Development of a novel method for trash segmentation of cotton fibre color measurement

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Abstract: The representation of cotton color is a key element in deciding the cotton grade. The color of cotton fibre is measured with instruments as well as visual assessment. But, these two methods always represent disagreement in the measurements. The main reason for disagreement is the trash particles on the cotton surface. The threshold segregation technique is used for the segmentation of trash and cotton fibres from the image of cotton sample. It is used in this research for the trash segmentation and precise color measurement. The reduction of disagreement between visual and instrument measurements is observed and the color of cotton is presented in more precise manner by using different correlation methods. In the presence of trash particles on the surface, it is not possible to measure the accurate color of cotton sample and the trash particles have to be removed. But, in this research image analysis method is used and the final color value will not include the trash color as it will be segmented from the image.

Key words: Cotton, threshold segmentation, visual measurement, image analysis, color attributes, comparative grading

1. Introduction

Bright white color is associated with cotton but due to prolonged exposure to sunlight the cotton color changes from white to yellow. This change in the color of cotton is not suitable for its market value. As the yellowness of cotton increases cotton fibers lose their strength and the quality of cotton decreases. The yellow color of cotton gives birth to problems like dye pick-up. The color of cotton is one of the parameters which decides the quality of cotton so, the yellow color of cotton is considered as low grade (Cheng et al., 1999). The white colored cotton is considered as a good quality cotton (Matusiak and Walawska, 2010). The sample of cotton fibre contains trash particles which vary in nature. The color trash of trash actually disturbs the cotton color measurement. Cotton quality is affected due to the presence of trash (Kang and Kim, 2002). The removal of trash from cotton is a basic phenomenon in the yarn manufacturing industry. In the textile industry, the color of cotton is measured with trash which is unfortunate (Matusiak, 2015). Cotton color is measured in two ways which are used globally in the cotton industry. Visual color classification of cotton color and instrumental evaluation of cotton color are the most common ways for cotton color measurements.

Humans can see color and cannot describe color in the instrumental manner. This is the reason why disagreement between instrumental and visual assessment happens. The principal of color measurement is different for these two methods and that is why a huge disagreement is present in these measurements (Nickerson, 1946). Instrumental measurements of cotton color which are used in the textile industry are not able to segment the color of cotton and trash. However, visual assessment can distinguish the trash color from cotton. At the same time, visual assessment can see cotton and present only the color of cotton, (Xu et al., 2000). This conflict in the measurement is present in the main industries like automobiles and paint (Vik et al., 2017a). The main aim of this study is the development of method for the textile industry which can separate the color of cotton and trash and gives color assessment more close to visual assessment.

The color values of cotton fiber are creamy white and yellow color which indicate the deterioration of the cotton color (Schanda, 2007). In this prospect, measurement of cotton fibre whiteness possesses great importance. Different processes for the assessment of whiteness are used in this research to study the whiteness index of cotton. The measurement of whiteness is effected by the trash
fragments on the cotton samples. Whiteness measurement is a complex phenomenon and different methods are used for the whiteness measurement. The color of cotton fibre can be bluish white or yellowish white. Bluish white cotton is considered to have good grade. Separation of trash color from the cotton fiber color is the main focus of this study. The precise and accurate color measurement of cotton sample is not possible in the presence of trash contents on the cotton samples. If the color of cotton is measured with instruments, then it will include the color of trash segments in the color of cotton. The main objective is to divide the image into meaningful parts and then emit the trash particles from that image to get the color of fibres. This objective will actually enhance the precision of the cotton color grading system (Pub, 2004).

2. Materials and methods

2.1. Sampling

Pakistani cotton is considered to be trashy cotton. The nature of trash particles in the cotton fiber is normally referred to leaves, burs and other parts of plants which possess dark colors compared to the bright white color of cotton fiber. Pakistani cotton samples are selected from different regions of Pakistan for this research and contain different types of trash particles on the surface. Therefore, Pakistani cotton samples are selected for this research. These samples contain trash of dark color and deteriorate the color of cotton.

2.2. Visual classification

In Pakistan spinning factories buy cotton from ginning factories through visual judgment. This visual assessment is performed to measure color and trash of cotton. Final assessment is done according to visual grading because there is no such instrument in the ginning or spinning of cotton industry which can assess the cotton fiber color while having trash particles on its surface. Visual grading system does not count the trash particles while giving the color grade to cotton as presented in Figure 1.

2.3. Image analysis method

There are many reasons which are responsible for incorrect color judgment of cotton fibre. Yellow color in cotton is actually color deterioration and that should be taken account while color grading but the dark color of trash particles is not the color deterioration and should be removed. In the spinning mills to get the final color grading by instruments the cotton samples are passed through Shirley analyzer for cleaning.

The regions which are not true representation of the cotton are known as irregular regions. In other words, trash and leaf particles are actually irregular regions which will be removed in this section. After the removal of the irregular region only cotton regions are present in the image for color measurement.

An image segmentation is a technique in which an image can be divided into important parts. These parts can be cotton and trash regions. This process is performed to distinguish the nonlint content.

2.4. Trash segmentation method for cotton samples block scheme

Figure 2 represents the block scheme of trash segmentation method which shows the processing of an image from raw form to statistically required form.

2.5. Color correction

The image can be obtained from different devices and these images are dependent on the devices used for the image. It means that the color interpretation is different for several devices. Color correction is required for the raw image by using meta-info. Standard color values are distributed around the image whose color values are already measured as presented in Figure 3 and 4.

Table 1 shows the L(lightness), a (redness/greenness) and b (yellowness/blueness) of A1 to A12 which are the color patch around the cotton samples for the color balancing.

Table 2 shows the L(lightness), a (redness/greenness) and b (yellowness/blueness) of N1 to N5 which are the neutral grey regions as shown in Figure 3.

Figure 4 shows the standard color regions around the cotton samples in order to control the color measurement fluctuations by providing the reference standards of color regions.

General formulas are as follows:

\[
[X] = \sum_{i=0}^{3} \sum_{j=0}^{3} \sum_{k=0}^{3} W_{X,i} R^i G^j B^k
\]

\[
[Y] = \sum_{i=0}^{3} \sum_{j=0}^{3} \sum_{k=0}^{3} W_{Y,i} R^i G^j B^k
\]

\[
[Z] = \sum_{i=0}^{3} \sum_{j=0}^{3} \sum_{k=0}^{3} W_{Z,i} R^i G^j B^k
\]

Here, \( W_{X,i,j,k}, W_{Y,i,j,k}, W_{Z,i,j,k} \) are polynomial weights and \( i, j, k \) are indices for \( R, G, B \) values and pixels of the images are to be corrected. Pixels are related to the color values through these polynomial weights.

\[
[c]_{(N,v,3)} = [p]_{(N,v,13)} [A]_{(1,v,3)}
\]

where \( c \) = output XYZ vector \( [p] = N \times Q \) vector of \( Q \) polynomial terms derived from the input RGB vector \( d \).
Whiteness index rank order for cotton samples using the below-given equation.

\[
D = \left[ (L - L_o)^2 + (a - a_o)^2 + (b - b_o)^2 \right]^{\frac{1}{2}}
\]

Here D is known as distance and \(L, a,\) and \(b\) are derived color assessment of the image and \(L_o, a_o,\) and \(b_o\) are the admitted color attributes of the standard color values. The placement of the pixels assures the minimum standard representing the square area of the exact colors and the placement and distance are also familiar with the cotton sample container.

The threshold value is measured to set the standard for vanishing pixels whose intervals are bigger and do not represent the color domains. The position of the color assessment area is described in the image.

In Figure 3 grey image is shown in which black is known as zero while white describes the maximum value that can be obtained. Therefore, the less distances are highlighted as darker areas and are also the desired regions to be measured. First of all, the assessment of the required region is performed then on the basis of these assessments the coordinates of the samples can be identified by using the distance values (Cheng et al., 1999; Myer III et al., 1994; Xu et al., 1998).

The cotton sample is placed in a container and it is not suitable to assess the cotton color near the edges due to the shadow effect. Therefore, the cotton sample is cropped smaller that the cotton sample holder. Figure 3 shows that the red circles are observed regions detected simultaneously and this area is cropped for detailed analysis and is presented in Figure 5.

2.7. Identifying irregular regions
The principal focus is to identify the irregular areas in the image, abandoned these areas and get color values other than the cotton fiber itself. These irregular areas have different shapes and can be used to identify irregular regions. Another option is to use color values to detect the nature of trash. It can be seen from the image that channels like lightness, chroma, hue, and redness/greenness and yellowness/blueness belong to different color spaces of cotton samples (159 CCRI). The required information about the color values of lightness, chroma, hue and lightness, redness/greenness, and yellowness/blueness color spaces are distributed in channels and all these are highlighted in the grey scale.

It is observed that the lightness value is the same in two color spaces. CIE Lab color space possess two chromatic axes (\(a^*\) - \(b^*\)) and \(a^*\) represents redness and greenness in the opposite direction and \(b^*\) represents yellowness/blueness in the opposite direction. The \(b^*\) axis shows a positive value towards the yellowness (Vik et al., 2015). As lightness, chroma and hue color space is basically a polar form of lightness, redness/greenness and yellowness/blueness color space and the \(b^*\) value in Lab provide equivalent value to C (chroma) in the LCH as the cotton sample container.

\[
[A] = Q \times 3 \text{ matrix of polynomial weights to be optimized}
\]

\[
\]

Leads to,

\[
\]

(A) shown above is nonsymmetric and inverse of matrix is required. Polynomial functions can be converted to obtain P values, color correction can be done by simple multiplication of the matrix.

2.6. Obtaining the center coordinates of cotton samples
The cotton samples and standard color are present there at fixed regions from each other and still the same color value was impossible to measure. To obtain the middle coordinates and cropped regions the standard squares are divided.

Color subdivision is registered for color squares which obtain color details from the pixels of the image. The distance between the color of pixels and the exact color values of the standard colors used can be measured by using the below-given equation.

\[
D = \left[ (L - L_o)^2 + (a - a_o)^2 + (b - b_o)^2 \right]^{\frac{1}{2}}
\]
Figure 2. Block scheme of trash segmentation method.
fibre color always represented in white and yellow color (Chakraborty and Bandhopadyay, 2017). Three channels in the color spaces can be used to identify the regions. L channel and b* channel of Lab and L and C channels from LCH identify enough information about the irregular region in the cotton sample (Xu et al., 2001).

There are different methods used for the image segmentation and thresholding is one of the elementary methods used for this purpose. In thresholding technique more than one value is obtained and is compared with all the pixels which tend to segment the image. So, this thresholding technique can be used for image:

\[
B_{i,j} = \begin{cases} 
0 & \text{if } I_{i,j} < T \\
1 & \text{if } I_{i,j} \geq T
\end{cases}
\]  

(8)

In the above given equation T represents threshold value, I represents the image pixel value and i,j, are the coordinates in the B (Binary Image) in similar locations of the pixel.

Figure 6a identifies that color channels have irregular areas and it is also observed that segmentation is performed through thresholding method. All three attribute lightness, chroma and hue can be used for the segmentation method. Lth is known as lightness threshold value, Hth is the threshold value and Cth is the chroma threshold value. The comparison of lightness with Lth, hue with Hth and chroma with Cth gives the result to identify the trash region present in the sample. Thresholding technique is applied to the color channels for the inspection. Thresholding values are derived through standard deviation and using mean of that image (µ) in the channel where µ+2σ, µ-2σ are the threshold values. In these images all the pixels

Figure 3. Cropped standard color patches regions and neutral gray regions.

Figure 4. Standard color regions used around the cotton samples.
Table 1. Colorimetric values of the surrounding colors of cotton samples.

<table>
<thead>
<tr>
<th>L</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>85.57</td>
<td>2.56</td>
</tr>
<tr>
<td>A2</td>
<td>76.25</td>
<td>–24.26</td>
</tr>
<tr>
<td>A3</td>
<td>59.58</td>
<td>–59.01</td>
</tr>
<tr>
<td>A4</td>
<td>47.68</td>
<td>–60.79</td>
</tr>
<tr>
<td>A5</td>
<td>41.62</td>
<td>–31.81</td>
</tr>
<tr>
<td>A6</td>
<td>38.44</td>
<td>–17.21</td>
</tr>
<tr>
<td>A7</td>
<td>39.39</td>
<td>16.75</td>
</tr>
<tr>
<td>A8</td>
<td>39.07</td>
<td>32.6</td>
</tr>
<tr>
<td>A9</td>
<td>42.56</td>
<td>57.64</td>
</tr>
<tr>
<td>A10</td>
<td>49.14</td>
<td>70.21</td>
</tr>
<tr>
<td>A11</td>
<td>61.32</td>
<td>60.14</td>
</tr>
<tr>
<td>A12</td>
<td>74.67</td>
<td>29.88</td>
</tr>
</tbody>
</table>

are analogized with given criteria. Through this criteria, the pixel of the sample is detected which fulfills the given criteria (Cheng et al., 1999).

On the basis of segmentation conclusion two channels from LCH color space (L and C) and similarly two channels from Lab color space (L and b) are optimistic to each other for the cotton sample image segmentation as shown in Figure 6a, Figure 6b, and Figure 6c. Channel a* of CIE Lab color space obtained an impressive information although it is not sufficient for detection of nonuniform area (Shiau et al., 2000). It is understood that most commonly used color space is CIE Lab color space but LCH is also used to represent the color. Basically, LCH is a polar form of Lab color space. It shows color values close to human vision system as it contains chroma and hue in its measurement. The observations of the segmentation results revealed that the L channel of CIE Lab color space gives similar value of the L channel from the LCH and similarly, a* channel from CIE Lab gives equivalent value to the hue (h) channel from LCH color space. The cotton fibre possesses white color in variable depths as well as yellow color but, the yellow color in cotton is not appreciable and a* region in CIE Lab color space presents yellowness which is quite promising as presented in Figure 6d, Figure 6e, and Figure 6f.

This research also concludes that the L and C channels contain almost all the important information about the segmentation process. To obtain the average nonuniform regions in the image through image segmentation method for ultimate threshold gain and this will be beneficial for the segmentation method (Vik et al., 2017b).

Here, the thresholds values are obtained through an automated process using equation (11) and equation (12).

Table 2. Colorimetric values of neutral grey samples.

<table>
<thead>
<tr>
<th>L</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>22.79</td>
<td>0.71</td>
</tr>
<tr>
<td>N2</td>
<td>40.89</td>
<td>–2.4</td>
</tr>
<tr>
<td>N3</td>
<td>59.07</td>
<td>–1.46</td>
</tr>
<tr>
<td>N4</td>
<td>76.48</td>
<td>–1.46</td>
</tr>
<tr>
<td>N5</td>
<td>92.82</td>
<td>0.92</td>
</tr>
</tbody>
</table>

Table 3. Regression values for Rd and +b values.

<table>
<thead>
<tr>
<th></th>
<th>Slope</th>
<th>Intercept</th>
<th>Correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rd</td>
<td>1.02</td>
<td>1.36</td>
<td>0.98</td>
</tr>
<tr>
<td>+b</td>
<td>0.95</td>
<td>0.43</td>
<td>0.98</td>
</tr>
</tbody>
</table>

\[
B_1 = \begin{cases} 
1 & \text{if } L_{i,j} < T_1 \\
0 & \text{if } L_{i,j} \geq T
\end{cases} \quad (9)
\]

\[
B_2 = \begin{cases} 
1 & \text{if } C_{i,j} \geq T_2 \\
0 & \text{if } C_{i,j} < T_2
\end{cases} \quad (10)
\]

The lightness and chroma channel of the LCH color space by using thresholding method give the irregular area of the binary image B1 and B2. Here, threshold can be found through following equations:

\[
T_1 = \mu_L - 2\sigma_L \quad (11)
\]

\[
T_2 = \mu_c + 2\sigma_c \quad (12)
\]

Here, \(\sigma_L\) represents standard deviation but, \(\mu_L\) represents mean of lightness channel, similarly, \(\sigma_c\) represents standard deviation of chroma but, \(\mu_c\) is average value of chroma channel. In the previous studies these two channels are combined together through AND operator. It indicates that to identify the irregular region the pixels should satisfy the criteria and otherwise it is labeled as cotton region. The trash contents from the image are not completely omitted. Therefor ‘OR’ gate is used to combine the image and all the trash contents are covered and the color of cotton is obtained only. "OR" operator is used for the detection of irregular regions in the cotton samples as shown in the Figure 7 and the trash contents from the image are not completely omitted. Therefor ‘OR’ gate is used to combine the image and all the trash contents are covered and the color of cotton is obtained only.
The images can be transformed from one color space to another color space and similarly the RGB image is transformed to CIE L*a*b* color space through CIE color conversion equations.

3. Results

3.1. Visual grading

Although cotton is graded by using different methods like visual judgment and instrumental assessment using HVI and spectrophotometer. This color measurement can be represented in various color spaces. In the visual grading of cotton, it is observed that the factors which affect the visual grading should be addressed properly. Ambient light used for grading and the room should be in proper manner to avoid the error in the measurement.

Diffuse lighting is preferred in the color grading of cotton samples as it provides the depth in perception for the cotton color observer (Xu et al., 1998). The glare is highly prohibited in the visual grading as well as cross-lighting. Till now, the visual grading system is the most reliable source for the color grading of cotton fibre as compared to instrumental color grading. There is a huge difference between the instrumental measurement and visual assessment and it is present in the automobile industry as well as paint industry. In the previous studies it is concluded that 45° should be used for the classer and cotton sample. No other light is used for the cotton grading in the room and cross-lighting is prohibited strictly (Vik et al., 2016). In general, black table top is used for the cotton grading.

Figure 5. Cropped cotton sample region without color patches and neutral grey.

Figure 6. Cotton samples.
sample placement and the table color should near to neutral grey while the color of ceiling should be white. In this study the color of trash particles will not be considered during the final cotton color grade and the results will be comparable with the visual grading. The cotton samples used for this research are acquired from the (CCRI) central cotton research institute, Multan. These samples contain trash on it naturally and the nature of the trash is leaves and burs from the agriculture field. These trash particles generally represent dark color than cotton which makes it easy for distinguishing between cotton trash (Thomasson, 1990; Tutak et al., 2011).

Figure 8 represents the comparison between the visual grading and trash segmented method. It can be seen that the difference of visual assessment and instrumental measurement is reduced. As the color diagram indicates grades according to the sample fall in the color diagram curvilinear lines, it is proven that the sample will get the same grade in the visual grading as well as in the trash segmented method.

Main aim of the study is the reduction of disagreement between these two methods. Linear relationship is shown in Figure 9 and Figure 10, between degree of reflectance (Rd) and yellowness (b).
Figure 11 shows that the sample contains very low amount of trash content. Histograms can also be used to represent the color of trash and cotton fibre as well. This also helps to differentiate between color of trash and cotton. Shapes of histograms describe the cotton region as well as trash region inside the cotton sample. Three histograms are produced from the software. Figure 12 shows the CIE L,a,b values of cotton and trash region in the combined section while Figure 13 shows the CIE L,a,b values of cotton region and similarly Figure 14 indicated the CIE L,a,b values of trash region in the cotton sample. It is also observed from these histograms that the presence of trash particles in the cotton sample can be estimated and represented in percentage.

These histograms are clear way to differentiate the color and trash region to achieve the accurate color grade of cotton.

Figure 15 shows that the sample contains more trash particles as compared to the previous sample. In Figure
the pixels indicate that the sample contains more trash particles as compared to the Figure 11 which contains less trash particles expressed by the pixels. Figure 16 shows the CIE L, a, b values of cotton and trash region and Figure 17 indicates CIE L, a, b values of the cotton region only. The y-axis in all the figures is constant in scale wise because it shows the cotton and trash region comparison to identify the trash percentage in the cotton sample. The difference in the three histograms will enable to distinguish between these regions. These histograms are also helpful in describing color values because trash particles cannot disturb the true color values of the cotton samples. As it happens in the case of visual grading when trash particles are not considered for final color grade. This method indicates that it will reduce the difference between the visual grading to cotton and instrumental grading to cotton and both grading systems will be equally reliable for the final color grade of cotton.
Figure 18 clearly indicates that the histogram is capable for detecting the trash particles and due to the large scaling of y-axis the trash contents are not visible but the amount of trash particles is more than the previous cotton sample.

4. Conclusion
The major advantage of development for this image analysis based prediction system is that in the presence of trash segments color of cotton fibre can be measured. The process of removing trash from the cotton sample is no longer a requirement for cotton color grading. This image analysis based color measurement system will not only precisely measure the color but also segment the trash contents. The disagreement obtained through visual assessment and instrumental measurement is minimized and both values are almost similar. Final color grade of
Figure 15. Cotton image with small amount of trash particles.

Figure 16. Histogram showing the L,a,b values of the cotton and trash particles.

Figure 17. Histogram showing the L,a,b values of the cotton.
cotton can be assigned through instrument as the color of trash is not included in it. This research will optimize the precision of color measurement devices for accurate color measurement and the presence of trash will not affect the color measurement. It will also enhance the capability of the instrument to represent the color in three attributes rather than using two attributed Rd and +b.

References


