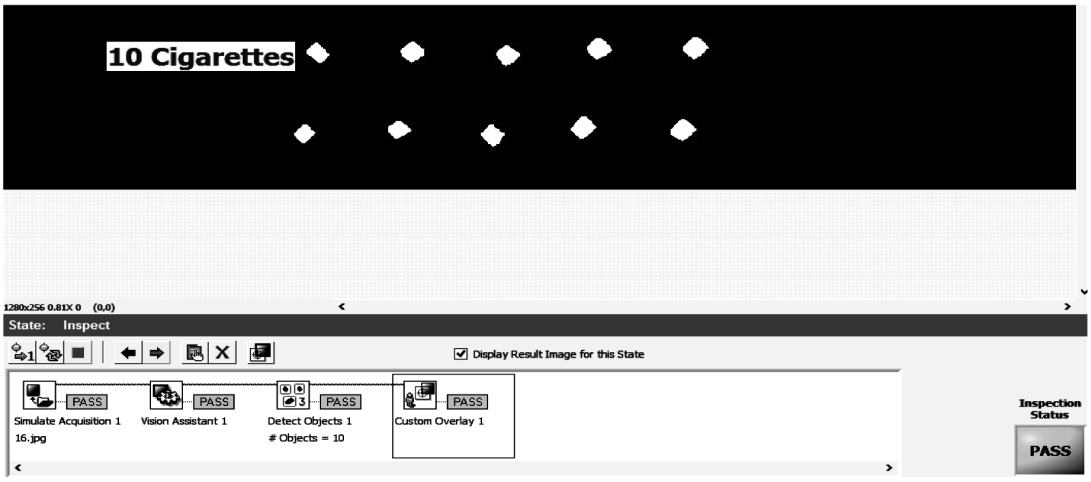

Figure 6: Successful detection of ten cigarettes using Otsu's technique

The results of the test considering 100 cigarette images which contain 70 good images, 10 out of focus images, 10 low light images, and 10 extra bright images are represented in Table 1. Mean accuracy indicates the percentage of correct detection for each said technique.

Table 1

Comparison table of different detection techniques showing mean accuracy

Techniques	*Good Image (70 Nos.)*	*Low Light (10Nos.)*	*Out of focus (10 Nos.)*	*Extra bright (10 Nos.)*	*Mean Accuracy (100 Nos.)*
Template Matching	97.1 %	80 %	70 %	90 %	84.275 %
Hough Transform	95.7 %	100 %	10 %	100 %	76.875 %
CLAHE	92.8 %	90 %	40 %	80 %	75.7 %
Proposed Method	100 %	100 %	90 %	100 %	97.5 %

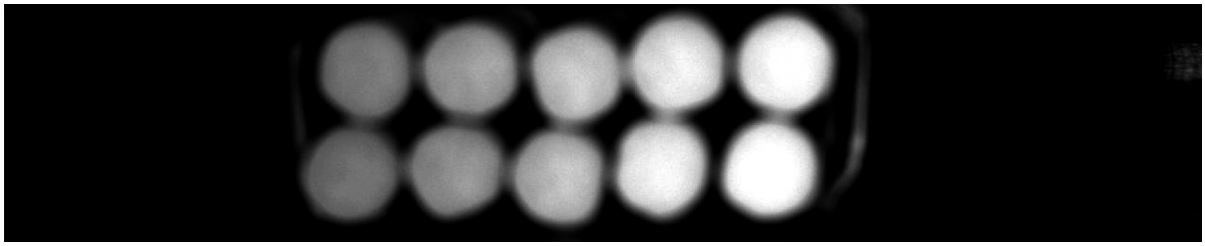

Figure 7: The sample defective image having variable lighting and out of focus

It is observed from the table that the Otsu's based counting technique provides the highest mean accuracy, i.e. 97.5%. This technique experienced a single failure only with an out of focus image with variable lighting shown in Fig. 7. CLAHE based counting technique provides lowest mean accuracy, i.e. 75.7% is also shown in Table 1.

5. CONCLUSION

In this paper, four counting algorithms are designed in LabVIEW and Matlab to detect and count the number of cigarettes. Their performance based on different quality of images is also shown in Table 1. Otsu's based counting and detection method is found to be best one with mean accuracy 97.5%. The mean accuracy can be increased by proper arrangement of camera aperture and scheme of light. Hence, this paper achieved its objective and contributes on the best choice of counting algorithms.

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