

*Article*

## **A Multi-Level Colour Thresholding Based Segmentation Approach for Improved Identification of the Defective Region in Leather Surfaces**

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**Abstract.** Vision systems are widely adopted for defect detection in leather surface to overcome difficulties of labour intensive, time consuming manual inspection process. Suitable image processing techniques need to be developed for accurate detection of leather defects. Existing gray scale based image processing techniques require conversion of colour images using a single threshold value and it also lacks sensitivity for detecting the leather defects due to the random and texture surface of the leather. This work presents a colour image processing approach for improved identification of leather defects using a multi-level thresholding function. In this work, the leather images are processed in 'Lab' colour domain for improving the human perception of discriminating the leather defects. In the present work, the specific range of values for the colour attributes is identified using the colour histogram to detect the different leather defects. MATLAB software routine is developed for identifying defects in specific ranges of colour attributes and the results are presented. From the results, it is found that proposed method provides a simpler approach for identifying the defective regions based on the colour attributes of the surface with improved human perception. The proposed methodology can be implemented in graphical processing units for efficiently detecting several types of defects using specific thresholds for the automated real-time inspection of leather defects.

**Keywords:** Colour thresholding, colour image, histogram technique, leather defects.

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## 1. Introduction

Leather is a natural material and it is created through a process of tanning of hides and skins of cows, sheep and goats. Typical leather contains natural and artificial defects such as heavy grain, medium grain, light grain, folding marks, chick wire, veining, cuts, wrinkles etc. Defect detection in leather surface plays a vital role in leather industries for ensuring the quality of finished leather products such as gloves, shoes, hand bags etc. Manual inspection is widely adopted and it has limitations in terms of accuracy, coherence and efficiency for detecting defects due to the random texture surface of the leather. Also the manual inspection process is time consuming and it is often subject to human error. Vision based automated inspection systems are recently employed for defect detection in leather surface. However, detection of defects using a vision system requires suitable image processing algorithms as the defect detection is affected by the random nature of the leather texture surface and types of defects.

Various image processing tools have been proposed by the researchers for the detection of defects in leather. In early years, edge detection based image processing algorithm is used for leather defects identification using a CCD camera. Then a morphological segmentation [1, 2] process is applied on the collected images to extract the texture orientation features of the leather. Kohli et al. [3] proposed a histogram analysis approach for extracting the low-level image features. Image thresholding and segmentation techniques have been developed for leather defect detection [4, 5, 6]. Most of algorithms used statistical analysis of the grey levels of image for detecting the leather defect by extracting a set of textural features using co-occurrence matrix approaches [7], the Fourier transform, the Gabor transform [8] and the wavelet transform [9]. Traditional texture analysis techniques such as co-occurrence matrix methods [8, 9] in the spatial domain, and Fourier-based textural features in the spectral domain [10, 11] are too computationally expensive for developing an efficient inspection system. These methods are focused on gray scale processing of images for defect detection in leather surface which has random and texture in nature.

More advanced image processing techniques using neural networks (NNs), fuzzy systems (FSs) and support vector machines (SVM) are presented to overcome the limitations of classical image processing approaches. An image processing technique based on fuzzy logic is employed to analyse the features set of the leather images to perform the surface defects recognition [11]. Support vector machine (SVM) is a powerful mathematical computational model for classification of defects [12]. A neural network approach is adopted as an effort to improve the classification accuracy of the decision tree approach and neural networks have provided the most efficient solutions for a wide spectrum of problems in many fields particularly pattern classification problems. Recently, Winiarti et al. [13] proposed feature descriptors

and deep learning neural network architecture for defect classification using a pre-trained Alexnet. A new approach is introduced involving Pixel Intensity Analyser (PIA) together with Extreme Learning Machines (ELM) classifier for defect detection and classification [14]. An automatic leather defect detection method for shape-defects and colour-defects is presented for the printed matters using multi feature extraction of image [15]. Luo et al. [16] used decision trees and neural nets as a learning classifier for defect detection and classification in leather surfaces. The method mainly include Fourier transform and wavelet transform [17]. The identification of real fabric defects is done by choosing a small subset of pixels from the image as input using neural network [18-19]. A multi resolution random field method is applied for segmentation in images [20]. These approaches require complex image processing work flows and more number of data for improving the accuracy of defect detection in leather surface.

It is found that recent works are focusing on developing improved image processing algorithms for defect detection in leather surfaces. However, many of the existing approaches have focused on defect detection in gray scale processing of leather images with complex work flows and computations. As the conventionally followed gray scale processing approaches use single threshold value for the pixels, it is difficult to distinguish the defective regions in the leather surface. Taking the advantages and benefits of modern graphics processing unit (GPU), this work presents a colour processing approach with a multi-level thresholding based image processing function for the identification of defective regions in leather images.

## 2. Vision Acquisition System for Defect Identification in Leather

### 2.1. Image Acquisition

In a typical leather, there are many types of defects such as scars, mite nests, warts, open fissures, healed scars, holes, pin holes, folds. As a part of developing an automated vision inspection system for identifying leather defects, a machine vision system consisting of a CMOS camera (BASLER acA4600), Personal computer with MATLAB software (Version. 2019a) is established in the present work and it is shown in Fig. 1. Fibre optic illumination system is used for providing the noise free and uniform illumination on the leather surface. It also avoids the flickering effect of conventionally used white light system. The magnitude of luminance for the fibre optic illumination is measured using Lux meter and it can be controlled using a light controller knob. It is found that the magnitude of luminance varies in the range of 1145-1150 Lux at laboratory conditions.

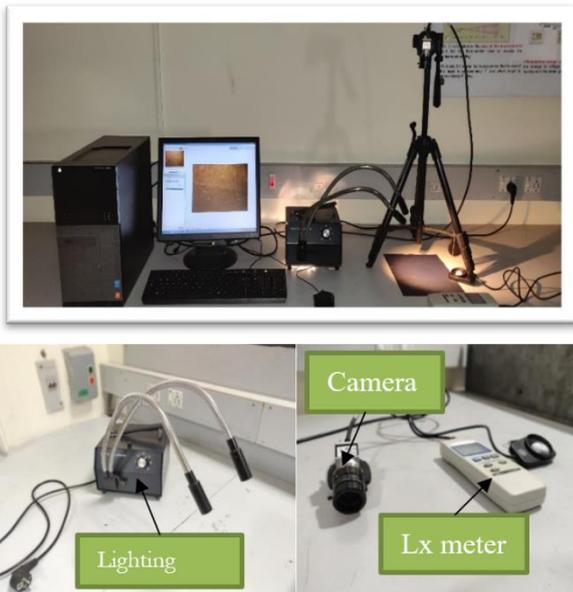


Fig. 1. Experimental setup of vision inspection system for defect identification in leather samples.

Table 1 lists the general specifications of the CMOS camera used for the inspection of leather sample. Images of leather samples of different colours with various defects are captured and stored in PC for further processing. **Fig. 2(a)** shows the colour images of three leather samples with the hand marked defects such as folding marks, chick wire, and heavy grains.

Though the folding marks are visible in the image shown in Fig. 2(b), it is difficult to identify the other defects such as chick wire, and heavy grains in the leather by human perception due the non-uniform texture of the leather surface. Hence there is a need for developing image processing algorithms for the detection of defects in the leather samples.



(a) Different leather samples with different colours and defects under natural lighting



(b) Different leather samples under fibre optic illumination



(c) Gray scale images of different leather samples.

Fig. 2. Images of defective leather samples under fiber optic illumination.

Table 1. Major specifications of camera used for leather image acquisition.

S.no	Specifications	Description
1	Sensor type	CMOS
2	Sensor size	6.5mm×4.6mm
3	Resolution (H×V)	4608 px×3288 px
4	Resolution	14 MP
5	Pixel size (H×V)	1.4 μm×1.4 μm
6	Frame rate	10 fps
7	Mono/colour	colour
8	Interface	USB 3.0

## 2.2. Gray Scale Processing of Leather Images

Due its simplicity of processing the images using the single threshold value, gray scale processing of leather images is conventionally followed in many image processing applications for defect identification. In the present work, the colour image of leather samples consisting of  $4608 \times 3288$  pixels is converted to 8 bit gray scale image using the weighted average of three luminance or intensity for primary colour components (Red, Green and Blue) for each pixel. The gray scale image of leather samples are shown in Fig. 3. In a typical 8 bit gray scale image, there can be 256 different possible magnitudes of intensities for each pixel and it can be interpreted graphically using histogram and intensity map.

### 2.2.1. Histogram analysis and Intensity map of leather images

It can be seen that histogram of the leather images are Gaussian in shape and it is continuous in nature as shown in Fig. 3. It indicates the non-uniform intensity variation of the pixels in the leather image which is due to the random nature of the texture pattern of the leather surface. The maximum intensity level of the leather images is found to be around 100.

### 2.2.2. Thresholding of gray scale leather image

In order to identify and distinguish the defective region in the gray scale images of the leather, conventionally followed binary thresholding is followed using a thresholding function as given in by Eq. (1).

$$g(x,y) = \begin{cases} 1 & \text{if } f(x,y) \leq T \\ 0 & \text{if } f(x,y) > T \end{cases} \quad (1)$$

In the above equation,  $f(x, y)$  is the input gray scale leather image and  $g(x, y)$  is output binary image  $T$  is the magnitude of threshold. Fig. 4 is the visual representation of thresholding function and it can be considered as a mapping of input gray scale image  $f(x, y)$  to the output binary image  $g(x, y)$  for the given threshold  $T$ .

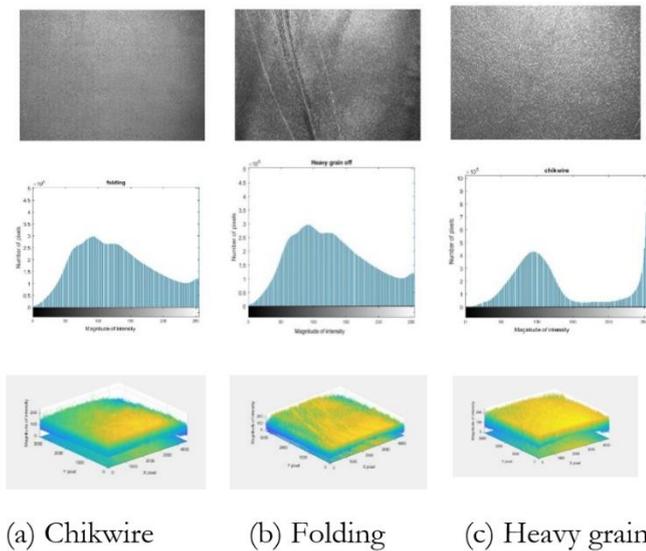


Fig. 3. Histogram and Intensity maps for analysing intensity variations in leather images.

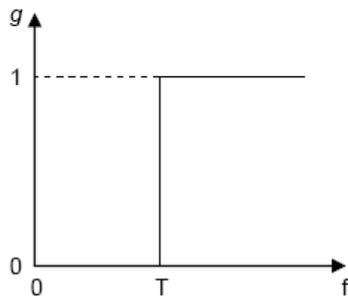


Fig. 4. Thresholding function for the gray scale image.

In the present work, different threshold values of 150, 138 and 129 is fixed for identifying the various defects in the leather images and the thresholding results are shown in Fig. 5. Apart from the detection of folding marks in the leather surface as shown in Fig. 5, it is difficult to identify the defective regions of chick wire and heavy grains using a binary thresholding. It is due to the random nature of defects and the texture pattern of the leather surface.

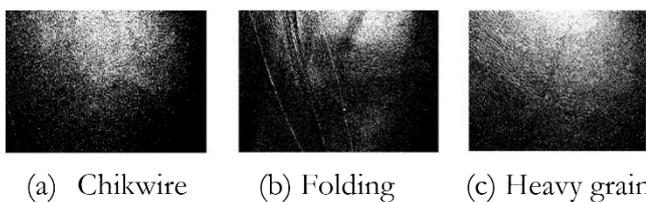


Fig. 5. Binary thresholding of gray scale leather image.

It is found that the thresholded images using the binary thresholding of different leather images lacks the sensitivity and specificity for human perception in distinguishing the leather defects as it is based on single threshold value and the averaging of the intensity of values of pixels during gray scale conversion.

### 3. Proposed Multi-Level Color Thresholding Approach for Defect Detection in Leather Images

Colors are important features for visual recognition and discrimination. In the present work, Lab colour space is used for analysing the leather images due its advantages of natural human perception. Fig. 6 shows Lab colour model which consists of a luminosity layer 'L', chromaticity-layer 'a' and chromaticity-layer 'b'. Here positive and negative values of 'a' represents magnitude of red and green respectively. Similarly, positive and negative values of 'b' represent yellow and blue respectively. The zero represents neutral gray for both the axes.

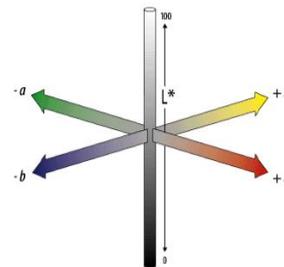


Fig. 6. Lab colour model.

As the leathers has different colors and the defective regions of leather image have the same magnitude of colour attributes, this work presents a simple colour processing approach using a multi thresholding function for the improved detection of defective regions in the leather images. Fig. 7 shows the steps followed in the proposed colour processing approach for defects detection in different colour leather samples. In the proposed approach, the colour images of the leather samples are converted into Lab colour space and colour attributes of the leather image are determined in the colour histogram. A multi-level thresholding function based on colour attribute is proposed for distinguishing the defect in the image. More details of the proposed approach are described in this section.

#### 3.1. Color Feature Extraction Using Color Histogram For Region Identification

A colour histogram is used to understand the magnitude of variations in colour attributes. A colour histogram for given leather image is represented by a vector whose components indicate the similar colors in an image as given below:

$$H = \{H[0], H[1], H[2], H[3], \dots, H[i], H[n]\} \quad (2)$$

where  $i$  is the colour bin in the colour histogram and  $H[i]$  represents the number of pixels of colour  $I$  in the image, and  $n$  is the total number of bins used in colour histogram.

Using the colour histogram of the leather image, the colour regions are identified using peaks ( $H_{max}$ ) in the

histogram which shows the predominant colour regions in the defect image. Further the statistical features such as range of magnitude of colour attributes ( $L_{\min}$ ,  $L_{\max}$ ,  $a_{\min}$ ,  $a_{\max}$ ,  $b_{\min}$ ,  $b_{\max}$ ) in luminosity 'L', chromaticity 'a' and chromaticity 'b' of the colour histogram are useful for thresholding of leather image.

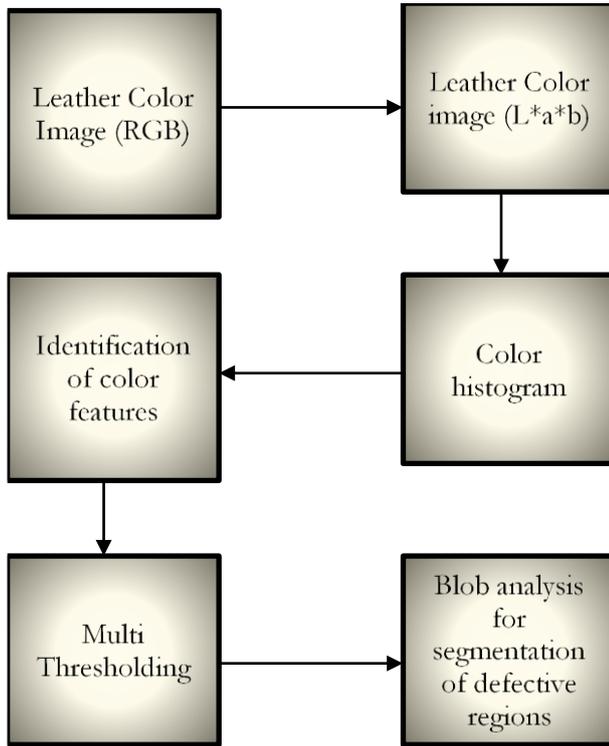


Fig.7. Proposed methodology for detection of defective regions in leather.

### 3.2. Multi Thresholding Based Color Segmentation of Thermal Image

Based on the magnitude of colour attributes such as luminosity 'L', chromaticity 'a' and chromaticity 'b' in colour space, a multi thresholding function is developed for grouping the similar pixels in the leather image as given by Eq. (3).

$$g(x, y) = \begin{cases} 0 & f(x, y) < T_1 \\ f(x, y) & T_1 \leq f(x, y) \leq T_2 \\ 0 & f(x, y) > T_2 \end{cases} \quad (3)$$

Here  $T_1$  and  $T_2$  represent the lower and upper threshold value for the colour attribute respectively. Figure 8 shows the visualization of multi thresholding function with a pair of thresholds.

Based on the identified range of magnitude of colour attributes ( $L_{\min}$ ,  $L_{\max}$ ,  $a_{\min}$ ,  $a_{\max}$ ,  $b_{\min}$ ,  $b_{\max}$ ) in luminosity 'L', chromaticity 'a' and chromaticity 'b' in the colour histogram, following multiple thresholding functions are applied to the leather image as given by Eq. (4), (5) (6) and (7) for segmenting the specific colour regions

according to the requirements of identifying the defects in the leather image.

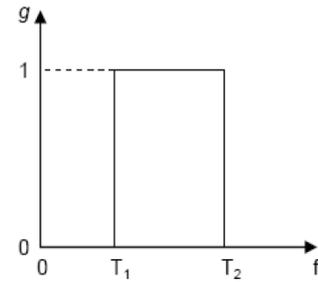


Fig. 8. Multi thresholding function.

$$g_1(x, y) = \begin{cases} 0 & f(x, y) < l_{\min} \\ f(x, y) & l_{\min} \leq f(x, y) \leq l_{\max} \\ 0 & f(x, y) > l_{\max} \end{cases} \quad (4)$$

$$g_2(x, y) = \begin{cases} 0 & f(x, y) < a_{\min} \\ f(x, y) & a_{\min} \leq f(x, y) \leq a_{\max} \\ 0 & f(x, y) > a_{\max} \end{cases} \quad (5)$$

$$g_3(x, y) = \begin{cases} 0 & f(x, y) < b_{\min} \\ f(x, y) & b_{\min} \leq f(x, y) \leq b_{\max} \\ 0 & f(x, y) > b_{\max} \end{cases} \quad (6)$$

$$G(x, y) = g_1(x, y) * g_2(x, y) * g_3(x, y) \quad (7)$$

### 3.3. Segmentation and Defective Region Identification Using Blob Analysis

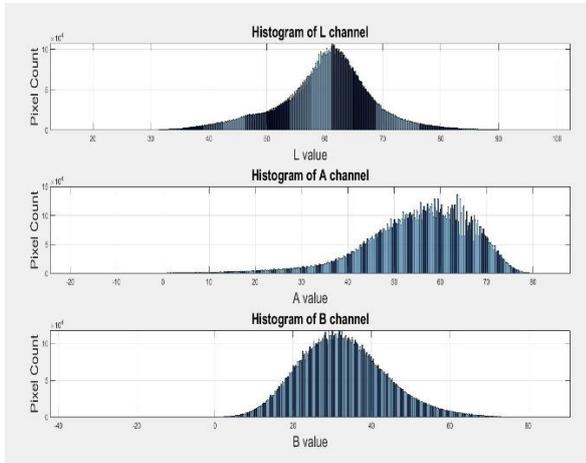
After thresholding of leather image, binary large object (BLOB) analysis is applied for segmenting defective regions which has similar properties. Connected component labeling algorithm is applied to identify the defect region and extract it from the segmented image. The extracted defective region is further processed for estimation of features such as perimeter, length, width, center of mass etc. Based on the geometric property of the BLOB, detection of defects can be done. It provides the region of interest (ROI) and enables us the decision making of leather defects.

## 4. Results and Discussion

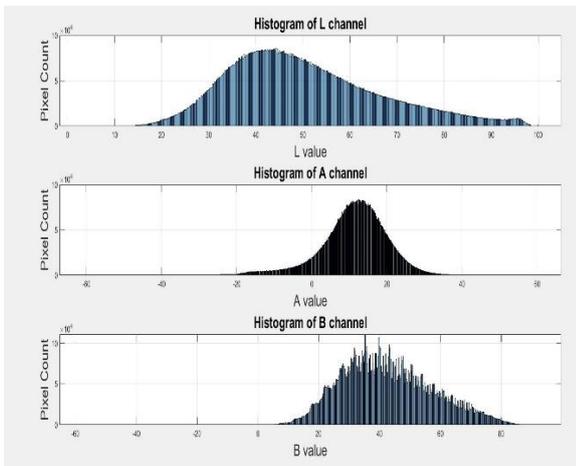
In order to prove the effectiveness of the proposed approach for the improved identification of defective regions in leather images, it is applied in the images of leather samples with different colors and defect. Specific range of values of colour attributes such as for L, a, b are fixed based on the given colour of the leather sample using colour histogram analysis. A software code is developed for the proposed multi thresholding function in MATLAB environment and applied for segmenting the defective regions in leather images and the results are presented in this section.

### 4.1. Color Feature Identification Using Histogram in Leather Image

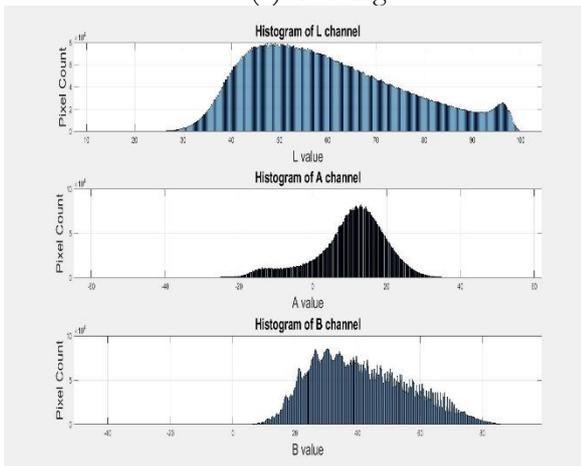
Fig. 9 shows the colour histogram plot for the leather images of different colour samples. The magnitude of colour features such L, a and b are listed in Table 2 for different leather samples of different colors. It can be noted that the maximum values for the colour attributes A, and B differs for each leather sample which indicates the difference colour of the leather samples.



(a) Chikwire



(b) Folding



(c) Heavy grain

Fig. 9. Color histogram plot of leather images with different defects.

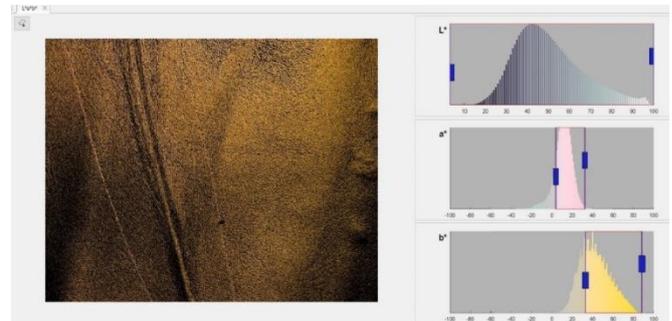
Table 2. Magnitude of color attributes for different leather samples.

Leather Samples	L		A		B	
	Max	Range	Max	Range	Max	Range
Chikwire	60	30-90	65	0-80	35	0-75
Folding	45	15-95	10	-10-38	40	10-85
Heavy grain	55	28-100	15	-10-35	30	10-85

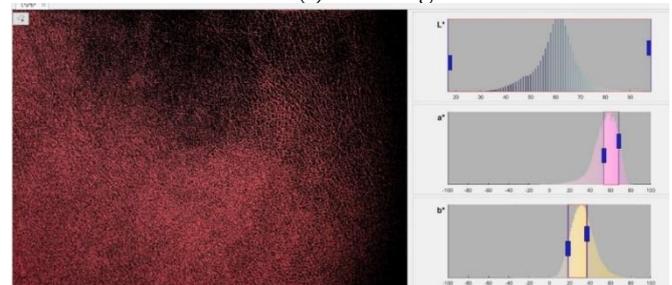
For identifying the colour values for the improved perception of defective region, the range of values are fixed for thresholding each class of defects and the multi thresholding function is applied for segmenting the defective regions in the leather images.

### 4.2. Multi Thresholding of Different Leather Defects

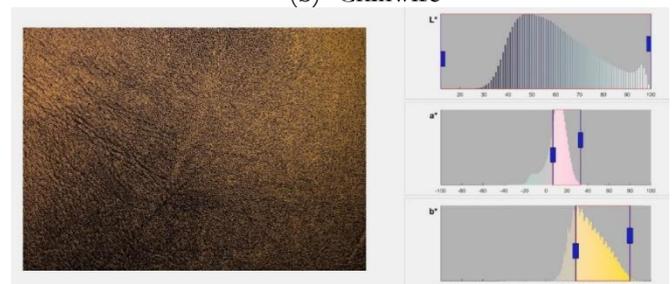
Proposed colour thresholding and segmentation approach is applied to the leather image of different colors and defects. The defective regions are extracted for the given values of colour attributes in Lab colour spaces as shown in Fig. 10.



(a) Folding



(b) Chikwire



(c) Heavy grain

Fig. 10. Segmentation of colour image and defect region identification.

Table 3 shows the range of values of 'a' and 'b' for identification of defective regions in Lab colour space with the improved human perception.

Table 3. Range of values for colour attributes.

Leather samples	Magnitude range of colour attributes		
	'L'	'a'	'b'
Chikwire	16 to 98	53 to 68	18 to 37
Folding	3 to 100	3 to 32	32 to 88
Heavy grain	11 to 100	6 to 32	28 to 79

It can be noticed that there is no significant variation in 'L' value for images of all leather samples as it indicates the luminosity of pixels in the leather. However, there are significant variations in range of value of 'a' and 'b' for leather with folding marks and chick wire as the colors of the leather surfaces are significantly different. The range of values for the leather surfaces with chick wire and heavy grain are found to be similar which is due to the similarity of colour of the leather sample and the similarity in the nature of the defect.

#### 4.3. Leather Defect Identification Using Blob Analysis

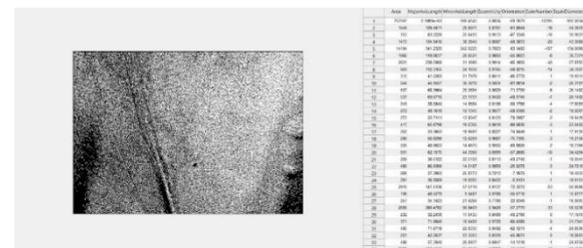
Thresholded images of the leather samples are further analysed using BLOB analysis. Connected component analysis is used to extract the features of BLOBs and segmenting the defecting regions. The segmentation results of defective regions in leather images are shown in Fig. 11.

#### 5. Conclusion

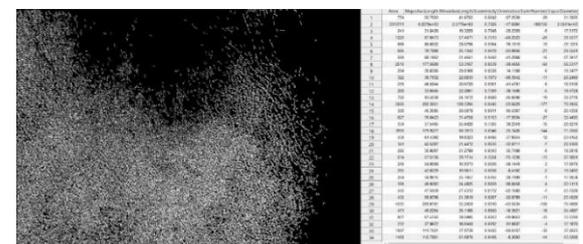
As colour is an important attribute for visual recognition of discrimination and also the leathers has different colors, this paper proposed a colour based thresholding and segmentation approach for leather defect identification. Instead of analysing the leather images in gray scale, colour images of leather samples are analysed in Lab colour domain using the range of colour attributes for improved identification of defects in the leather images. Multi-level colour thresholding function with given range of colour features is proposed based on colour attributes such as L, a and b to distinguish the defective region in the image for improved human perception. Different leather defects such as chick wire, heavy grain, folding marks are identified using the proposed multi thresholding function and the results are analyzed. The range of values for the colour attributes (L, a, b) for different defects can be standardized for improved human perception and detection leather defects. These values can be standardized by conducting field tests applications in leather industry. Proposed approach improves the subjective analysis of texture defects. Proposed method can be improved and

extended for classification of defects in leather with different colour variations.

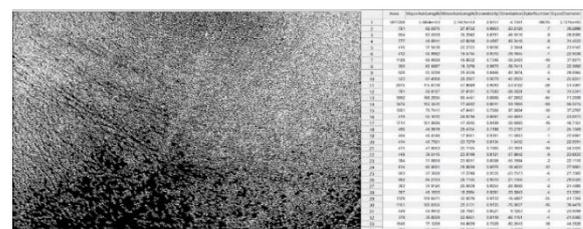
It can be seen that the folding mark in the leather image is clearly visible and it is much better for human perception as compared to the gray scale thresholded leather image as shown in Fig. 11. Nature of chick wire defect and high grain defect in the leather sample is similar and it is shown in Fig. 11. Proposed approach provides an interactive and subjective approach for discriminating the defective regions in the leather samples with improved human perception. This approach will be highly useful leather industries for the computer based inspection of leather defects.



(a) Folding



(b) Chikwire



(c) Heavy grain

Fig. 11. Defective regions in different leather samples.

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