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A Novel Method for Color Measurement of Cotton Fiber

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SUMMARY OF THE THESIS

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Abstract

The color measurement of the cotton fiber is very important property of the cotton fiber and it plays important role in grading of the cotton. Globally used color parameters of the cotton fiber are Rd and +b. These parameters are measured by HVI (High volume instrument). Cotton color standards are ceramic tiles and cotton samples which are provided by USDA. The focus of the research is the utilization of the LEDs as a light source in the cotton color measurement system. Conventional lighting used for cotton color measurement is xenon and incandescent. LEDs have potential benefits over the conventional lighting system as these are more energy efficient, offers more working hours, safer and environment friendly.

Non-contact method is used from a specific distance. This method enables to measure the cotton color with immense precision due to the minimum area of the surface used for the measurement. The chromaticity and luminance values measured through the no-contact method are hypothetically arrangement of visual assessment. Non-contact method is also used for the evaluation of the color variation.

Cotton color representation can be misleading in a way that the surface of the cotton sample contains the trash particles. As far as the instrumental measurement of cotton color is concerned the presence of these trash particles is a big obstacle in the way of exact measurement of cotton sample. But, cotton industry also uses visual inspection technique for the color measurement of cotton. This technique involves the human assessment. It is more reliable in a sense that the human assessment does not take into consideration the trash particles and gives the color values only of the cotton region. Image processing technique is used in my research work which enables us to eliminate the trash particles from the surface of the cotton and gives only the color of the cotton region.

According to the industrial point of view the disagreement between the visual assessment of cotton color and instrumental assessment of the cotton color measurement is quite high. Although, lots of efforts have been made to minimize this disagreement but still, the final grading is performed on the basis of visual assessment. Thresholding technique is used for the trash segmentation. Three regions L* (Lightness), C*(Chroma), H* (Hue) is used for the thresholding technique.

This Visual assessment is performed according to the USDA standards for the cotton color grading. USDA cotton samples are also used for the assessment of the cotton color. And the visual assessment is compared with the thresholding technique. Satisfactory results are obtained with a clear reduction of the disagreement between visual assessment and instrumental measurement. The objective of the research is achieved by developing an improved color measurement system for cotton grading.

Keywords: Cotton, LEDs, Visual assessment, Image processing.

Abstract (In Czech)

Měření barevnosti bavlněných vláken je velmi zajímavou vlastností těchto vláken a hraje důležitou roli v klasifikování bavlny. Obecně užívané parametry barevnosti bavlněných vláken jsou Rd (odrazivost) a +b (žlutost). Tyto parametry jsou měřeny pomocí HVI (High Volume Instrument). Bavlněné barevné standardy jsou keramické dlaždice a bavlněné vzorky produkované USDA. Cílem výzkumu je využití LED světelných zdrojů při měření barevnosti bavlny. Běžně používané světelné zdroje pro měření barevnosti jsou xenony a žárovky. LED zdroje mají potenciální výhody oproti běžně užívaným světelným zdrojům, protože jsou energeticky účinnější, umožňují delší pracovní dobu, jsou bezpečnější a šetrnější k životnímu prostředí.

Bezkontaktní metoda měření se používá ze specifické měřící vzdálenosti. Tato metoda umožňuje měření barevnosti bavlny s velkou přesností vůči minimální ploše měřeného povrchu. Hodnoty barevnosti a jasu měřené bezkontaktní metodou měření jsou hypoteticky uspořádané jako vizuální hodnocení. Bezkontaktní metoda se také využívá pro hodnocení barevných změn.

Barevnost bavlny je navíc ovlivněna i tím, vyskytují-li se na jeho povrchu odpadové částice. Tyto částice ovlivňují i instrumentální měření bavlněných vzorků. V bavlnářském průmyslu se k hodnocení bavlny používá vizuální technika zahrnující vizuální posudky. Toto hodnocení je spolehlivější v tom smyslu, že lidský zrak nebere v potaz částice na povrchu vláken a dává tak barevnost pouze v oblasti bavlny. Další užívanou možností pro hodnocení barevnosti bavlny je obrazová analýza, která umožňuje odstranit zbytky částic na povrchu a poskytuje tak barevnost čisté bavlny.

Podle průmyslového hlediska jsou však vizuální posudky a přístrojové hodnocení v poměrně vysoké neshodě. Nicméně bylo vynaloženo značné úsilí pro snížení této neshody mezi způsoby hodnocení. Přesto je konečné hodnocení prováděno na základě vizuálního hodnocení. Pro techniku prahování v rámci obrazové analýzy se používají tři hodnoty, a to hodnoty světlosti L*, čistoty C* a odstínu H* bavlny.

Vizuální hodnocení se provádí vůči standardům USDA pro barevné třídění bavlny. Standardy USDA se používají pro hodnocení barevnosti bavlny. Vizuální hodnocení je porovnáváno technikou prahování. Bylo dosaženo uspokojivých výsledků s jasným snížením neshody mezi vizuálním a instrumentálním hodnocením. Cíle výzkumu je dosaženo vytvořením zlepšeného systému pro měření barevnosti pro třídění bavlny.

Klicova Slova: Bavlna, LED, Vizualni hodnoceni, Obrazova analyza.

SUMMARY

List of figures

List of tables

1. Introduction

Color is very important property of cotton as a raw material so; it gives us help to determine and classifying the quality of fibers according to the universal cotton standards. Normally cotton possess bright white color but, due to the different factors like continuous exposure of light, extreme weather conditions, rainfall, excessive moisture, soil contact the color of cotton is deteriorated significantly. The up given factors are not the only factors but there also some other factors which also damage the color of cotton fiber to the different extent. It is also very important to measure the color in the correct manner because if we will not measure them correctly then it will have huge impact not only in the yarn color quality but also on the processing of the cotton fabric as well because the dye pick up of cotton fabric is dependent on the color grading (1).

There are so many methods are used in these days for the classification of cotton on the basis of color property. But, still there are lot of efforts required in this field to make this phenomenon more reliable and accurate for the grading of cotton. The current instrumental measurement which is used now days for the color measurement is not reliable as it contains a strong disagreement between the visual grading systems. In this study, some of the problems which are actually needed to be discussed in the cotton color grading are discussed comprehensively and with achieved objectives (2).

One of the objectives of the study is to measure the color of cotton by using LEDs as a light source. USDA proposed xenon as a light source for the cotton color measurement in their universal cotton color standards. This light source comprises of less working hours as compared to the LEDs which are used now a days in almost every industry.

Trash particles in cotton like leafs, grass and bark are considered as foreign matters in the cotton which have different color if compare to the cotton lint. The color of the cotton is affected deeply due to these trash particles if measured through the colorimeter (3). And the measurement of the colorimeter is strongly dependent on the amount of the trash particles and as well as type of the trash particles. So, it is very obvious that to get the correct reading of the measurement to separate the trash particles from lint. The separation of the trash particles from the cotton image and then the measurement of cotton color are performed to see the effect of trash particles on cotton color.

2. Purpose and the aim of the thesis

The main aim of the study is to represent the cotton color with a completely unique method which is quite different as compared to the conventional methods used for the cotton color measurement. Globally, color of cotton is measured with the help of HVI (High volume instrument) which, is not only used for the color measurement of cotton but it can also measure other physical properties like length, strength, fineness, trash, etc. These properties plays important role in cotton grading. HVI represents color of cotton in two parameters Rd (degree of reflection) and +b (yellowness). Rd and +b value of the cotton color is used to grant the official color grading to the cotton based on the Hunter and Nickerson colorimeter diagram and this also represents the relationship between the HVI and the color grades. Rd and +b which are actually known as color parameters of the cotton are not globally recognized. The reproducibility and repeatability of different HVI systems is also unsatisfactory. Commercial Standardizing of the instrument testing of cotton showed variation between the different HVI results in the cotton color measurement. Potential causes are as follow:

- The maintenance and the age of color tiles.
- The age of the lamps used by HVI (900).
- HVI malfunction.

HVI color measurement is also not compatible if compared with the visual human color perception. There is a strong disagreement between the visual classification and HVI measurement. The main cause of the disagreement is occurred when the HVI color parameters are placed on the Nickerson Hunter diagram. So, the thin line between the white and light spotted cotton is the main cause of the disagreement. These parameters of cotton are very old and there is a strong urge to represent the color of cotton in a better way.

The focus of our study will be color measurement of cotton by using LED as light source. LEDs are never been used in the cotton grading. But, in this era as LEDs are taking place in every field so, LED can also be used in cotton color grading. The unique method which is used in our study is a non-contact method (telescopic method) and it is not used before this in the cotton color grading. The results of non-contact method used for cotton grading will be compared with HVI and also with the other instrumental color measurement. The removal of trash particles from the cotton surface will be most important part of the study because the trash particles causes a great deal of discomfort. The results will also be compared with the visual color classification by taking the trained professionals which assign the color grade of cotton in the cotton mills on the basis of its Rd and +b values. One of the group will be professionally trained persons from the cotton industry and the others will be the students of the technical university of Liberec. This method allows representing the color of cotton close to the visual sensation just like a human being can see. The dis-agreement between the HVI and visual inspection is the main example of this argument. The Human can see the light in the range of

(400-700)nm whereas HVI is not capable to do that. But this this new method (non-contact) will provide us with the luminance values which will be used further to represent the color parameters in other color scale. In this manner the results will be a strong representation to reduce the disagreement between the Visual inspection and instrumental measurement of the color of cotton fiber.

The required experiments are performed in the LCAM (Laboratory of Color and Appearance Measurement) in the Technical university of Liberec (Czech Republic). Some part of the research is performed in the (CCRI) Central Cotton research institute, Multan Pakistan with the co-operation of the University of Agriculture Faisalabad (Pakistan).

3. Overview of the current state of the problem

The major problem now a day is the disageement between the visual classification and the instrumental grading. Due to this disagreement still now the final grades are given to the cotton by classer (2). There are lots of efforts required in this field to make this phenomenon more reliable and accurate for the grading of cotton fiber. In the beginning the cotton was classified with the help of human classifiers with the use of cotton standards. But, due to the inconsistency of the result and the variation in the results due to visual inspection. In 1930s the USDA department began the efforts to develop the instrument for the color grading of cotton fiber. Due to the effort the measurement of Rd (degree of reflectance) and the +b (yellowness) became the attributes of the color measurement in the 1950s with the invention of hunter colorimeter in 1950s (4). In the 1970s the colorimeter technology was brought in use for the classification of cotton and till the end of 1970s that technique was fully integrated into the high volume instrument (HVI) but the final official grading was assigned to the cotton by the classifier. This practice was maintained till 2000, and after that the grading based on Rd and +b values was approved as official grading in the classification of cotton (5).

The main reason of the difference between visual and instrumental grading is the presence of trash particles on the surface of the sample. The removal of these trash particles from cotton fiber enables the precise measurement of cotton color (6). When the visual classification takes the cotton classer does not take into consideration the trash particles this is the reason but on the other hand the HVI cannot eliminate the effect of trash particles from cotton fibers. One of the major points is that by removing the trash particles from the surface of the cotton fiber the precise and accurate measurement of cotton color can be obtained. This measurement should be in good relation with the visual classification (7).

The process of trash segmentation from the cotton sample is very simple process in which the different trash particles like leaves, burs of different colors are identified and then they are removed by the technique given in the later part of the repot. Theoretically, the results obtained after the trash segmentation should be matching the official grading of cotton assigned by the visual classer (8).

The use of non-contact method also helps us to make correct measurement due to the measurement area of cotton sample. In the HVI the sample is placed against the window of 10.1 inch wide. The sample size is so big that it cannot measure the variation within the sample. In our studies the use of non-contact method is quite capable to measure the intra-sample variation which helps to provide the precise color assessment. In the non-contact method the LEDs with full spectrum are used which actually helps to see the color near to the human perception. This is because the human can also see the color between the range of (400-700) nm. The solution of these problems which are described earlier is main basics for this study where the efforts are made to solve these problems. In the results and discussion part the segmented part of the cotton sample in which the trash particles are omitted from the sample should be near to the visual inspection of cotton classer (9). The required results are satisfied with this strong relationship. In our research the Pakistani cotton is also used for the experimentation. According to the USDA in the year (2016/2017) 11.5 million bales (each bales contains weight of 170 kg) were produced. After China, India and United States of America, Pakistan is the fourth largest cotton producing country. In Pakistan, most of the cotton is processed by saw ginning factories. While in the other big cotton producing countries the roller ginning is used instead of saw ginning process. Saw ginning process is a quantity oriented process and it does not take into consideration the moisture content. It also damages the cotton parameters up to a great deal like length and strength (10). Color of cotton is also affected by the saw ginning process due to the presence of moisture inside of the raw cotton. The cotton which is processed in roller ginning contains less moisture because this process needs very less amount of moisture in raw cotton. Roller ginning of cotton consists of leather rollers and with excessive moisture the cotton fiber tends to stick with the roller of machine and complicate the ginning process. Somehow in the baling process ginners try to add the moisture. These are some of the reasons inside the cotton industry which also affects the cotton color deterioration (11).

Cotton is mostly picked from the fields three times in the cotton season and this picking of cotton is based on the maturity of cotton during its growing period in the field. In the first pick of cotton the *Rd* of cotton is mostly very higher with almost negligible yellowness. But, due to the immaturity of the cotton balls this pick of cotton is not able to get the importance of cotton classers. Second pick of cotton is the most important pick and possess high economic value almost all the balls of cotton are open fully mature for the further process but till this span of time due to the weather condition and exposure to the sun the *Rd* values decreases and some of the discoloration also comes into the cotton balls (12). And in the last and third pick the *Rd* value of cotton is of very low value. Because this cotton is actually not picked in the first two picks and it has to bear a long period of time the excessive weather conditions. This cotton contains higher spots and yellowness. Besides these factors the attacks of insects and soil contact in the fields are also the major causes for the cotton discoloration (13).

When the classification of cotton is performed the precision of *Rd* and *+b* is set at one decimal point. It is concluded so many times that the *+b* is always reported in the one decimal point but on the other hand the *Rd* value is always reported in the rounded number as far as classification status is concerned (9). It is obvious that the value of *+b* is reproducible at the desired tolerance but, it is not possible for the *Rd*. From the late 80s till mid 90s the reproducibility of the color parameters of cotton has increased up to a certain level. According to a survey by USDA in 2003 the reproducibility factor of USA cotton has increased 94% (11). These figures are based on the cotton grading by the human classers and then these samples are also tested in the Memphis based quality assurance department. It is very significant that the first decimal place of the cotton color parameters is very important for the precision purpose. The color grading system is based on the color diagram which is mentioned in the earlier part of the work (14). The *Rd* and *+b* both parameters are used in the color diagram for the color grading of cotton. The color look up tables are the numerical values and gives grades for every value of *Rd* and *+b.*

4. Methods used studied material

The samples which are used for the analysis are AMS (Agriculture Marketing Service) standard ceramic tiles (1 set contains 5 tiles) and AMS standard cotton fibers (2 box contains 12 samples). An example of the samples is given in the figure (1). All these samples were measured at the Laboratory of Color and Appearance Measurement in the Technical University of Liberec, Czech Republic. These standards were provided by the AMS, Memphis TN, United States department of agriculture. The set of tiles possess a smooth surface for the evaluation. White, Brown, Yellow, Grey and central are the colors of ceramic tiles which obviously possess different values for their Rd and +b values. And these values are also provided by the AMS department. Similarly, the set of cotton box is provided with twelve cotton samples with different values of Rd and +b. The laboratory conditions used for the color measurement are (20 ± 2 °C and 65± 2% RH).

Each sample, which is shown in the figure (1) , is measured 5 times (5 replications) on each color measuring instrument. Measurement was divided into two methods: contact and noncontact (telescopic). Contact method is based on standard measurement via portable spectrophotometer MiniScan XE (Hunter Lab, USA) with 25 mm diameter of measuring aperture, which was protected by covering glass and 45°/0° geometry. Because covering glass was used during calibration it wasn't necessary to compensate reflectance values of measured samples. Reported values beside spectral reflectance factor ρ were reflectance Rd and yellowness +b both computed using illuminant D65 and 2° observer conditions.

Figure 1. Representative set of Five AMS ceramic tiles.

Figure 2. Miniscan XE (spectrophotometer) used for the Spectral data as well as CIE XYZ values in the LCAM at Technical University of Liberec.

Lighting booth AT (Atelier Technik, Czech) was used during non-contact (telescopic) method of measurement. This lighting booth is equipped with fluorescent simulator of D65 and at Technical University of Liberec was made adaptation for full-spectrum white LEDs, based on violet pump chip: V-WLED. Each sample was measured by non-contact colorimeter CA-210 (Minolta, Japan) from controlled distance of 30 cm. As basic set calibration samples were used grey scale samples from X-Rite Color Checker standard. Such calibration allows transformation of measured values x, y and Lv (luminance value) into CIE color space XYZ for both used light sources and 2° observer, which is internal setup of CA-210. The transformation of x, y, Lv values into CIE XYZ values. CIE XYZ values are converted into Rd, a and b values.

Konica Minolta CA-210 is used for the color measurement with the non-contact method. Lighting booth AT (Atelier technic, Czech Republic) was use to enlighten the samples. White LEDs with the full spectrum are used for enlighten the samples. The lighting booth is also equipped with the fluorescent simulator D65 (6500K). 20 observations are used for the measurement, which is also the internal setup of the CA-210. Grey scales samples from X-rite color checker standard are used to check the linearity of the samples. As the CA-210 provides the x, y, Lv (luminance value) and the color checker standards allow the transformation of the luminance values into the CIE XYZ. The relationship between the luminance values obtained from the non-contact method and the Y value, which is CIE XYZ, system is observed. For the comparison of these values with the HVI color parameters (Rd, +b) it is also necessary to calculate the Rd and b_{Rd} values from CIE XYZ values by using expansion factors:

Ka = 172.3; Kb = 67.2 for illuminant D65

Ka =171.9; Kb = 71.6 for V-WLED (Violet pump Chip).

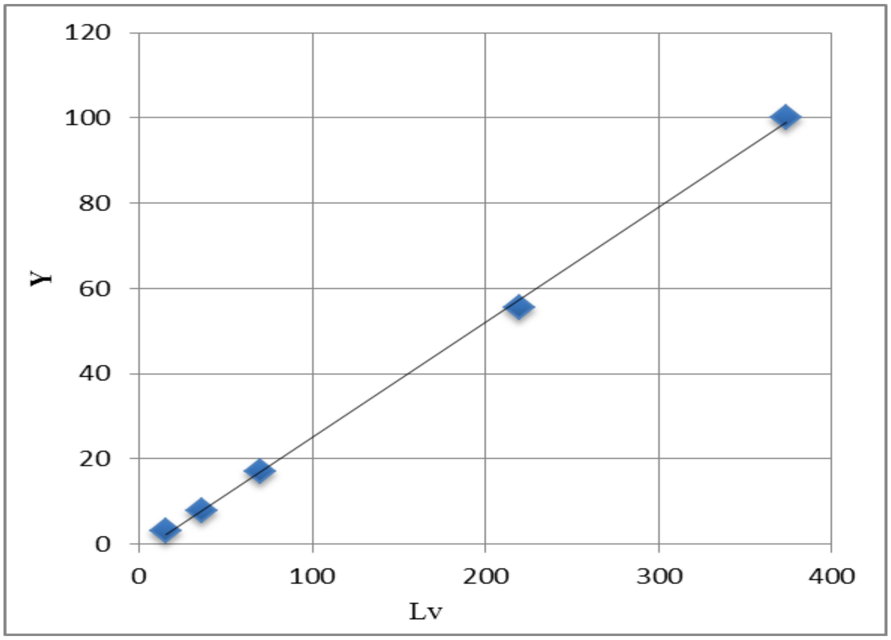


Figure 3. Relationship between the Lv (Luminance) value and the Y value of CIE XYZ.

4.1. Digital Image Processing for Color Measurement:

All the cotton samples are placed in light cabinet and images are acquired under the same illumination conditions with a digital camera "Panasonic SDR-H280". The auto white balance and the other auto color correction functions of the camera are set off so that the obtained image colors are not altered significantly. The color values of images might deviate from the real colorimetric measurements due to the lack of calibration and characterization of the digital camera. But, as it is mentioned previously, the images are acquired under same conditions without color corrections, so, relative comparisons of color measurements between samples are meaningful. The original images (72 dpi resolution) are shown in Fig (4). The images are cropped in order to include 700x700 pixels.

(a) Sample 1

(b) Sample 2

(c) Sample 3

Figure 4. Original samples.

(a) Sample 1 (b) Sample 2 (c) Sample 3

Figure 5. Cropped images.

All images were captured in the RGB space. Images converted from RGB space into the CIE L*a*b* space in which a* axis corresponds to red–green opponent hues, with distances along the positive a* axis corresponding to a measure of redness (15).

The process of visual classification involves groups of people, which grade the cotton according to the USDA specified standards. People which are selected for the color assessment of cotton visually possess enough knowledge of the cotton classing (16).

Black top of the table is normally used for the cotton classification generally. In our experiment three different colors of the table top are used. In which Neutral grey, Black and white color is used. The effect of different backgrounds on the cotton grading is studied (17). The visual comparison is performed not only to grade the cotton but also it was performed to rank the cotton according to its whiteness which helps to predict the whiteness of the cotton sample. WCIE (whiteness index) of the cotton sample is also determined which is totally based on the CIE whiteness values and the correlation of these samples studied. The trilobite QC expert software is also used here for the analysis of the data (18). The cotton samples which are taken from the Pakistan contain the trash particles on the surface of the sample but the classer does not take these trash particles into consideration while grading of the cotton. The effect of these trash particles is studied while instrumental measurement of the cotton samples. Because the instrument does not ignore these particles and takes those as significant color deterioration of the cotton sample. This affects the color of the cotton samples (19).

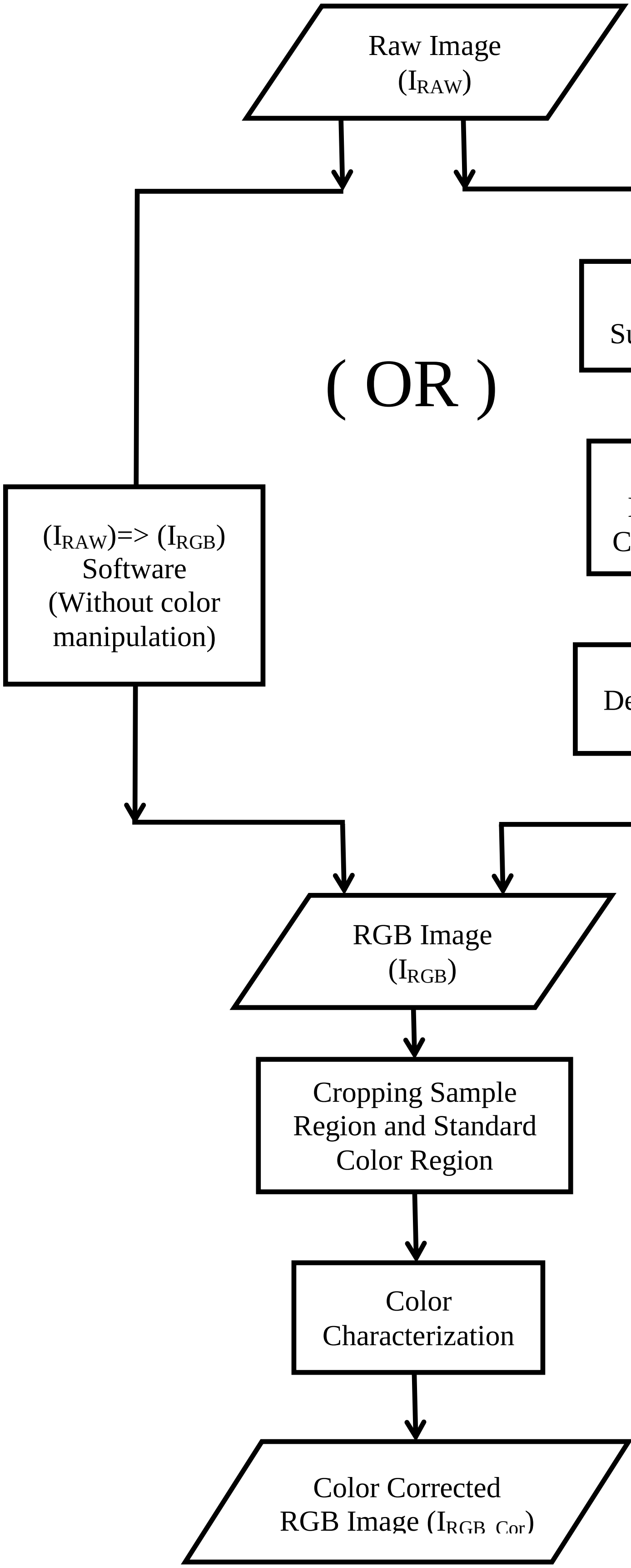
Figure 6. Rank order according to the degree of whiteness on the black background.

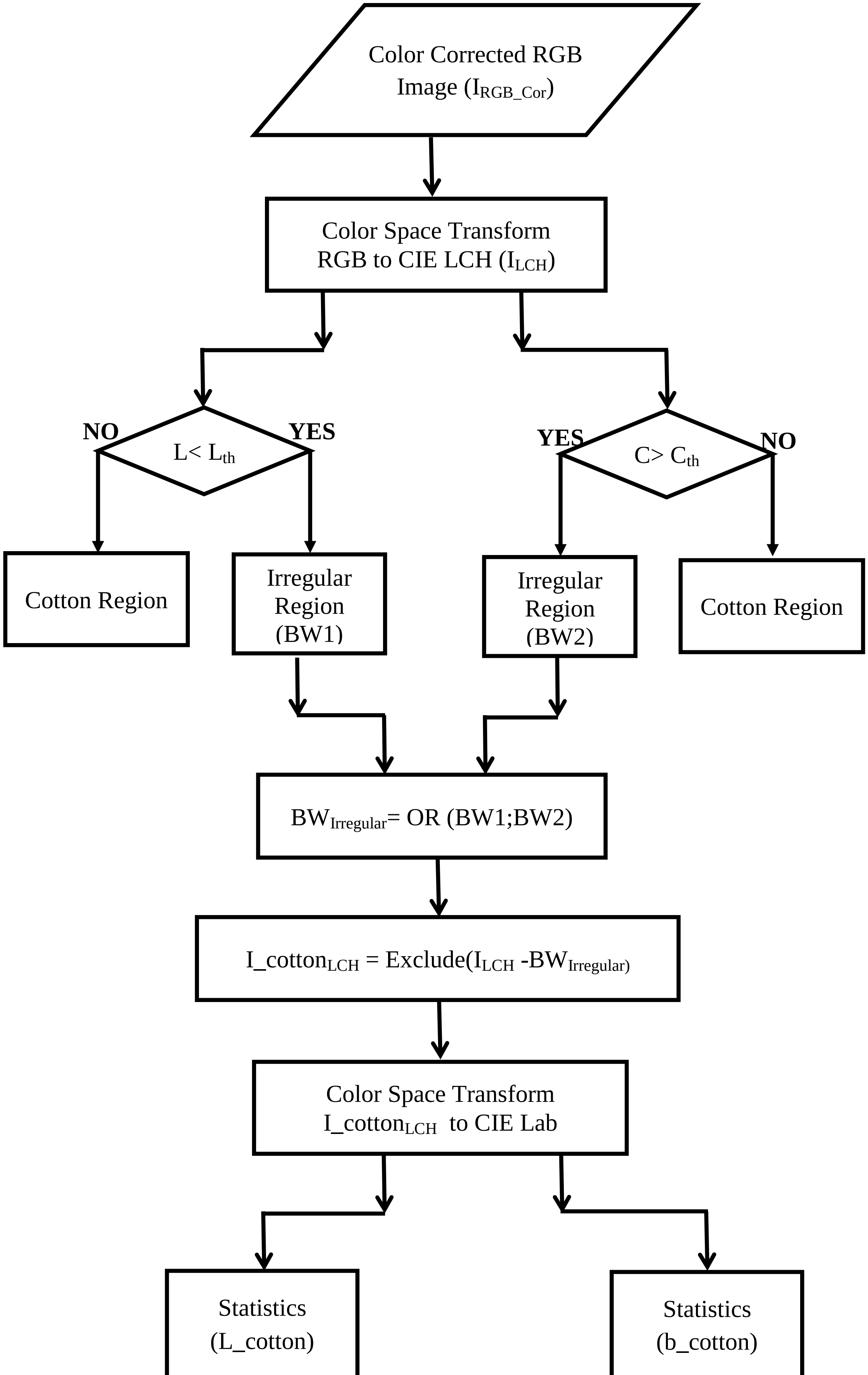
Figure 7. Visual assessment of Pakistani cotton with white background by taking USDA cotton as reference standard.

4.2. Image analysis method:

Generally raw cotton samples may lose brightness and have a yellow color due to different disturbances although cotton is expected to have a bright white color. Cotton also may contain thrash particles in addition to color varieties which are imposing problems for color measurements of raw color samples. All these color disturbing regions will be called irregular regions. The main aim of this step is to exclude the irregular regions (spot, thrash, leaf etc) from the images of cotton samples in order to obtain the color information of the raw cotton samples only. This step involves mostly image segmentation methods (20).

Image segmentation is the process of dividing an image into multiple meaningful parts. Segmentation is usually understood as the decomposition of a whole into parts. Image segmentation analysis was applied to detect non-cotton items, such as leaf particles, and the classer denoted bark/grass objects (21).


Raw Image
(IRAW)
Black
Subtraction
(OR)
White
Balance
Correction
(IRAW)=> (IRGB)
Software
(Without color
manipulation)
Demos icing
RGB Image
(IRGB)
Cropping Sample
Region and Standard
Color Region
Color
Characterization
Color Corrected
RGB Image (IRGB_Cor)


Color Corrected RGB Image (I_{RGB_Cor})
Color Space Transform RGB to CIE LCH (I_{LCH})
NO
L< L_{th}
YES
YES
C> C_{th}
NO
Cotton Region
Irregular Region (BW1)
Irregular Region (BW2)
Cotton Region
$BW_{Irregular}$= OR (BW1;BW2)
I_cotton$_{LCH}$ = Exclude(I_{LCH} -$BW_{Irregular}$)
Color Space Transform I_cotton$_{LCH}$ to CIE Lab
Statistics (L_cotton)
Statistics (b_cotton)

4.2.1. Color Correction:

Color information obtained from digital cameras is device-dependent, i.e. the color information can be interpreted differently by different devices. The images obtained from the raw file using meta-info needs to be further color correction (22). In every acquired image there are standard color samples whose colorimetric values are known:

Figure 8. Cropped Standard Color patches regions and Neutral gray regions.

Table 1. . Colorimetric values of the surrounding colors of cotton samples.

	L	a	b
A1	85,57	2,56	83,06
A2	76,25	-24,26	68,2
A3	59,58	-59,01	22,86
A4	47,68	-60,79	-3,26
A5	41,62	-31,81	-30,55
A6	38,44	-17,21	-40,77
A7	39,39	16,75	-38,57
A8	39,07	32,6	-32,55
A9	42,56	57,64	-2,57
A10	49,14	70,21	26,35
A11	61,32	60,14	59,44
A12	74,67	29,88	70,51

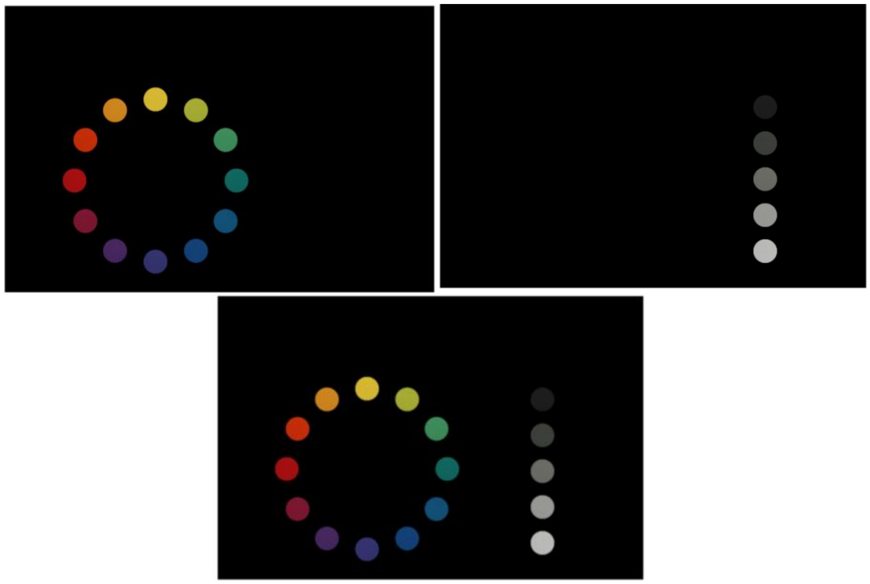


Figure 9. Standard Color regions used around the cotton samples.

General Formulas as follows:

$$[X] = \sum_{i=0}^{3}\sum_{j=0}^{3}\sum_{k=0}^{3} w_{X,l} R^i G^j B^k \qquad (1)$$

$$[Y] = \sum_{i=0}^{3}\sum_{j=0}^{3}\sum_{k=0}^{3} w_{Y,l} R^i G^j B^k \qquad (2)$$

$$[Z] = \sum_{i=0}^{3}\sum_{j=0}^{3}\sum_{k=0}^{3} w_{Z,l} R^i G^j B^k \qquad (3)$$

where, $w_{X,l}; w_{Y,l}; w_{Z,l}$ polynomial weights and l: i, j, k indices for the combinations, R,G,B values are input image pixel values to be corrected (3) (23). The known color values are related with these pixel values by polynomial weights.

$$[c]_{(Nx3)} = [p]_{(Nx11)} [A]_{(11x3)} \qquad (4)$$

where c= output XYZ vector

[p] =N × Q vector of Q polynomial terms derived from the input RGB vector d

[A] =Q × 3 matrix of polynomial weights to be optimized

$$[c][A]^{-1} = [p][A]\,[A]^{-1} \qquad (5)$$

Leads to,

$$[c][A]^{-1} = [p][A]\,[A]^{-1} \qquad (6)$$

Generally A is not symmetric and here it is needed to pseudo inverse of matrix. After determining p weights which are actually the transformation polynomial coefficients, color correction is straightforward and only a process of matrix multiplication and transformation with color spaces.

4.2.2. Obtaining the center coordinates of cotton samples:

Although the standard color and the cotton sample regions are located in a standard order and pre-determined distances to each other, it was not always possible to obtain the exact same position of the system. First of all, standard squares are segmented by color segmentation in order to compute the center coordinates and the potential region of the desired cropping area automatically (24).

Color segmentation is realized for standard color squares obtaining the color information of every pixel in the image and calculating the distance of pixel color values to the known color values of standard color squares using following equation (24) (25).

D=[(L-L0)2+(a-a0)2+(b-b0)2](1/2) (7)

Where, D is the distance, L, a, b are the obtained pixel color values from the image and L0, a0, b0 are the know color values of standard colors. The pixel locations satisfy the minimum criteria indicating the square region of the known colors whose locations and relative distances are also known to the cotton sample holder region. A threshold is determined to be the criteria for eliminating pixels whose distances are higher and not representing the searching color region. Location of the first standard color square region is shown as an example (18) (26).

The figure shows the gray level image of the distance values where black is the zero and white is the maximum number that image file can contain. Therefore the minimum distance values are indicated darker and the black region is the desired area to be detected. After detecting the exact location of a known region it is possible to calculate the coordinates of the cotton sample holder by using the relative distances of the region (27) (28).

Cotton sample region is obtained by cropping the region smaller than the cotton container so as to eliminate the shadow effects close to edges. In the figure the red circle shows the automatically determined region which is the area to be cropped for further analysis.

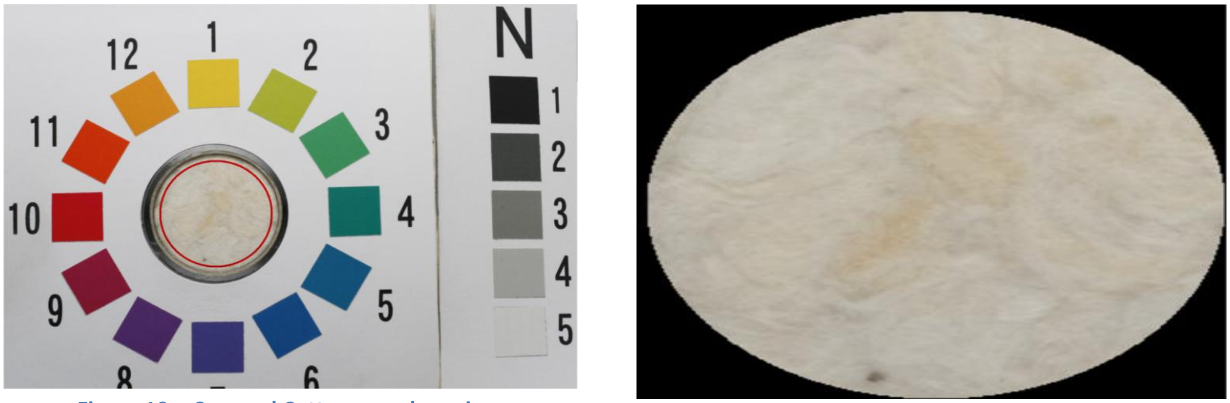


Figure 10. . Cropped Cotton sample region.

The main aim is to detect irregular regions, leave out these regions and obtain color information without any disturbances other that cotton lint itself. Although these irregular regions possess different shapes and these shape features might be used for irregular region detection, one another option is using color features of the irregular regions. Figures show the every channel values of the LCH and CIE Lab color spaces of ten different cotton sample images (159 CCRI) shown in below given Figures (11).

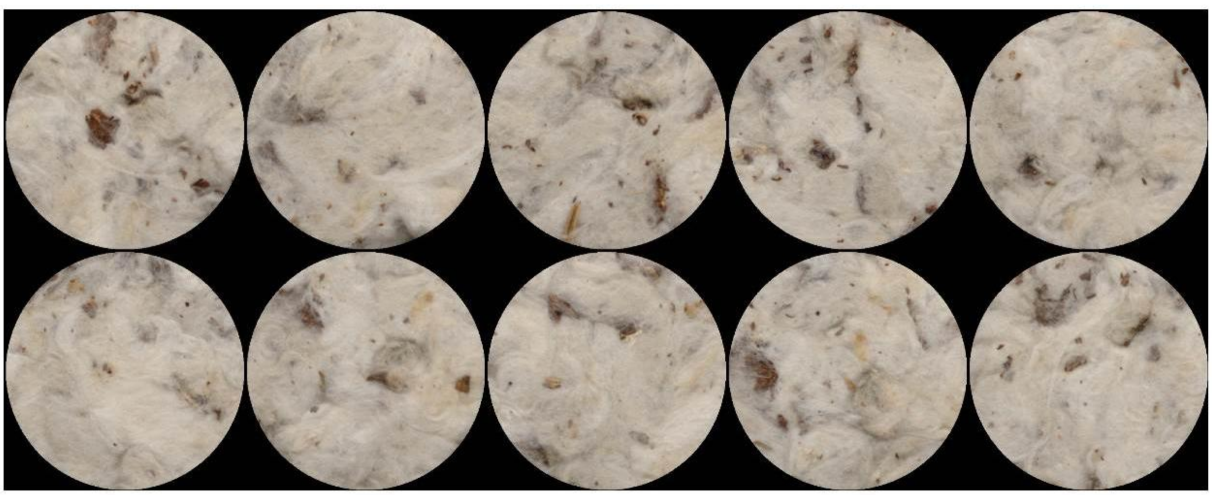


Figure 11. Original Samples.

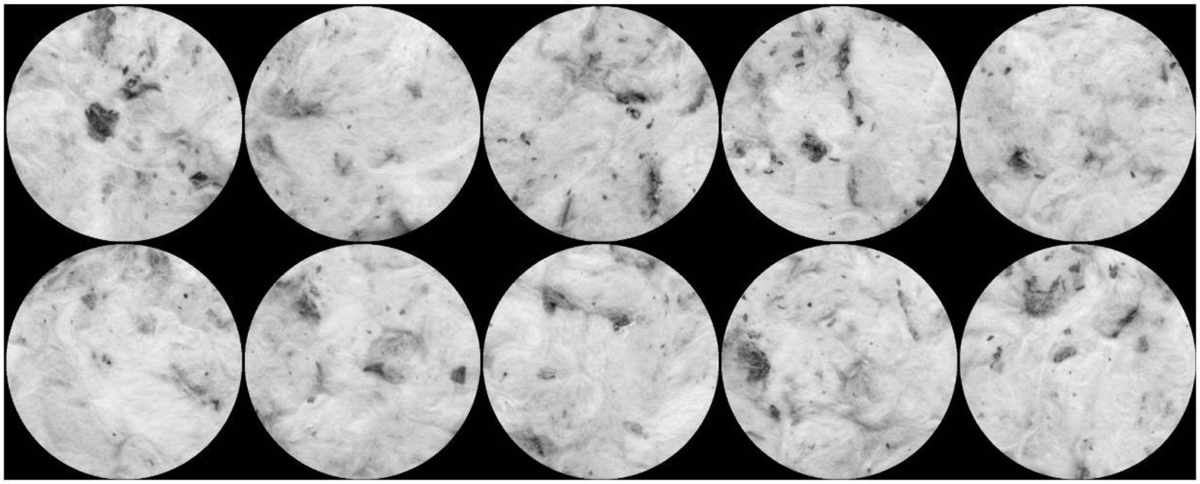


Figure 12. LCH-L.

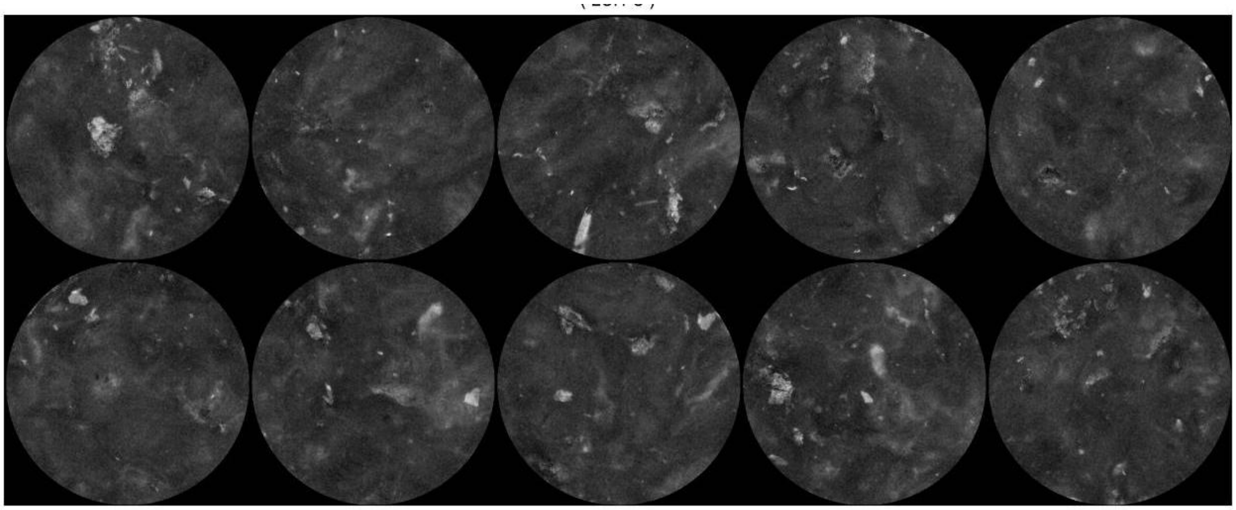


Figure 13. LCH-C.

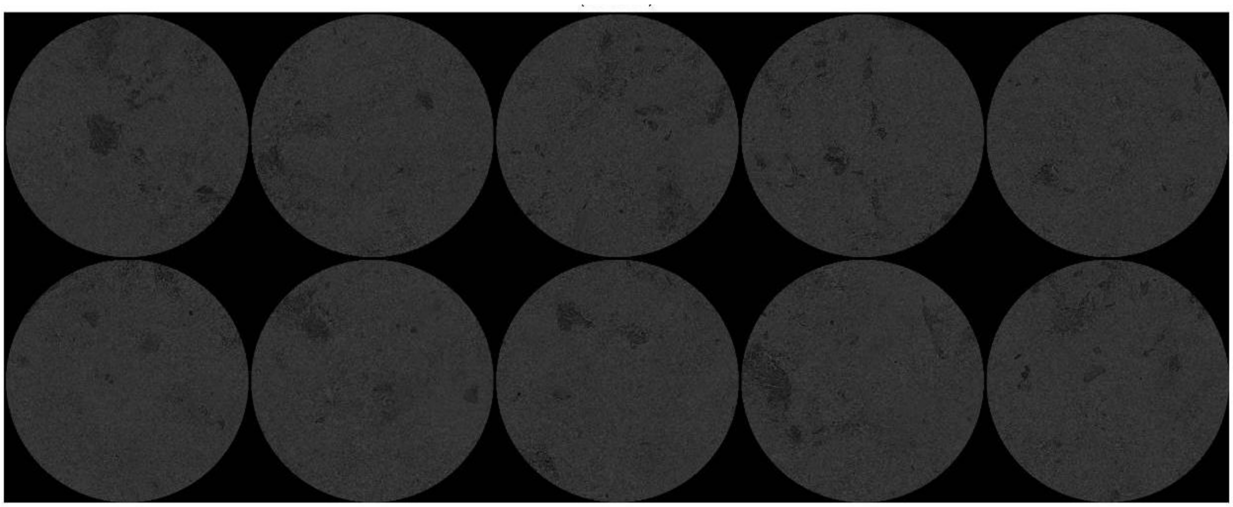


Figure 14. LCH-H.

The color information in LCH color space and CIE Lab spaces are separated into constituent channels and values of every channel are shown in gray scale. When both spaces are examined L channels have similar Lightness information. Although in CIE Lab space (a*-b*) are the chromatic axes where red/green opponent colors are represented along the a* and yellow/blue opponent colors are represented along the b* axis with yellow at positive b* values. Cotton sample is composed of mostly white and yellow colors b channel of CIE Lab color space and C channel of the LCH shows mostly similar information. Although hue angles obtained from H channel of LCH color space and a* channel values of CIE Lab color space obtain some information about irregular regions, CIE Lab, L and b* channels or LCH L and C channels obtain enough information for irregular region detection (30).

Thresholding is one of the most widely used and one of the simplest image segmentation methods. In this method one or more threshold values are determined and comparing threshold value/s with every pixel lead to segmenting the image into different regions. The Thresholding operation can be applied to image:

$$B_{i,j} = \begin{cases} 0 & if \quad I_{i,j} < T \\ 1 & if \quad I_{i,j} \geq T \end{cases} \qquad (8)$$

Thresholding operation where T is the threshold, I is the image pixel value at i,j coordinates result in binary image B at the same pixel location.

When the figures of color channels are examined it can be concluded that some color channels reveal irregular regions and cotton samples separately which reveals that these are candidates of segmentation by using thresholding method. All the color channels are separately threshold for comparison and examination. Two threshold values are determined by calculating the standard deviation (σ) and the mean of the images (μ) in that channel and $\mu+2\sigma$ and $\mu-2\sigma$ are the thresholds. Every pixel is compared with corresponding criteria which are greater than $\mu+2\sigma$ and less than $\mu-2\sigma$ the figure shows one of the sample and detected pixels which satisfies the corresponding criteria.

Figure 15. LCHL (L < Lth).

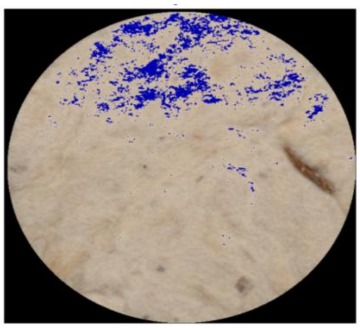


Figure 16. LCHL (L > Lth).

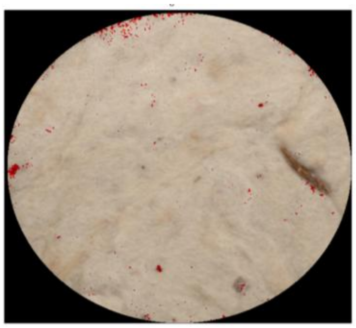


Figure 17. LCHC (C < Cth).

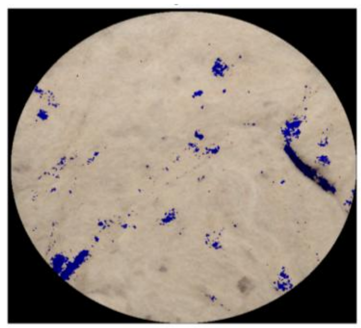


Figure 18. LCHC (C > Cth).

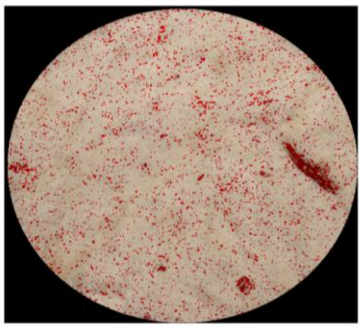


Figure 19. . LCH (H < Hth).

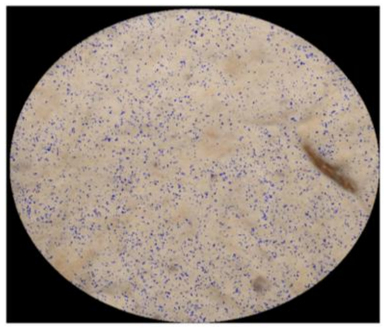


Figure 20. LCHC (H > Hth).

4.2.3. Logical OR Gate:

When the segmentation results are examined the L and C channels of LCH space are promising to be used as well L and b channels of CIE LAB space. a* channel of CIE Lab space also has some promising information although it is not enough to determine the irregular regions (22) (31). When the promising channel segmentation results are examined further CIELAB L channel is same (as was expected) LCH_L channel and b channel has similar results with Hue angle segmentation. Cotton lint has the color white and yellow in different depths in general and while the CIE LAB-b channel includes the yellow color information this finding is meaningful (14) (32).

Further the paper suggested using L and C channels for segmentation and here it is shown that these channels obtain most of the information for segmentation process. In order to determine the threshold values suggested to obtain the average values of irregular region color values manually and using these as thresholds for the segmentation process (33) (34).

But in this process the threshold values are actually calculated automatically with the help of eqn (9).

$$B_1 = \begin{cases} 1 & if \quad L_{i,j} < T_1 \\ 0 & if \quad L_{i,j} \geq T \end{cases} \tag{9}$$

$$B_2 = \begin{cases} 1 & if \quad C_{i,j} \geq T_2 \\ 0 & if \quad C_{i,j} < T_2 \end{cases} \tag{10}$$

Thresholding L channel and C channel using T1 and T2 thresholds respectively leads to B1 and B2 binary images revealing irregular regions where thresholds are calculated using following relations:

$$T_1 = \mu_L - 2\sigma_L \tag{11}$$

$$T_2 = \mu_C + 2\sigma_C \tag{12}$$

Where σL is standard deviation and μL is the mean of L channel values, similarly σC is standard deviation and μC is the mean of C channel values of LCH color space. These two criteria must be used in connection with each other suggested to combine two criteria with a logical "AND" operator. This means the pixels whose values satisfy both of the criteria at the same time are labels as irregular region otherwise labeled as cotton region. Following images show that logical "OR" operator must be used in order to detect irregular regions (35).

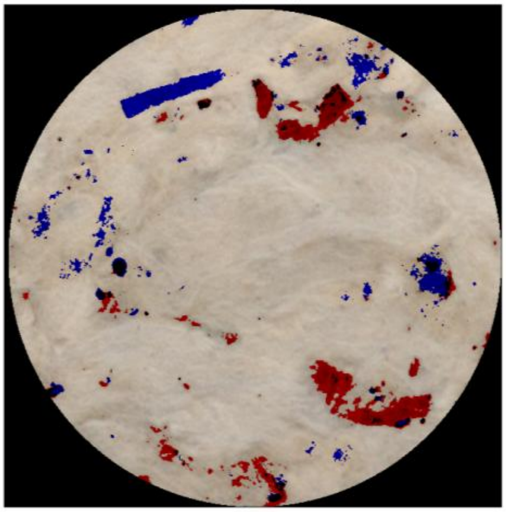


Figure 21. (L < Lth) (C > Cth).

Images in RGB space can be converted into the CIE L*a*b* space with the help of the following conversion equations.

$$L^* = 116 f(Y/Y_n) - 16 \quad (13)$$

$$a^* = 500[f(X/X_n) - f(Y/Y_n)] \quad (14)$$

$$b^* = 200[f(Y/Y_n) - f(Z/Z_n)] \quad (15)$$

where $f(t) = t^{1/3}$ if t > 0.008 856, else $f(t) = 7.787t + 16/116$

5. Summary of the results achieved

5.1. AMS Cotton Samples:

Twelve cotton samples used in this experiment with provided Rd and +b values. These values compared with the new method and observed with a new light source. The reflectance data of each cotton sample is measured with the Hunter lab Miniscan XE. The non-contact method which is used for the color measurement of cotton sample is very useful. It gives precise measurement of the color because the luminance values are used in this method.

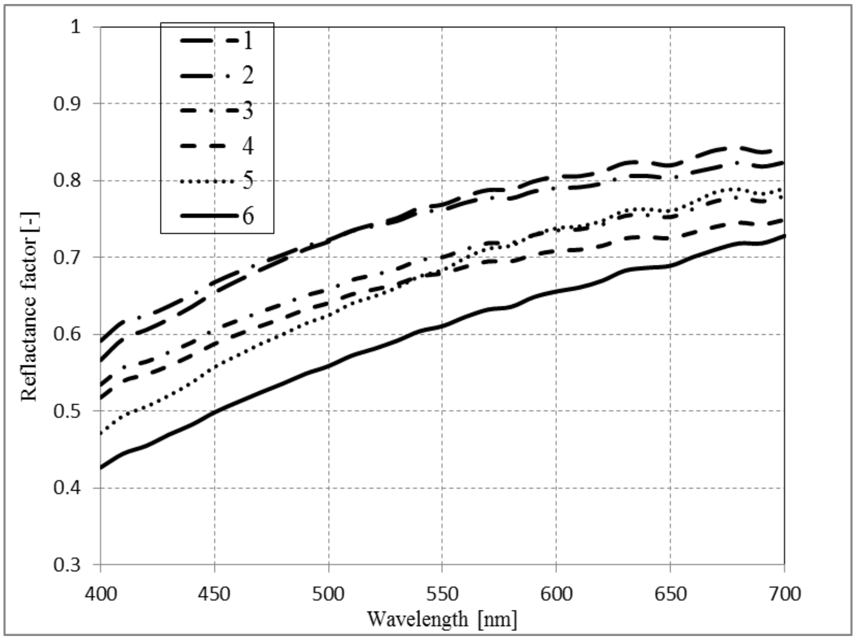


Figure 22. . Reflectance data obtained from the HunterLab Miniscan XE for cotton samples 1,6.

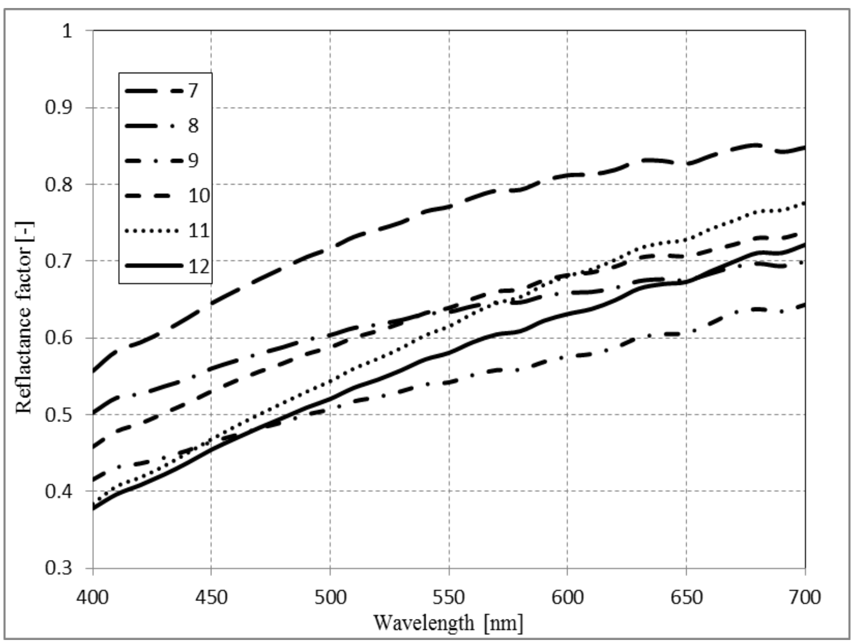


Figure 23. Reflectance data obtained from the HunterLab Miniscan XE for cotton samples 7, 12.

According to the CIE this is hypothetical typical human visual system and its application is useful in the cotton color grading. The disagreement between the instrumental measurement of cotton color and the visual inspection of cotton color is present since 1930s. The human observer can see in the range of (400-700) nm in the spectral region. On the other hand HVI is not capable for doing this due to the fact it uses two filters for lightness and yellowness. So, the non-contact method is a good alternate for the visual color measurement. This method is capable to reduce the disagreement between the visual grading of cotton and instrumental grading of cotton (36).

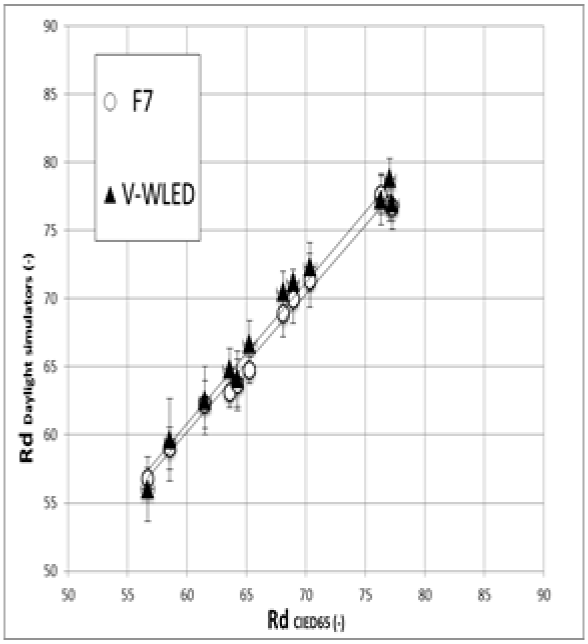


Figure 24. Comparison of Rd values between VW LED and AT D65 Simulator.

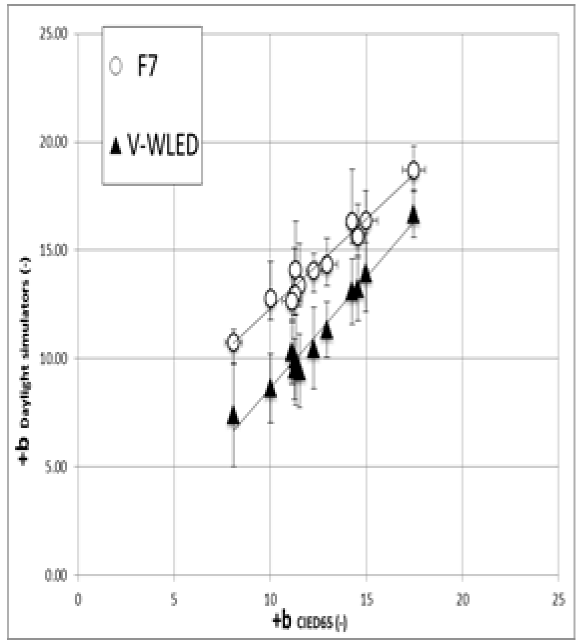


Figure 25. Comparison of +b values between VW LED and AT D65 simulator.

Fig (24) and (25) shows comparison of Rd and +b is shown between the daylight simulator and the VW-LED. The correlated color temperature of AT D65 is (6200K) and the VW LED is (5910K). The Rd values show a great correlation between these two light sources. But (+b) the yellowness values shows a small shift of the AT D65 values. This effect is due to the color temperature of the used light source which is not equal to the Xenon color temperature as used in the HVI system (37).

The LEDs which are equipped with the blue chips do not possess the full range of spectrum. These LEDs are easily available in the market but their use in the cotton color grading is not possible due to the lack of range of full spectrum. As the instrumental measurement of cotton color should be in the range of (400-700) nm. This is because of the human eye can see the color in this range of spectrum (38). This shift of +b values confirmed that the light source used for the color grading of cotton is having a lower temperature than the Xenon so, the same sample can be graded in the different color grade with different color temperature of the light source.

Table 2. . The values of slope, y-intercept and correlation coefficient for Rd by using AT D65 simulator and V-W LED.

	a	b	R^2
AT D65 simulator	1.01	.46	.99
VW LEDs	1.03	1.48	.98

Table 3. The values of slope, y-intercept and correlation coefficient for +b by using AT D65 simulator and V-W LED.

	a	b	R^2
AT D65 simulator	.91	.39	.97
VW LEDs	.94	3.76	.98

Similarly like AMS tiles the reflectance data of these samples is measured which is shown in above given figures. The results indicates a strong relationship between the non-contact methods (in which LED are used as light source) and HVI. AMS cotton standards were selected for the experiment because they are the globally recognized standards for the cotton color grading. USDA provides these standards with the given Rd and +b values. Strong correlation between HVI and Non-contact method shows that this new method is appropriate to use in the color grading system of cotton globally. The reflectance data used for the color space conversions. And it is available to analyze the reflectance at each wavelength (39).

5.2. Comparison of the Rd values (USDA cotton samples) between the Miniscan and Labscan:

Table 4. CIE XYZ values comparison between Miniscan and Labscan foe USDA cotton samples.

Cotton Samples	Miniscan XE			Labscan XE		
	X	Y	Z	X	Y	Z
USDA 1	72.79	76.48	70.38	64.37	67.73	61.56
USDA 2	72.09	75.85	71.73	64.26	67.67	63.11
USDA 3	66.63	69.85	65.07	60.33	63.37	57.98
USDA 4	64.38	67.63	63.14	56.64	59.58	55.12
USDA 5	65.51	68.25	59.9	57.67	60.21	51.94
USDA 6	58.52	60.93	53.65	51.48	53.69	46.97
USDA 7	73.02	76.63	69.45	65.13	68.47	61.32
USDA 8	60.19	63.24	60.19	53.80	56.54	53.44
USDA 9	52.06	54.29	50	46.72	48.78	44.99
USDA 10	61.07	63.7	57.12	53.75	56.05	49.11
USDA 11	59.53	61.44	50.57	51.74	53.45	42.79
USDA 12	55.81	57.89	48.99	49.00	50.92	42.44

The comparison between the Miniscan and hunterlab is made to confirm that sometime the instruments measures same parameters but the geometry used for measurement is different and it affects the parameters. Same is with the Hunterlab Miniscan and Labscan. These two instruments measures same parameters and apparently look same but actually the Miniscan XE possess $45^0:0^0$ geometry and Labscan possess $0^0:45^0$ geometry. The influence can be seen clearly in the values obtained from these two instruments. The reason behind this is that the light fall on the sample and the difference of the refractive indices (40).

The Y values obtained from the Miniscan XE are higher than the Y values from Labscan. Y values here are representative of the Rd values. The Rd values dependent on the incident angle of light source and the geometry of the instrument in which the angle of incident light source is different from the other instrument is a major reason of different *Rd (Y)* values (41).

The refractive indexes of a section through a mineral can be determined by maximum and minimum refractive indexes of the section through the optical indicatrix. The vibration directions of the light ray travelling perpendicular to this section are given by the directions of the maximum and minimum refractive indexes. These directions are described as the fast and slow ray and can behave as two separate polarized rays of light.

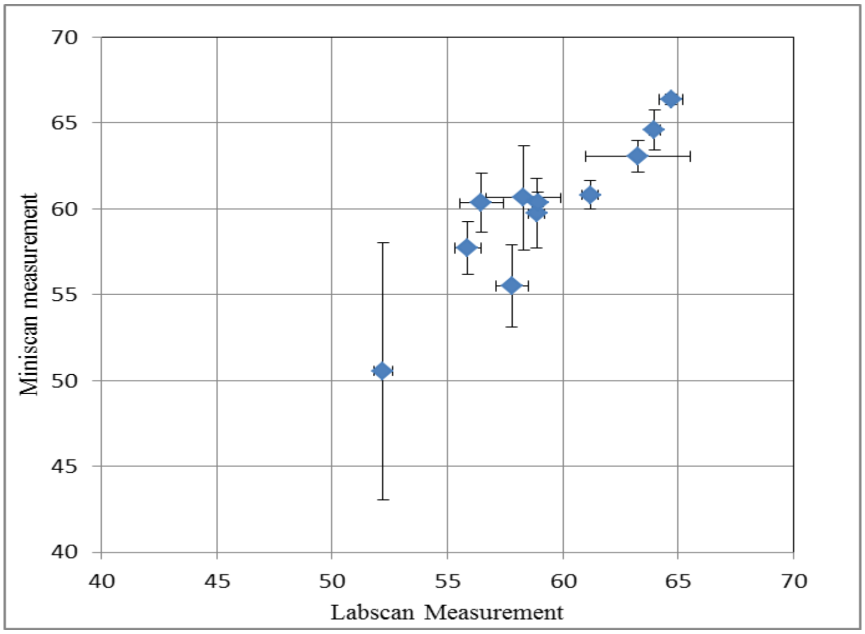


Figure 26. Comparison of USDA cotton samples Rd values between Labscan and Miniscan XE.

5.3. Use of different Illuminants for the color measurement of Cotton samples.

Cotton samples are observed under illuminants for the CIE XYZ values. (D65) illuminant is used with the correlated color temperature of (6500K). (A) Illuminant is used for the correlated color temperature of (4000K). (F11) illuminant is used for the correlated color temperature of (2800K). The three illuminants show good relationship in all the cotton samples. As discussed earlier that the CIE XYZ values does not represent the actual visible phenomenon of color grading of cotton. The Rd and +b values are the better representation of color grading of cotton. So, it is very easy to convert the CIE XYZ values into Rd, a, b values (42).

Table 5. . Comparison of CIE XYZ values obtained under different illuminants.

Cotton Samples	D65			A			F11		
	X	Y	Z	X	Y	Z	X	Y	Z
1	73.12	77.05	71.88	87.25	78.22	23.83	78.74	77.75	42.08
2	72.38	76.32	73.17	85.89	77.26	24.20	77.77	76.89	42.90
3	66.95	70.34	66.40	79.80	71.42	21.98	72.01	70.95	38.91
4	64.66	68.09	64.45	76.98	69.05	21.33	69.54	68.65	37.77
5	65.92	68.93	61.28	79.58	70.52	20.37	71.28	69.79	35.79
6	58.89	61.53	54.88	71.13	62.95	18.24	63.67	62.32	32.09
7	73.38	77.26	70.96	87.82	78.57	23.55	79.14	78.05	41.52
8	60.45	63.61	61.38	71.73	64.41	20.29	64.88	64.04	36.00
9	52.35	54.71	51.03	62.75	55.74	16.89	56.34	55.23	29.91
10	61.42	64.28	58.38	73.86	65.61	19.37	66.32	65.04	34.17
11	60.02	62.25	51.85	73.54	64.25	17.31	65.26	63.34	30.22
12	56.23	58.57	50.20	68.48	60.20	16.73	60.95	59.46	29.27

The HVI diagram which is actually based on the Rd and +b values is used for the cotton grading. Initially in 1930s when it was presented first time it was based on the Munsell value and the chroma. But, this diagram is not based on these values. The lines which play a role of separating the grades from each other were not in this shape first but then these lines were actually moved to curvilinear shape. We have done some analysis on this diagram and showed that which of the function is fitted for these curvilinear lines statistically. Four polynomial functions are used here to get the best fit model for these curves.

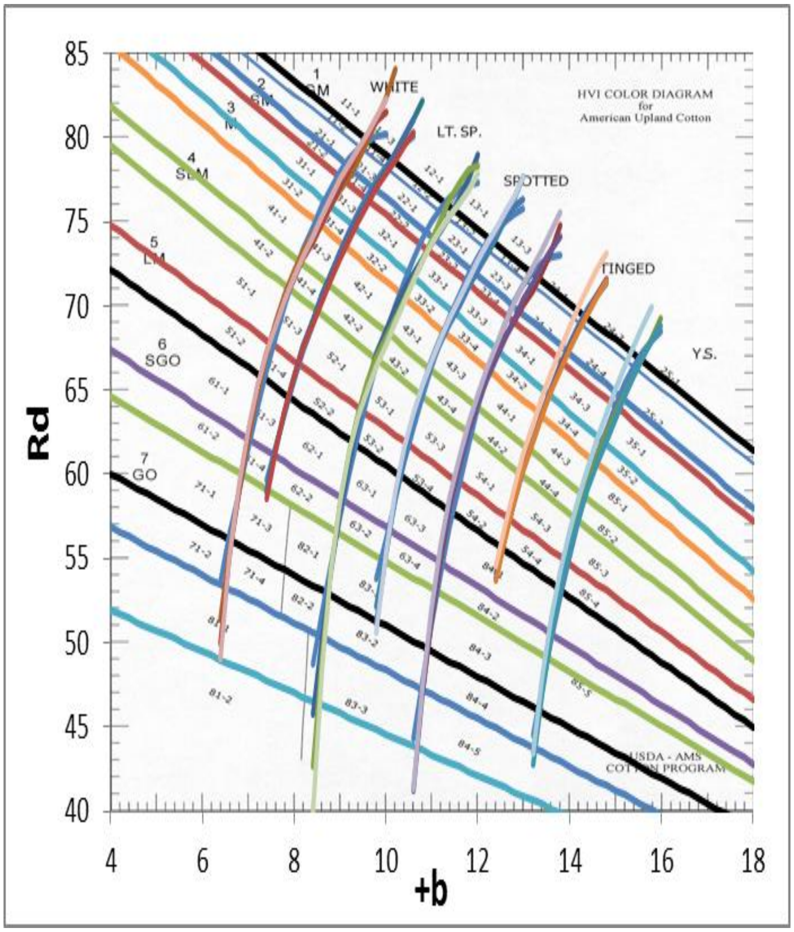


Figure 27. HVI diagram shows comparison of the different polynomial functions.

In the above shown figure the vertical lines which are curvilinear are used to separate the cotton color grades. These grades are the major grades. And the horizontal lines which are the subcategories of the major grades. In the vertical lines which can also be known as border lines the 4 polynomial functions have been used. Second degree, third degree, fourth degree and fifth degree polynomial function is used for the comparison. The statistical values related to these models are given below. The statistics software origin pro is used for the analysis. The points which are taken on the HVI diagram are as Rd and +b.

Table 6. 2nd degree polynomial function for HVI diagram vertical lines.

	df	Sum of square	Mean square	F value	Prob>F
White	2	8263.03	4131.52	2.67E+29	0
White dotted	2	36971.27	18485.63	5.39E+29	0
Lt. Spotted	2	25812.98	12906.49	2.55E+29	0
spotted	2	136387.14	68193.57	6.81E+29	0
Tinged	2	332401.41	166200.71	2.04E+30	0
Tinged dotted	2	127143.37	63571.69	1.75E+30	0
Spotted dotted	2	40820.55	20410.28	5.31E+29	0

Table 7. 3rd degree polynomial function for HVI diagram vertical lines.

	df	Sum of square	Mean square	F value	Prob>F
White	3	199748.2	66582.75	6.33E+28	0
White dotted	3	1.36E+06	453266.7	1.32E+29	0
Lt. Spotted	3	407887.4	135962.5	2.15E+28	0
spotted	3	1.19E+06	396048.7	2.15E+28	0
Tinged	3	3.23E+06	1.08E+06	8.79E+28	0
Tinged dotted	3	627629.9	209210	6.44E+28	0
Spotted dotted	3	388579.3	129526.4	1.67E+28	0

Table 8. 4th degree polynomial function for HVI diagram vertical lines.

	df	Sum of square	Mean square	F value	Prob>F
White	4	199748.2	49937.06	5.58E+28	0
White dotted	4	1.73E+07	4.33E+06	1.65E+28	0
Lt. Spotted	4	3.85E+06	963655.8	7.68E+26	0
spotted	4	4.84E+06	1.21E+06	9.48E+26	0
Tinged	4	5.91E+07	1.48E+07	5.40E+27	0
Tinged dotted	4	876892.9	219223.2	1.99E+28	0
Spotted dotted	4	1.40E+06	349979.8	3.55E+26	0

Table 9. 5th degree polynomial function for HVI diagram vertical lines.

	df	Sum of square	Mean square	F value	Prob>F
White	5	4.06E+07	8.11E+06	1.25E+27	0
White dotted	5	4.49E+08	8.98E+07	5.25E+27	0
Lt. Spotted	5	6.16E+07	1.23E+07	9.06E+25	0
spotted	5	2.20E+07	4.40E+06	8.32E+25	0
Tinged	5	1.23E+09	2.47E+08	5.31E+26	0
Tinged dotted	5	1.47E+08	2.94E+07	1.31E+26	0
Spotted dotted	5	1.70E+07	3.40E+06	2.90E+25	0

The purpose of using the polynomial function which are given below is to show that which model is best for the diagram. Origin pro statistical software is used for the statistical analysis and this analysis is helpful for predicting the best model. 4^{th} degree polynomial function is best fit for the curvilinear lines. In the first step we took the points on each line which is shown in the graph and on the basis of these points the polynomial function is applied for all the curves. 4^{th} degree polynomial function is best fit for all the lines shown in the vertical direction of the graph.

5.4. Comparison of non-contact method with HVI and Hunter Lab Miniscan XE:

The Rd values of the obtained from different methods are shown. The samples which are used actually from the USDA department and the Rd values of HVI is provided with them from the AMS department USDA. It is observed that the Rd (degree of reflectance) values obtained from different instrumental measurements possess a strong relation. Non- contact method which actually uses luminance values for the color measurement also shows good results as compared to the HVI and spectrophotometer. As far as the +b (yellowness).

Table 10. CIE XYZ values of Contact method and non-contact method.

Cotton Sample	Contact Method			Non-contact Method		
	X	Y	Z	X	Y	Z
1	73.12	77.05	71.88	76.66	78.84	64.72
2	72.38	76.32	73.17	74.68	77.28	65.12
3	66.95	70.34	66.40	69.79	72.35	59.56
4	64.66	68.09	64.45	68.17	70.51	57.78
5	65.92	68.93	61.28	69.63	71.19	53.68
6	58.89	61.53	54.88	60.79	62.52	46.03

Values are considered, it also shows that the comparison between the HVI (+b) and non-contact method (+b) have same trend within the samples. But due to the variation in the color temperature which enables samples to be enlighten inside the box, there might be the possibility that the value of the yellowness with the non-contact method higher. But, if the exact color temperature is used within the box to enlighten the sample carefully strong relationship is observed (37).

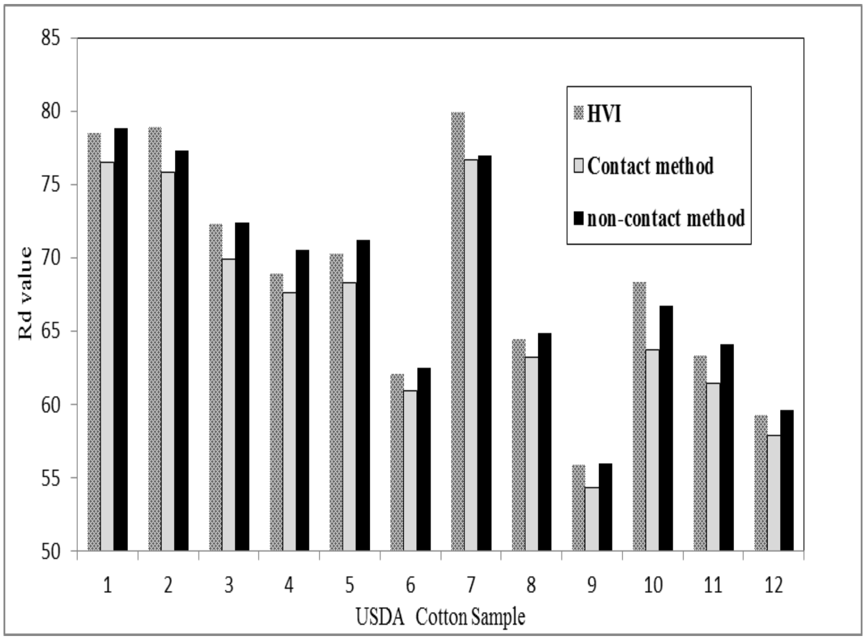


Figure 28. Comparison of Rd values of non-contact method with the HVI and contact method.

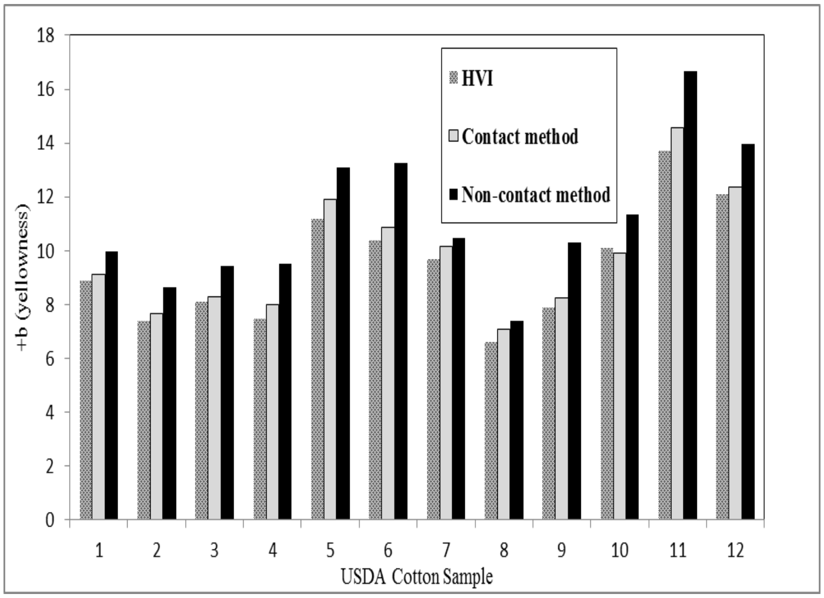


Figure 29. comparison of +b values of non-contact method with the HVI and contact method.

As the LEDs are used for light source. The LEDs which are used to cover the full spectrum range (400-700 nm). In our previous studies it was observed that the correlated color temperature which is used for the enlightenment of cotton samples is very important. It really effects the +b (yellowness) of the cotton samples. So, it is very important to use the LEDs with the full spectrum and also used the same range of temperature as it is used in the HVI and contact method (Hunter Lab Miniscan XE) Xenon lamp. Although the spectrophotometer method which can be used for the color measurement of cotton is not used gl (43).

5.5. Non-contact method for measurement the color variation in a cotton sample:

In this research, 12 cotton samples of known Rd and +b value are used in order to investigate the color variation of cotton samples which are provided by the CCRI, Multan Pakistan. The research conducted in this study reveals the variation of color which further affects the cotton grade when it is classified. The properties of the cotton samples measured with the HVI are given below:

Table 11.Properties of cotton samples measured with HVI.

Cotton Sample	Length (mm)	Strength (cN/tex)	Elongation	Micronaire (µg/inch)	Rd (Degree of reflectance)	+b (yellowness)
159 CCRI	23.8	23.92	6	5.4	60.6	9.1
2013/2 CCRI	25.4	27.35	5.8	3.8	64.9	11.6
2012/3 CCRI	26.6	27.55	6.3	3.7	71.5	12.7
131 CCRI	24.9	27.65	5.4	3.8	66.1	8.4
2014/1 CCRI	24.7	26.37	6.1	4.5	68	13.6
2014/3 CCRI	26.4	28.63	5.9	3.5	74.7	8.9
117 CCRI	24.6	24.61	5.2	4.9	53	10.6
149 CCRI	25.2	25.20	5.3	4.8	68.2	8.8
156 CCRI	25.2	28.04	5.4	3.8	62.3	9.6
143 CCRI	27.3	29.31	6.3	3.9	64.4	9.6
2014/2 CCRI	26.8	26.86	6.1	3.8	76.4	12
109 CCRI	25.4	30.98	6	3.2	58.5	8.9

When the cotton is classified according to the color parameter visually, there are so many factors which really effect the cotton color grading. So, it is very important that the ambient light and the room should in correct manners so, that the error should be as less as possible. Generally, the lighting which is installed should be diffused and it should give the classer a perception of depth as the classer looks into the sample. The glare and the cross-lighting should be avoided and the brightness contrast should be kept at the minimum level. Since, the development of instrumental measurement the visual inspection of cotton color is still the more reliable grading method. This is because of the disagreement between the visual color measurement and instrumental color measurement. In our new method (non-contact method) 45^o is used for the measurement of cotton color. So, it was necessary in the visual grading that the classer should stand at 45^o of viewing angle for the classification of cotton. No ambient light and cross lighting is allowed in the room for the classification. And the Samples effect is considered significant. Currently the visual grading system which is used globally contains black background of the table top and the color of the table should be neutral gray with white ceiling. In this study while carrying out the visual inspection experiment three different kind of backgrounds are used here, in which black, neutral grey and white backgrounds are used. The Pakistani cotton used for this experiment and contains no. of trash particles in it. The observer is being asked to grade the cotton according to the reference of USDA samples which are used in the earlier part of the research. The observer is called three times with constant light source and different background appearance (44).

While giving cotton a grade the cotton observer is asked to rank the cotton sample according to the degree of the whiteness. Then by using statistical software trilobyte QC expert the observation were analyzed with and the given results are examined.

Table 12. Effect on Rd values due to the different backgrounds examined by visual grading.

Neutral Background		Black Background		White Background	
Cotton Sample	Rd	Cotton Sample	Rd	Cotton Sample	Rd
109 CCRI	68.9	109 CCRI	68.3	109 CCRI	64.4
117 CCRI	68.3	117 CCRI	55.9	117 CCRI	55.9
131 CCRI	64.4	131 CCRI	62.1	131 CCRI	68.3
143 CCRI	68.9	143 CCRI	68.9	143 CCRI	68.3
149 CCRI	78.5	149 CCRI	68.3	149 CCRI	68.9
156 CCRI	62.1	156 CCRI	68.3	156 CCRI	59.3
159 CCRI	55.9	159 CCRI	68.9	159 CCRI	68.3
2012/3 CCRI	63.3	2012/3 CCRI	59.3	2012/3 CCRI	63.3
2013/2 CCRI	59.3	2013/2 CCRI	62.1	2013/2 CCRI	59.3
2014/1 CCRI	63.3	2014/1 CCRI	63.3	2014/1 CCRI	63.3
2014/2 CCRI	70.3	2014/2 CCRI	70.3	2014/2 CCRI	70.3
2014/3 CCRI	79.9	2014/3 CCRI	78.5	2014/3 CCRI	79.9

Table 13. Anova table for the Different background observation.

Anova table for Rd values								
Source of variability	Sum of suares	Mean squares	Degree of freedom	St. Deviation	F-statistic	Criticle quartile	Conclusion	p-value
Background	18.87	9.44	2	3.07	.35	3.44	Insignificant	.70
Cotton samples	705.67	64.15	11	8.01	2.42	2.30	Significant	.04
Interaction	5.82	5.82	1	24.13	.21	4.32	Insignificant	.65
Residuals	576.35	27.45	21	5.24				
Total	1306.71	37.33	35	6.11				

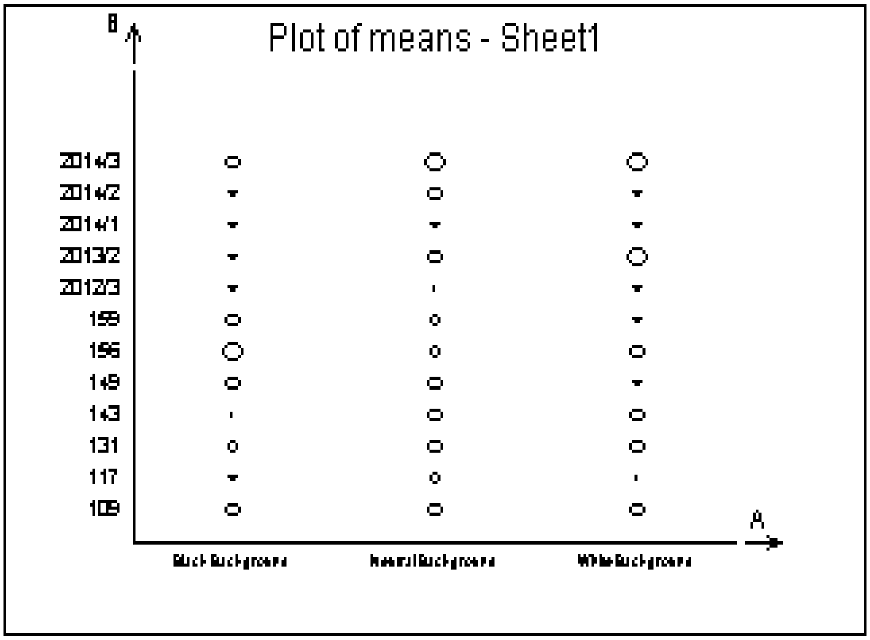


Figure 30. Plot of means with different background effect.

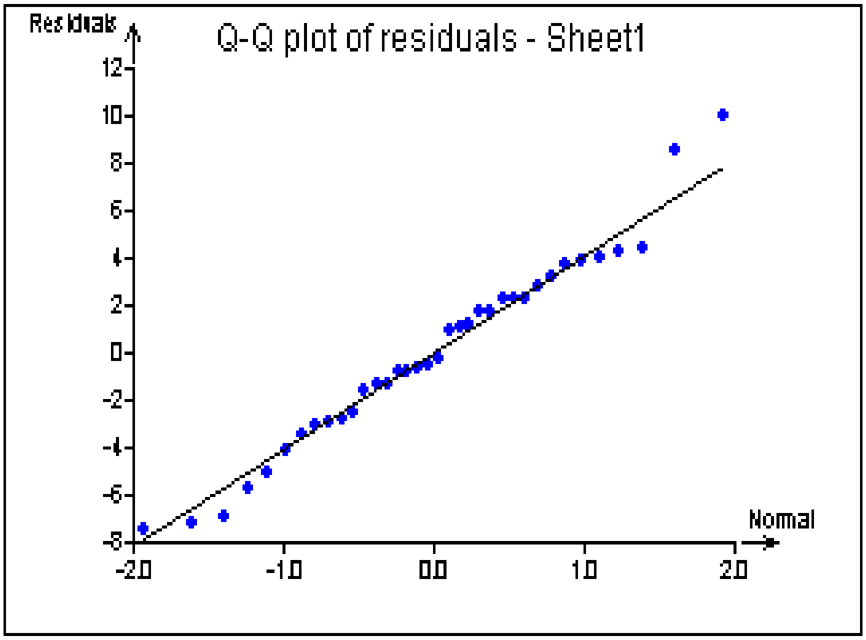


Figure 31. Q-Q plot of residuals.

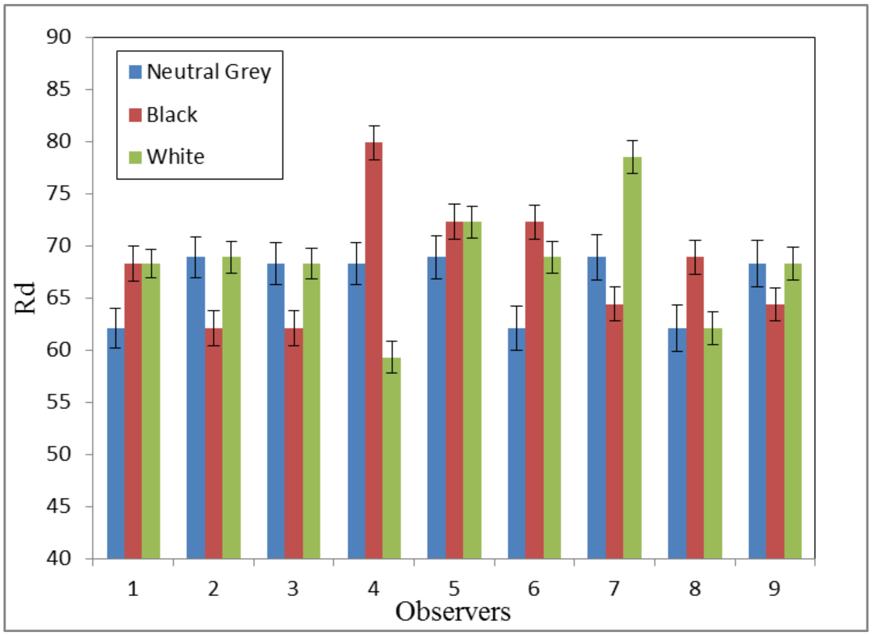


Figure 32. Effect of different backgrounds on the Rd values.

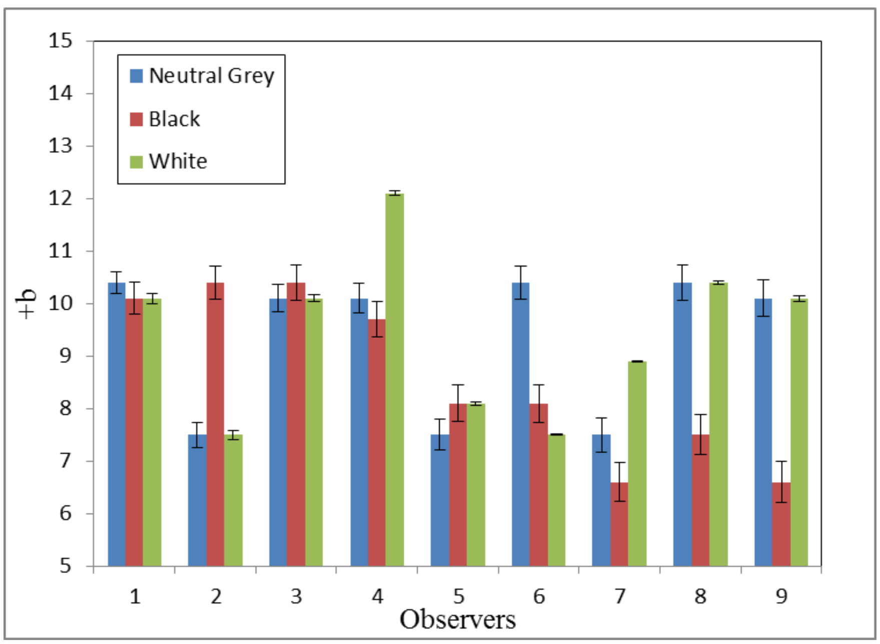


Figure 33. Effect of different cotton samples on +b values.

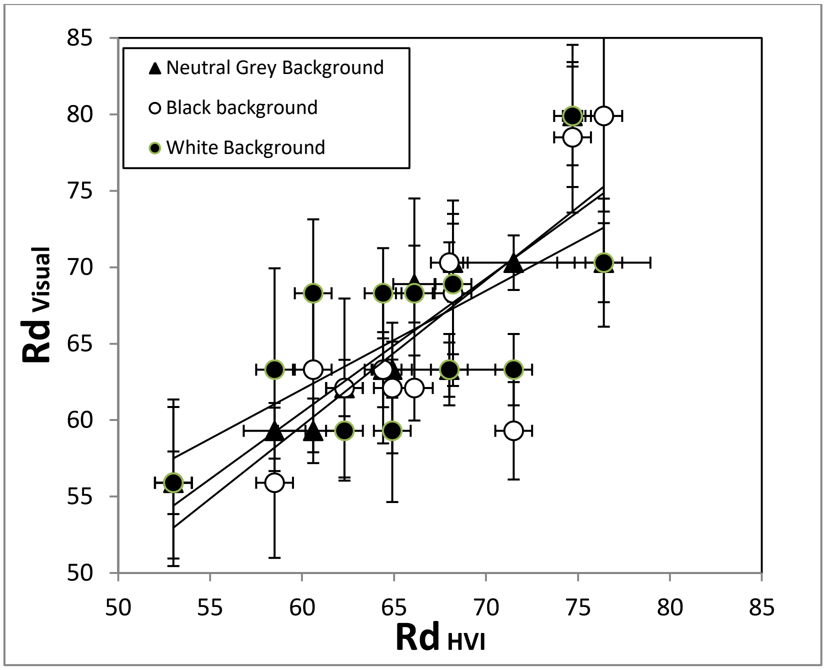


Figure 34. Rd values comparison between HVI and visual inspection.

Table 14. Equation of the line for different backgrounds.

	a	b	R^2
Neutral Grey Background	.87	8.1	.78
Black Background	.95	2.37	.66
White Background	.64	23.3	.45

The spearman rank co-relation is used for analysis of cotton samples degree of whiteness. The objective of this analysis is to compare the visual results from different backgrounds for the conclusion that whether on the industrial scales the neutral background or the white backgrounds is capable to use for the grading of the cotton sample. The observers of same age level were selected and they were fully aware of the cotton grading system internationally according to the USDA provided visual system. Below given tables are showing the capability of the observer to classify the cotton on the basis of its color. All the observers were aware that the trash particles present on the surface of the cotton should not be taken into consideration while giving the ranking to the cotton according to whiteness (45).

Table 15. Rank order between Black and neutral grey background assigned by the observers.

Cotton Samples	Neutral Grey Background	Black Background
	Ranking Order (x)	Ranking Order (y)
119 CCRI	5	5
117 CCRI	7	8
131 CCRI	5	5
143 CCRI	3	3
149 CCRI	3	3
156 CCRI	6	6
159 CCRI	7	6
2012/3 CCRI	11	11
2013/2 CCRI	9	9
2014/1 CCRI	11	12
2014/2 CCRI	9	10
2014/3 CCRI	2	1

For the comparison of neutral grey background and black background the spearman rank co-efficient (r_s = .99) is observed. Which enables to conclude that neutral background results are quite capable to represent the cotton color just like black background.

The comparison between the white background and black background is also of great importance. The spearman rank co-efficient (r_s = .98) is observed. This comparison enables us to predict that in the case of cotton whiteness measurement the all three backgrounds show quiet similar results to each other. It is also very interesting that the observer were not aware of the sample name during the ranking and only the physical appearance of the cotton was available for them for the measurement. In the next part of the trash segmentation is performed and the comparison of the results from visual experiment with instrumental measurement is observed.

The above given results indicates whiteness index measurement with comparison to the visual ranking of the observer. The below given formula is used for the measurement of W_{CIE}. And the visual experiment is performed on the basis that observer rank the cotton sample according to its whiteness (46).

$$W_{CIE} = Y + 800\,(x_n - x) + 1700\,(y_n - y) \quad (16)$$

The transformation from RGB space to CIE L*a*b* space requires an intermediate step in which R, G and B variables are corresponding of the red, green and blue values of the color image in RGB space respectively:

$$X = 0.412453\ R + 0.357580\ G + 0.180423\ B \quad (17)$$

$$Y = 0.212671\ R + 0.715160\ G + 0.072169\ B \quad (18)$$

$$Z = 0.019334\ R + 0.119193\ G + 0.950227\ B \quad (32)$$

Table 16. Image processing tool box transforms color images from RGB into CIE L*a*b*.

	Cotton Sample	109 CCRI	117 CCRI	131 CCRI	143 CCRI	149 CCRI	156 CCRI
L	Min	27.61	19.64	25.62	31.7	25.23	22.33
	Max	86.66	85.93	89.03	88.0	89.20	89.02
	Mean	73.36	71.04	76.07	76.0	75.16	73.94
	Median	74.02	72.11	76.88	76.3	76.47	74.74
	Std.Dev	5.12	6.47	5.17	3.94	6.13	5.42
a	Min	-3.76	-5.13	-3.08	-4.2	-3.96	-4.23
	Max	21.96	24.73	23.35	20.5	23.00	27.11
	Mean	2.41	3.07	2.73	2.27	2.50	2.83
	Median	2.37	2.94	2.63	2.23	2.43	2.72
	Std.Dev	1.31	1.63	1.46	1.29	1.40	1.56
b	Min	1.09	-0.15	0.26	2.29	1.99	-1.37
	Max	34.44	35.89	31.27	27.8	34.46	31.83
	Mean	9.45	10.57	10.03	9.49	9.31	10.07
	Median	9.29	10.28	9.70	9.14	9.11	9.81
	Std.Dev	1.88	2.37	2.32	2.17	1.93	2.12

Table 17. . Image processing tool box transforms color images from RGB into CIE L*a*b*.

	Cotton Sample	159 CCRI	2012/3 CCRI	2013 2 CCRI	2014/1 CCRI	2014/2 CCRI	2014/3 CCRI
L	Min	12.46	43.56	28.24	34.93	47.01	36.52
	Max	85.10	88.62	87.45	85.75	89.20	88.82
	Mean	69.70	76.14	74.91	76.02	78.70	78.06
	Median	71.44	76.43	75.41	76.20	78.88	78.37
	Std.Dev	7.76	3.60	4.32	2.86	3.34	3.86
a	Min	-4.17	-2.17	-2.76	-2.02	-2.78	-3.54
	Max	25.12	21.63	23.48	18.75	19.08	16.79
	Mean	2.70	3.90	3.46	3.97	3.16	2.56
	Median	2.50	3.86	3.40	3.96	3.13	2.52
	Std.Dev	1.84	1.31	1.36	1.18	1.23	1.23
b	Min	-0.43	5.16	2.34	6.59	4.46	2.11
	Max	32.28	30.36	27.13	28.36	24.74	22.91
	Mean	8.95	14.90	11.58	14.67	12.83	9.81
	Median	8.65	14.82	11.47	14.65	12.71	9.75
	Std.Dev	2.31	2.04	1.85	1.37	1.93	1.56

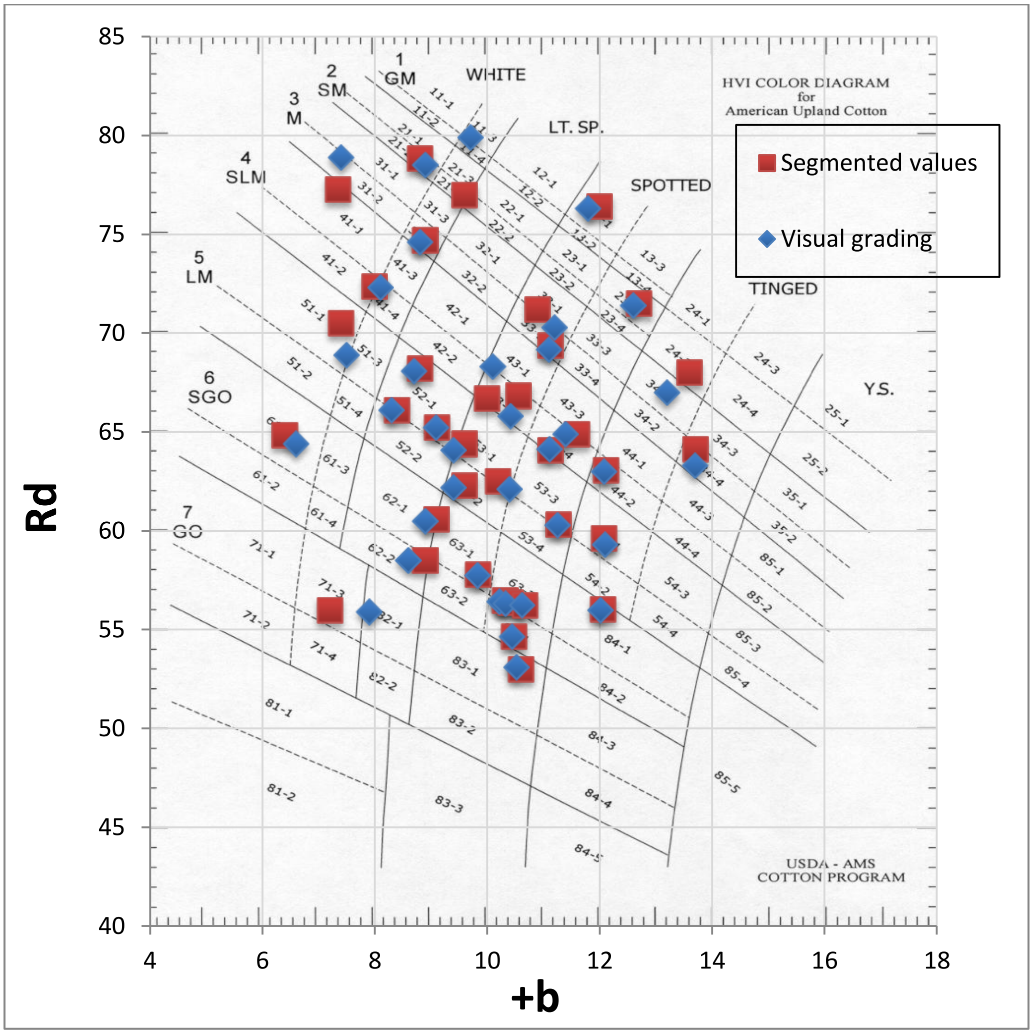


Figure 35. HVI Color Diagram representing Segmented and visual inspection values.

Fig. 35. HVI color diagram includes the samples graded with visual grading and by using segmented method by thresholding technique. The disagreement between these two methods is decreased upto a considerable extent. It means that the sample which is graded by visual inspection with some category will also have the same category if it is graded with the image analysis method as well. Purpose is to show the reduction of the disagreement between the visual grading and instrument grading. In the below given fig.36 and 37 the linear relationship between two color parameters Rd and +b is shown.

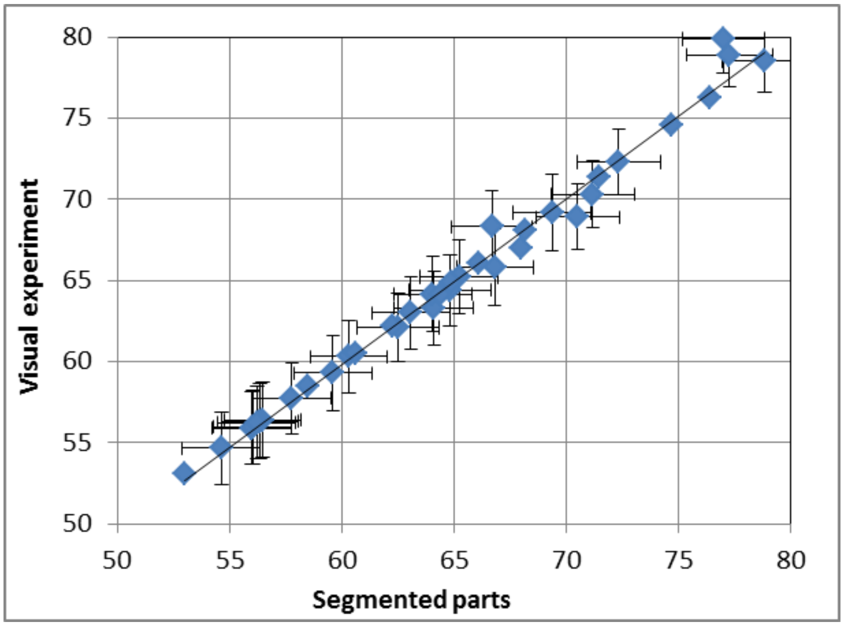


Figure 36. Comparison of Rd values between visual assessment and segmented parts.

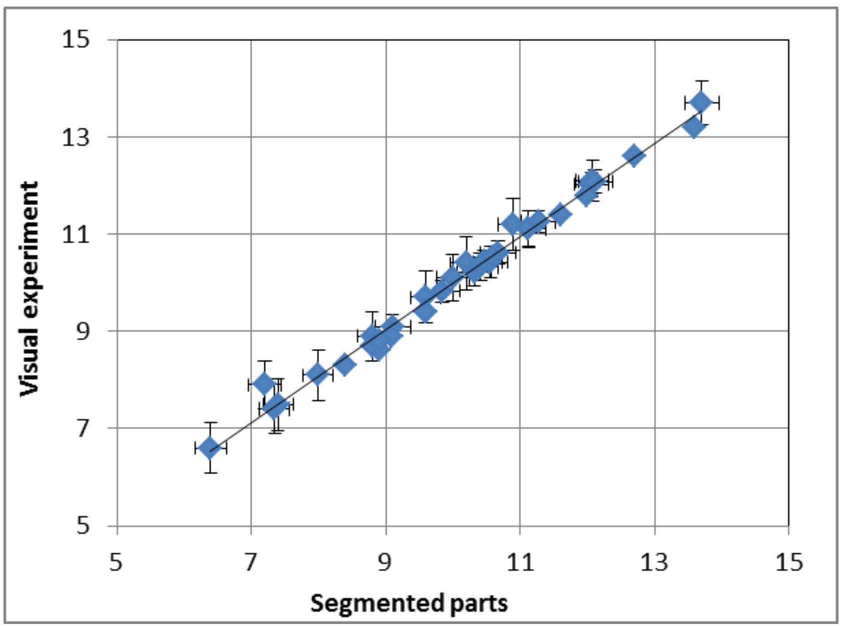


Figure 37. Comparison of +b values between visual assessment and segmented parts.

In the above given figures the results shows that he visual inspection of the cotton and the segmented techniques used with the help of image analysis possesses a strong relationship. This relationship is with both Rd and +b values. These diagrams represent one important thing that the thresholding technique is quite usable in the cotton grading system (47).

Table 18. Whiteness index measurement for cotton sample.

Sample	Y	x	y	WCIE	Visual Ranking
119 CCRI	57.7	0.33	0.35	8.14	5
117 CCRI	50.6	0.34	0.35	-5.73	7
131 CCRI	60.7	0.33	0.35	10.41	5
143 CCRI	59.7	0.34	0.36	-6.92	3
149 CCRI	63.1	0.33	0.35	18.78	3
156 CCRI	60.3	0.34	0.35	2.94	6
159 CCRI	55.5	0.33	0.35	6.48	7
2012/3 CCRI	60.8	0.35	0.36	-21.16	11
2013/2 CCRI	58.8	0.34	0.35	-3.93	9
2014/1 CCRI	60.4	0.35	0.36	-20.02	11
2014/2 CCRI	66.4	0.34	0.36	-1.12	9
2014/3 CCRI	64.6	0.33	0.35	10.29	2

The above given table gives an indication of the whiteness measurement by using CIE formula and also its comparison with the Visual inspection. Each visual inspector is asked to perform the ranking of cotton samples according to the whiteness and give the cotton samples grades. Similarly the whiteness of cotton samples is measured with the help of tristimulus values and putting these values in the CIE whiteness formula. The spearman rank order is used in this data and .75 rank order correlation is obtained there.

6. Evaluation of results and new findings

On the basis of this research it was observed that the LED can be used as a light source in the cotton grading system. There is a strong relationship between the HVI results and the non-contact method results. White LEDs (VW LED) and F7 are used for the comparison of cotton sample color measurement. It is observed that with the different color temperature the cotton sample can be graded in the different color grade. In the previous studies it was seen that the LEDs with the blue chip are available in the market and does not cover the full range of the spectrum. In future LEDs with the color temperature equal to Xenon will be used to characterized the cotton sample in the color grade. A good to excellent color unit agreement is seen in the results. The evaluation of the globally recognized system was a successful attempt. It was also observed that the color parameters of cotton fiber can be observed in some other color space system. The feasibility of the cotton color standards is also seen satisfactory although the light source used in this research is never used in cotton color grading system before. So, it can be stated that non-contact method which possess strong relationship between HVI values is applicable in the cotton industry to measure the color parameters of the cotton fiber.

As color is a collaborative property of individual fibers it is difficult to predict the color property of cotton bale on the basis of the sample. As sample possess color variation within its area of measurement. We have used the non-contact method for the measurement of color variation within sample. In this method the measurement is taken from different area of the sample because the probe of the non-contact method is very small in size. Then these values are used to compute the Rd and +b values. These values help to see the color variation within cotton sample. Image analysis method is also used for the measurement of color variation and its results are compared with the non-contact method. So, the non-contact method can be effectively used to determine the color variation in cotton sample. As the samples used in this method were not containing any trash particles on the surface of the sample which can affect the color measurement process. In this method, the contact with the sample is not used as the contact may cause unevenness or roughness of the sample surface. The result shows that the color variation in the cotton samples even without the presence trash particles and dark spots exists. It can also be concluded some further investigation is needed to enhance the precision in the cotton color measurement. The non-contact method also can be effectively used for the measurement of cotton color distribution and variation.

The trash segmentation part is also used here to apart the trash particles from the cotton sample surface for the correct measurement of color. In this part of the study the new technique of trash segmentation is introduced. This method of trash segmentation is capable to emit the trash segments from the cotton image and enables us the correct measurement of the cotton fiber. This technique is not used till now in the cotton color measurement. And in the relation of our studies, it is revealed that this method gives quite satisfactory results for the color measurement. Aim is to detect irregular regions, leave out these regions and obtain color information without any disturbances other that cotton lint itself. Although these irregular regions possess different shapes and these shape features might be used for irregular region detection, one another option is using color features of the irregular regions. And the visual grading of cotton fiber which, is in disagreement with the color measurement of instruments shows quite good relation with image analysis segmented results as well as non-contact methods. Neutral grey background which is used for the color measurement of cotton shows incredible spearman correlation with conventional system. This trash segmentation technique gives a better system for the color grading of the cotton. Software is developed with the help of mat lab and this gives us this opportunity to provide the precise color values with taking into part the trash particles. This software eliminates automatically the trash particles from the cotton surface and only cotton color values are obtained.

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8. List of papers published by the authors

8.1. Publications in journals

[1a] Vik M, **Khan N**, Vikova M, Foune, Polarimetric Sensing Technique for Textile Material. Defect & Diffusion Forum . 2016, Vol. 368, p198-202. 5p. **(IF = .31)**
[2a] Vik M, **Khan N**, Vikova M, LED utilization in cotton color grading.journal of natural fiber. Doi.(10.1080/15440478.2016.1240643). **(IF = .31)**
[3a] Vik M, **Khan N**, Vikova M,. Non-contact method to measure the color variation in cotton sample (doi.*10.5604/12303666.1228180)*. **(IF = .31)**
[4a] Vik, M., Vikova, M. , and **Khan, N**. Comparison of different methods used for color measurement of cotton. Fibres and textiles (Vlákna a textil). 1. ed. Bratislava: FOART s.r.o., 2016. Pp. 101 – 105. ISSN 1335-0617.

8.2. Contribution in conference proceedings

[5a] **Khan N**, Vik M, Vikova M, Relationship between the different methods used for cotton color grading; 4th CIE Expert Symposium on Colour and Visual Appearance, 6-7th sep,2016. ISBN 978-3-902842-59-6; p 493-500.
[6a] **Khan N**, Vik M, Vikova M, Comparison of different methods used for the color measurement of cotton. XXIV International Federation of associations of textile chemist and colorists: Pardubice 13-16, June: Czech Republic, 2016; p201-204.
[7a] **Khan N**, Vik M, Vikova M, Relationship between the different methods used for cotton color grading; The 90th Textile Institute world conference, 25-28th POLAND,2016; p119-120.
[8a] **Khan N,** Vik M, Vikova M, Color Measurement of Cotton Samples with feasibility of traceable color standards. Svetlanka workshop: 22-25th Sep, 2015: p97-102.
[9a] Hafiz Shahzad Masood, **Khan N**, Muhammad Zubair, Martina Thermal properties of yarn. Svetlanka workshop: 22-25th Sep, 2015: p113-117.
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9. Curriculum vitae

Personal information	
First name / Surname	**Nayab Khan**
Address	Teepu Chowk Barkatpura Faisalabad, Punjab.Pakistan.
Mobile	+92-348-6170978; +420-777-889689
E-mail(s)	knayabrpm@yahoo.com
Nationality	Pakistani
Place and Date of birth	Punjab (Pakistan) on 11th Sep 1985
Religion	Christian
Status and Gender	Married; Male
Work experience	
Dates	8/2010 to-1/2012
Occupation or position held	**Cotton Procurement Officer**, J.K. Spinning Mills Ltd. Sheikhupura Road Faisalabad.
Dates	3/2012 to 7/2013
Occupation or position held	**Assistant Manager**, Rupafil filament yarn production unit. (Pakistan)
Education and training	
Dates	**October 2012 to present**
Title/ Qualification	**Ph.D. STUDENT (Material Engineering)**
Name and type of organisation	Technical University of Liberec, Faculty of Textile Engineering, Department of Material Engineering
Research field/ Thesis topic	*Color Measurement of Cotton Fiber*
Dates	**09/2007 - 012/2010**
Title of qualification awarded	**MASTER'S Fiber Technology.**
Principal subjects / occupational skills covered	Identification of natural fiber
Research field/ Thesis topic	*Influence of UV radiations on bleached cotton knitted fabrics treated with*

	different optical brighteners.
Name and type of organisation providing education and training	Agriculture University Faisalabad Faculty of Agriculture Engineering Department of Fiber Technology.
Dates	**01/10/2002 - 15/01/2007**
Title of qualification awarded	**B.Sc. (Science)**
Name and type of organisation providing education and training	Punjab University. Punjab, Pakistan. Department of Mathematics and physics.
Computer skills and competences	Good command of Microsoft Office 2013 (Word, Excel, Power point, Project) Computer hardware. Networking and System Administration. Basic knowledge of graphic design, audio and movie applications (Adobe Photoshop, Movie Maker, Sony Soundforge, Adobe after effects.

10. Record of the state doctoral exam

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ZÁPIS O VYKONÁNÍ STÁTNÍ DOKTORSKÉ ZKOUŠKY (SDZ)

Jméno a příjmení doktoranda: **Nayab Khan, M.Sc.**

Datum narození: **11. 9. 1985**

Doktorský studijní program: **Textilní inženýrství**

Studijní obor: **Textile Technics and Material Engineering**

Termín konání SDZ: **2. 12. 2016**

prospěl ~~**neprospěl**~~

Komise pro SDZ:

		Podpis
Předseda:	prof. Ing. Jiří Militký, CSc.	
Místopředseda:	doc. Ing. Maroš Tunák, Ph.D.	
Členové:	doc. Ing. Ladislav Burgert, CSc.	
	doc. Ing. Petr Exnar, CSc.	
	doc. Ing. Ludmila Fridrichová, Ph.D.	
	doc. Ing. Martina Viková, Ph.D.	
	Ing. Michal Černý, Ph.D.	

V Liberci dne 2. 12. 2016

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11. Recommendation of the supervisor

Supervisor opinion on PhD thesis of Nayab Khan

Cotton color grading system which is in use globally is an important part of the cotton industry. There are different ways to grade the cotton color like visual grading and instrumental grading. The disagreement between the visual grading and instrumental grading system creates doubts on the current color grading system of cotton.

The main goal of the PhD thesis is to obtain the improved cotton grading system which is able to measure the cotton color in very precise manners. The novelty of the research is that LEDs are used in the research which give potential benefits over conventional light sources. Improved HVI diagram presented with different color space recognized globally. A new non-contact method is used for grading which can measure intra sample variation. Visual grading system of cotton is presented in good improved manners. A system is developed in which the color of cotton can be measured by excluding the trash particles from the surface of cotton samples.

The thesis is quite systematic, all experimental procedures are written clearly and language level is quite high.

The PhD candidate has followed objective measurements for the cotton color measurement. Author was studying fluently step by step and with care.

His publication activities are in very good level. He has four papers in impact factor journals and has got seven presentations in international conferences.

I can say that in this work, novel methods are used for the cotton color measurement which will enhance the color measurement of cotton fiber with precision. Results of this work are very good and indispensable for the cotton color grading and his work will be great addition in the cotton color grading system.

I therefore recommend the PhD thesis for defense.

Liberec, 05.05.2017

doc.Ing. Michal Vik, Ph.D.

Supervisor

12. Opponents view

EXTERNAL EXAMINER´S OPINION OF DISSERTATION THESIS

External examiner: doc. Ing. Tomáš Novák, Ph.D., VŠB-TU Ostrava
PhD student: Nayab Khan, M.Sc.
Theme: A NEW METHOD FOR COLOR MEASUREMENT OF COTTON FIBER

Assessing whether the topic of the thesis corresponds to the field of the dissertation and is current in terms of the present state of science:

The implementation and design of new measuring methods for evaluating qualitative (color) cotton properties that would be able to replace subjective assessment is a significant task not only from the point of view of eliminating the influence of each individual evaluator, but also from an economic point of view. Globalization and the ability to compare the color properties of cotton produced in different countries require increased pressure on the repeatability and provability of the measured qualitative parameters. In this work the author took advantage of two resources, which are currently being developed and improved. It is on one hand the measuring chain the usage of LEDs that correspond to daylight not only from the point of view of the color temperature, but especially from the point of view of the similarity of the spectral emission, so that it can be evaluated at all wavelengths causing visual perception. Standard white LEDs do not meet this qualitative aspect. The second means of measurement that the author used in his work is based on measuring the whole color map of the studied materials using camera chips, trying to leave a point measurement that integrates the color properties of whole studied samples that are inhomogeneous. So far, these inhomogeneities have been eliminated only on the basis of the experience of subjective observers (assessors).

I see the author's merit especially in performing a whole range of comparative measurements using the above-mentioned technologies. In my opinion the outputs measurements on specific samples with the specific types of LED and camera chips could be used in the construction of measuring STAND with LED and with camera chips, which will be supplemented by a standard evaluation software and a new internationally approved methodology for evaluating the color properties of cotton.

Opinion on the original parts of the work with the specification of their originality
The theoretical part of the dissertation deals with the history of the evaluation of the color properties of cotton in interesting, but very voluminous way (Chapter 1). This part can be understood as a textbook research of influences on the color properties development of cotton sorting itself. Chapter 2 provides an assessment of new light sources through a number of assessing methods and using different options (systems) to assess color systems. I consider very interesting the pointing out the possibility of assessing the spectral reflection of the tested cotton samples, so that there could be eliminated the influence of the light sources under which these properties are tested. Chapter 4 extends the possibilities of assessing color properties of cotton using photographic (multi-pixel) methods that are able to solve the properties of the studied samples not integrally, but per-partes as a map of individual assessed coordinates mathematically recalculated from visual to colorimetric channels. The use of camera systems also allows the implementation of

mathematical methods for the elimination of impurities from the color assessment. I was especially attracted by a relatively simple method using histograms. In Chapters 4 and 5, the author describes a whole range of experiments assessing the above mentioned methods of cotton sorting.

However I dare to reproach for some formal mistakes that decrease the quality of the work. I believe that the theoretical states mentioned particularly in Chapter 4 should be listed at the beginning of the work and not nearly at the end of it. I would also point out a large number of images that are unreadable or with missing units or a complete description of the axes. The list of abbreviations and relations is not complete either. Generally speaking, the work should be on a higher level in structural and formal aspect.

Opinion on publications related to the core of the dissertation:
The core of the dissertation was published at the international textile and light-technical forum. The author published the issue in indexed journals focusing on material properties and at the level of the International Commission of Illumination (CIE). Segments of the work were also published in domestic conferences.

Opinion on the applicant's scientific activity:
Based on the list of creative activities, it can be said that the applicant is with a scientific erudition. Attention is drawn to the fact that the author's publishing activity is not only theoretical, but deals with practical problems in determining the quality of cotton all over the world. The author was able to use not only samples of cotton from many sources, but he also used the ability of subjective evaluators who have been sorting it so far.

Conclusion:

I recommend Nayaba Khan´s, M.Sc. dissertation thesis for the defense.

Questions for defense:
Please explain why you have not dealt more with the possibilities of cotton assessing by its spectral reflection.

Can you explain the reasons for choosing the PANASONIC SDR-H280 from the point of view of the chip spectral sensitivity and scanning multiple images?

Could you specify more the spectral requirements for LED applicable to the color assessment of cotton?

In Ostrava 31th August 2017 doc. Ing. Tomáš Novák, Ph.D.

Review of the PhD dissertation
Nayab Khan, M.Sc.
"A Novel Method for Color Measurement of Cotton Fiber"

The main aim of the PhD dissertation is to develop a novel approach and a system for measurement of cotton color measurement and color grading that eliminates the disadvantages of visual grading system and HVI system.

Cotton fiber, which is one of the most important natural fibers used in textile industry, is produced in different regions of the world and its quality characteristics may possess a high variation. Accurate grading of cotton without confusion is important not only for textile processes which use cotton as raw material but also world cotton marketing. The grading process is mainly based on different fiber properties such as length, strength, Micronaire, thrash content and color of the cotton fiber and traditionally human classifiers are used for inspection and classification. Instrumental measurement is realized using HVI (High volume instrument) system for measurement of cotton quality characteristics in order to obtain quantitative data in addition to visual inspection.

Cotton color grades, one of the most important cotton properties, can be determined by human classifiers using visual inspection and/or HVI system using Rd and +b parameters measured by the system. Unfortunately, high disagreement between visual grading and HVI measurements is present. Although an objective instrumental grading system is needed for many reasons, it was not possible to eliminate the human inspection from the cotton color grading process until today due to the shortcomings of the instrumental measurement approach. The topic of this dissertation is up to date and the main aim of the research conducted is to overcome this worldwide problem. In order to solve the big problem, Khan partitioned it into parts each of which can be regarded as separate thesis. The chapters are dealing with each part extensively.

Khan researched the illuminants for color measurement of cotton in the first chapter and experimented LED illuminants having full range of spectrum (400-700 nm) to be used for color measurement instead of incandescent lambs which are generally used. In this part author experimented two different instruments for measurements; one is the standard portable spectrophotometer and the other is telescopic system as is used for non-contact method. Enough experimental work has been done in order to derive conclusions. In the second chapter, Khan researched a novel approach for color measurement which is capable of eliminating drawbacks of HVI system. Noncontact method using telescopic system is used to measure the color variation in the cotton sample which is not possible by HVI system. In this chapter also digital color camera is used for measurement of color variation. After trials and experimental studies the results obtained from noncontact method are compared with the data obtained from HVI and Hunter Lab Miniscan XE. In this chapter it is concluded that non-contact method can be used for developing an instrumental approach for color measurement of cotton which is also capable of acquiring color variation as well. The third chapter is an extensive experimental work for examining visual grading approach. Author developed a novel improved HVI diagram for color grading which consists of three parameters instead of two used in classical HVI diagram. 24 cotton samples were used for the visual classification which is consist of USDA standard cotton samples and Pakistani cotton samples. The visual comparison is performed not only to grade the cotton but also it was performed to rank the cotton according to its whiteness. It is shown that the instrumental measurement of color and visual grading of cotton have some differences due to the presence of the trash particles. This finding leads to another very important chapter where a system is developed for cotton color measurement using digital color camera and using image analysis methods which eliminates thrash particle regions while measuring color.

A complete theoretical and experimental research work has been done in the dissertation in order to examine the parameters which can affect the proposed grading system. This indicates the student's expert and theoretical knowledge is sufficient for developing novel scientific research on the subject of cotton color measurement and developing a novel grading system.

The dissertation consists of 181 pages including table of contents, acknowledge, list of figures and tables, list of abbreviation, abstracts in English, Czech and Turkish, and body of the thesis consists of 6 sections in addition to back-matter including appendix, references and Curriculum Vitae of the author. Tables and figures are given clearly within the dissertation and contribute to represent the results of the experimental work. At the end of each chapter novel contributions are derived, results are discussed in addition to the overall conclusions given in section 6 "New Findings of the Research". Khan has made several publications in indexed journals in addition to oral and poster presentations in conferences.

I believe that Khan achieved main goals in his dissertation and his findings contribute the field with completely novel and original knowledge. The topic in this dissertation is very important not only for the scientific community but also for the whole cotton related industries in the world. The problem solving approach in this work and its presentation were scientifically sound.

Depending on my evaluation, I consider the PhD thesis "A Novel Method for Color Measurement of Cotton Fiber" is a valuable scientific contribution and I RECOMMEND the PhD THESIS FOR THE DEFENSE

Assoc. Prof. Dr. Bekir YILDIRIM
Erciyes University
Kayseri (Türkiye) 30.07.2017