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A Novel Method for Color Measurement of Cotton Fiber

Dissertation

Study programme:	P3106 – Textile Engineering
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Table of content

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The core theme of this thesis is **A novel Method for Color measurement of Cotton Fiber** and contains 3 original papers published in impact factor journals, 1 book chapters and 6 papers published in conference proceedings. The idea, development and write up of all the published work related to this thesis were the principal responsibility of me (the candidate working in the Department of Material Engineering, under the supervision of **doc. Ing. Michal Vik, Ph.D.**

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Date: March, 2017

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List of figures

List of Tables

List of Abbreviation

AMS	Agriculture Marketing Service.
+b	Yellowness.
C*	Chroma.
CIE	International Commission on Illumination.
CCRI	Central Cotton Research Institute.
D65	Daylight (6500K).
HVI	High Volume Instrument.
H*	Hue.
K	Kelvin.
K_a	Expansion Factor.
K_b	Expansion Factor.
L*	Lightness.
LED	Light emitting Diode.
L_v	Luminance.
RGB	Red, Green, Blue.
Rd	Degree of reflection.
USDA	United States Department of Agriculture.
V-W	Violet White.
W_{CIE}	Whitness Index.
x,y	Chromaticity co-ordinates.

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.

Abstract (In Turkish)

Pamuk lifinin renk ölçümü pamuk lifi için çok önemli bir özelliktir ve bu özellik pamuğun tasnifinde önemli bir rol oynar. Dünyada pamuk lifinde kullanılan renk parametreleri Rd ve +b'dir. Bu parametreler HVI ile ölçülür. Pamuğun renk standartlarını seramik fayanslar ve USDA tarafından sağlanılan pamuk numuneleri oluşturur. Bu çalışmanın odak noktasını pamuk rengini led ışığından faydalanarak ölçülmesi oluşturur. Pamuğun rengini ölçmede kullanılan geleneksel aydınlatma yönetemi ksenon ve akkor ışıktır. Led ışıkların geleneksek ışıklandırma sistemleri üzerine bazı avantajları vardır bunlar; daha fazla enerji tasarrufu etmesi, daha uzun çalışma süresi sağlaması, güvenli ve çevre dostu olmasıdır.

Temassız metot yöntemi belirli bir uzaklıktan kullanılır. Bu metot ölçüm için çok küçük bir yüzey alanı kullandığından pamuğun rengini mükemmel bir hassasiyetlikle ölçülmesini mümkün kılar. Bu temassız metot ile ölçülen boyanabilirlik ve parlaklık değerleri görsel değerlendirmenin varsayımsal bir dizilişidir. Temassız metot ayrıca renk değişimlerini değerlendirmede kullanılır.

Pamuk renk gösterimi pamuk numunesinin yüzeyinde toz parçacıkları olduğunda yanıltıcı olabilir Pamuk yüzeyinde bulunan bu parçacıkların miktarına göre ölçüm sonucu gerçek değerden sapacaktır. Ama pamuk endüstrisinde ayrıca pamuğun rengini belirlemede görsel inceleme tekniğide kullanılır. Bu teknik insan tarafından incelenmesini içerir. Pamuk insan değerlendirmesinde toz partiküllerin dikkate alınmaması ve pamuğun renk değerinin pamuğun yetiştirildiği bölgeye göre verilmesinden dolayı daha güvenilirdir. Görüntü işleme tekniğini bu çalışmada kullanılmasıyla pamuk yüzeyindeki toz partiküllerin giderilmesi ve rengini ölçtüğümüz bölgenin g erçek renk değerine ulaşmak mümkün olmuştur.

Endüstriyel bakımdan pamuğun renginin görsel değerlendirilmesi ve bir alet ile değerlendirilmesi arasındaki anlaşmazlık olukça yüksektir. Bu anlaşmazlığı azatmak için yapılan çabalara rağmen, son tasnif işlemi görsel değerlendirme yöntemi kulanılarak yapılır. Eşikleme tekniği çöpleri parçalara ayırmada kullanılır. Üç bölge L* (Parlaklık), C*(renk parlaklığı), H(renk tonu) eşikleme tekniği için kullanılır.

Görsel değerlendirme yöntemiyle pamuğun rengini sınıflandırma işlemi USDA standartlarına göre gerçekleştirilir. USDA pamuk numuneleri ayrıca pamuk renginin değerlendirmede de kullanılır. Görsel değerlendirme ve alet ile ölçme arasındaki anlaşmazlık giderilerek tatmin edici sonuçlar elde edilebilir. Bu çalışmanın amacı pamuğu sınıflandırmak için gelişmiş renk ölçüm sistemini kullanmaya yöneliktir.

Anahtar Kelimeler : Pamuk, LED, Görsel İnceleme, Görüntü İşleme

1 Introduction

The grading of cotton is an important process and it is based on the different physical properties of cotton. Length, Strength, Micronaire, trash content and Color. These properties contribute mainly in the grading of cotton. Color of cotton is represented in its own color grading system. Color of cotton is an important process because it is related mainly to the yarn manufacturing and to the process performance as well. Cotton possesses actually bright white color but due to the severe weather condition its color can be affected very badly which have great influence on the cotton processing. Cotton can obtain yellow color which can be varying in the depth. This yellow color is actually a discoloration of cotton. Soil stains and attack of insects is the biggest cause of the cotton discoloration. Conventionally, the cotton is graded by the cotton classers who are professionally trained personnel and they are capable to classify the cotton by comparing raw cotton to the cotton reference standards given by the USDA (United State department of Agriculture). This is how the cotton color grades are determines by human classers. Due to the unpredictability and lack of consistency in the human classing system the measurement of cotton color with the help of instrument was highly in demand from the start of visual classing system (1).

In the 1930s the USDA started efforts to measure the color of cotton by using instrument. With the evaluation of Hunter colorimeter in 1950s *Rd (Degree of reflection) and +b (yellowness)* became the first parameters of cotton color grading. In the end of 1970s the colorimetry technology was fully transformed into HVI (High volume instrument) and it also started to classify the cotton (2). But, the official grading was actually assigned by the classers. From that moment of time till 2000 the grading was performed by HVI but the final grade was based on the human classer grading.

Color reference standards in USDA are based on the major five categories which are white, light spotted, spotted, tinged and yellow stained. And these five major categories are subcategorized into eight others. These eight subcategorized are good middling, strict middling, middling, strict low middling, low middling, strict good ordinary, good ordinary and below grade. This cotton color notation comprises of double-digits numbers. The digit on the right side indicates the five major categories and the digit on the left side indicates the eight subcategorized. Below given table indicates the representation of color grading of cotton (3).

Table.1. Represents the color grades of American Upland cotton

	White	Light spotted	Spotted	Tinged	Yellow stained
Good middling	11	12	13		
Strict middling	21	22	23	24	25
Middling	31	32	33	34	35
Strict low middling	41	42	43	44	
Low middling	51	52	53	54	
Strict good ordinary	61	62	63		
Good ordinary	71				
Below grade	81	82	83	84	85

The HVI is an instrument which measures the cotton properties. Besides all other parameters it measures color parameters of cotton as Rd (degree of reflectance) and +b (yellowness). And by using the Hunter and Nickerson diagram the original grade for the cotton is assigned. The cotton sample is placed in the HVI at the 10.1 sq. inch window and below this window a light source and two photo sensors are attached. The function of these photo sensors is to detect the reflected light from the cotton sample based on different wavelengths and to use the *Rd* and *+b* for the official grade. HVI can yield the repeatable color grades for the cotton but the disagreement between the HVI measurement and with the visual grading is present from the beginning till today. In 1995s the USDA took a survey and concluded that the disagreement between the visual grading and instrumental grading is present and it is present in all the classing offices globally. This disagreement was quite high as 33.8%. The disagreement between the instrumental grading and visual grading is not a pleasant point if the economic value of cotton is considered. This has deep impact on the economic value of cotton which directly effects buyer and producer both at the same time (4). The major disagreement is between the first two categories which are white and light spotted. So, if the HVI considered one sample as white sample and at the same time the visual classer can grade it light spotted. Although there are certain reasons that a sample can be graded differently according to its surface and these will be discussed in the research comprehensively. But this major disagreement can be increased up to 35.4% concluded by the USDA department (5).

Normally, the spinners who buy cotton from the ginners placed the cotton in the storage room according to the grades of cotton assigned to it by the human classer because the HVI machine is difficult to carry as it is not portable and also very costly (6). But, inside the spinning factories the presence of HVI ensures the disagreement between the visual and instrumental grading multiple times which affects the cotton spinning factory infrastructure. The season of cotton ginning is comprised of 6 months and this is reason that the spinning factories buy cotton for the whole year as the spinning factories run 12 months 24/7.

There are so many factors which affect the instrumental cotton color grading system and some of them are given below:

- Redness
- Spots
- Trash particles

As described above the color of cotton is represented in two parameters Rd and +b and these parameters are globally recognized. From the Nickerson hunter diagram it can be seen that the white/good middling sample can have same yellowness as spotted/strict good ordinary sample. This tells us that the yellowness cannot reflect the Chroma of the cotton color. And the third attribute should be taken into account in the instrumentally color grading of cotton fiber. Although Rd and +b have clear trends to decrease both within color grades and subcategories but (a) redness shows significant changes only among color categories. In the same color category (a) appears to be invariant with subcategories. The value of redness is 1 for the white 3 for spotted and 4.5 for tinged. This uniqueness of the redness attribute among the color categories makes it impossible to do color grading of cotton by ignoring this attribute (7).

The area of cotton which appears yellow is known as spots. And the sample which contains the spots makes it to be graded as light spotted category. If we measure the color of the cotton through colorimeter then in that case the spots have some influence on the cotton color grading. This influence depends on the depth of the spots and also on the viewing area of the cotton. If the spots present in the cotton are not negligible as compared to the viewing area of the colorimeter then in that case it affects the color of the cotton very deeply and also it affects the color grading of the cotton (8).

In the University of Texas an experiment was performed to see whether the spots have noticeable effect on the attributes of the cotton which are really responsible for the color grading of the cotton (9). To analyze 4 different grades 22, 32, 42 and 52 were selected. The Minolta CR-210 was used for the measurement of two selected areas on each sample. And it was understandable that one area is spotted and the other is unspotted. The viewing area is circular and also has the diameter 5cm. The change in one color attribute (*Rd, a, b*) caused by a spot is quantified by the relative difference ΔE, which is defined as:

C = is the color attributes of cotton sample without spots.

Co = is the color attributes of cotton sample with spots.

Positive ΔE indicates increase in the color attributes without a spot being present. Results showed clearly that all the color attributes of the samples were affected by the presence of the spots. Δ*E (Rd)* showed the positive change and the Δ*E (a)* and Δ*E (b*) showed the negative change. So, the spots in the cotton make the cotton darker and more chromatic. An as a result of this the grade of the cotton is much lower when the spots are present inside the viewing area. In some cases is that the cotton color category is not changed but it is sub graded.

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. 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 (10).

Five samples have been selected which actually possess the same classifier grade but possess the different leaf grades were selected to test the influence of leaf on the color measurement made by the imaging technique. A higher value of leaf grade means higher value of leaf content. The readings were taken from the sample and then the trash particles were removed manually from the sample and again the readings were taken and it was observed that Rd value of the sample increases, (a) decreases and (b) shows only a slight increase. The change in (a) is more than the change in (b). It shows that leaves contribute more (a) component to the cotton Chroma. In the below given table you can see that if the leaf grade of the sample is not greater than 3 then the color difference caused by the leaves is not enough to alter the color grade and if the leaf grade is more than 3 then the difference can create a difference to alter the color grade. It is visible that the sample contains leaf grade 7 is not suitable for the color measurement on this instrument as the viewing area is small. It is strongly recommended that highly contaminated cotton with more trash particles should not be tested with this technique because its viewing area is so small. The high viewing area is suitable for the high leaf grade cotton samples. Color grades are very near to the classifier because the classifier is also trained to classify the cotton without taking into consideration the trash particles (11).

Actually when the cotton is picked from the fields manually in the eastern part of the world it contains lot of moisture which is not acceptable. The reason behind this excessive moisture is that mostly the picking of cotton starts very early in the morning and the dew drops in the early stage of the day added inside of the cotton. These dew drops causes more moisture content in the cotton. And due to the unawareness of the cotton pickers they store the cotton in the shape of big heaps. If the cotton contains unwanted moisture more than expected then it is necessary to dry the cotton in the open air before the formation of big heaps. This process is not common and it causes a great amount of discoloration among cotton fibers in the shape of yellowness. So, it can be stated as the excessive amount of moisture in cotton can enhance the degree of yellowness in the cotton which is totally unacceptable and complicates the phenomenon of cotton color measurement (12).

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. 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 (13).

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. 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 (12).

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. 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%. 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. 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* (14).

In the below given figure the color diagram is shown which is used for the grading system of the cotton. This diagram is actually developed by the Nickerson in the 1950s. And still this diagram is in use for the cotton color grading globally. The basic idea for the development of this diagram is to grade the cotton on the basis of its Rd and +b values. There is no doubt that the a value is neglected in this diagram just to consider that it does not have that much impact on the cotton color grading. So, in our research the modified form of the HVI color diagram can be represented on the basis of the three color factors. This modified diagram will not only be represented in one color space but also in different color spaces.

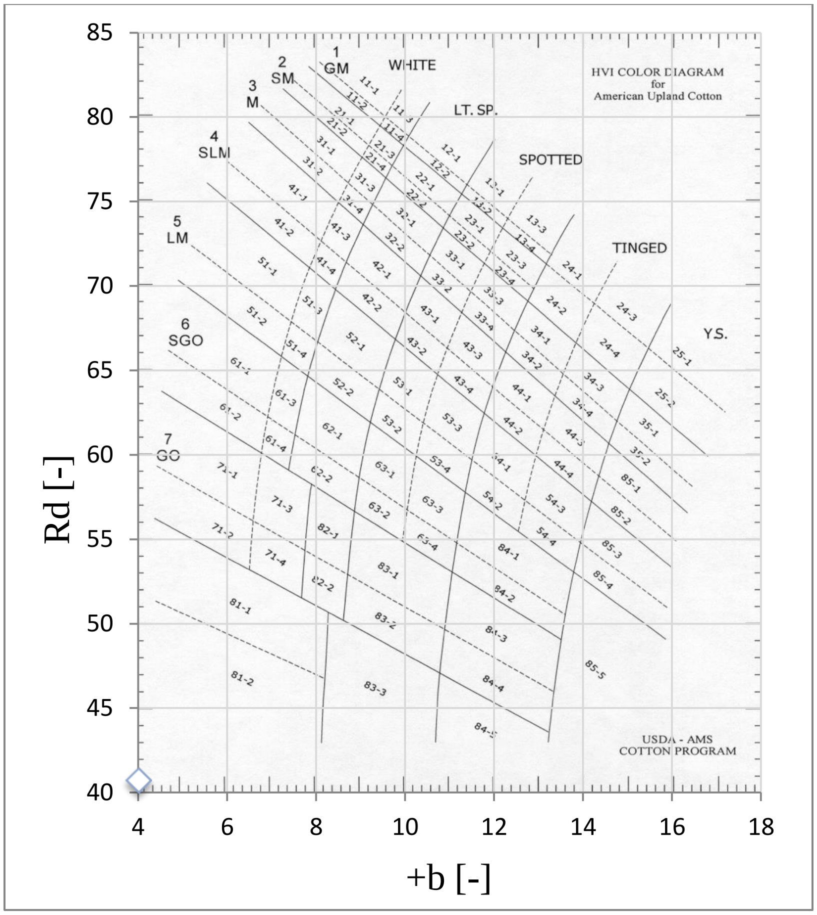


Figure. 1. Color diagram for the American upland cotton

This table currently contains 6486 conversion points for the *Rd* value to the whole number. And if decimal point is also added with the *Rd* then this table will be upgraded by a factor of ten. By using the upgraded table the crops data is normally evaluated on this upgraded table to secure that the distribution of the color grade is kept constant (15).

In the cotton colorimetry five set of ceramic tiles are used for the calibration purpose and these tiles are designed as white, grey, brown, yellow and central colors. The standard values for these color tiles are maintained by the cotton standardizing committee in Memphis, Tennessee state USA. They use the instrument for the colorimetry same as it is used in the late USTER HVI model (16).

Since the 1950s the color references (*Rd, +b*) for cotton are saved by the USDA. Multiple color tiles set are placed at 0^{o} F and these samples are maintaining a constant *Rd* and *+b* which is very necessary for the utilization and marketing of the cotton. It is important to maintain the consistence in the cotton color parameters because it is not related to the time but with the classing location as well. It is also necessary to check the agreement between the instruments. More than six instruments were placed by the USDA in the different location inside USA and outside USA. Two sets of cotton colorimeter will be tested on these instruments. And this study also allows checking the agreement between the instruments measuring the cotton color parameters. The need of the hour is to attract more and more cotton producing countries towards the instrumental color measurement of cotton rather than visual grading. Now the major focus is on the precise and accurate measurement of cotton and the development of internationally recognized standards is very critical task.

The color reference standards provided by the USDA are available in both Xenon and Incandescent light source whether its color tiles or cotton. In our studies the USDA reference standards are also used for the different measurement of cotton grading. The light lamps used inside the HVI and the age of the color standards are very important factors in this regard for correct measurement of cotton color parameters (17).

Hue, saturation and Chroma are the three attributes which play important role in the color measurement as these are equally scaled with respect to the human visual perception and also these attributes are easy to interpret. When the colorimetry started the measurement of cotton color grading *Rd, a, b* became the first parameters of the cotton color grading because this system has Uniform perceptual spacing by Munsell system. *Rd, a*, and *b* are the measures of lightness/darkness, redness/greenness, and yellowness/blueness. The (a) attribute was taken off from the grading system and the reason was given that it is of less important. As described in the earlier part of the research it is not appropriate to measure the color of cotton by skipping the major color attribute. Currently used HVI in the cotton color measurement consist of two photo sensors which actually measures *Rd* and *+b*. USDA adjusted the boundaries of the color grades inside the color diagram to minimizes the disagreement between the human classer and the instrumental measurement. This effort from the USDA was not useless and they found a decrease in the disagreement of 20 % but it does not indicate a precise measurement of the color. There are some problems with the HVI still now and these problems need to be discussed address to make the HVI a perfect system for the color grading. The main problems are given below,

- No uniform illumination
- Lack of color distribution information
- Less reliability

These problems which are associated with the cotton still are not solved and these are the major causes for the disagreement and not accurate cotton color measurement. One of the major obstacle is that *Rd, a, b* values are not globally recognized and there are no other instruments available with which these values can be compared. The calibration between instruments to instrument is compulsory to check the reliability of the device used for the measurement. There is a great need to use other color system for the cotton color grading so that other system can be adopted in this regard. The separability of official cotton color grades in the CIE $L^*a^*b^*$ space, the distribution models of data in individual color grades, and a method to derive a boundary equation separating two color grades from the normal distribution models. The study is based on experiments with the USDA physical standards for Upland cotton and cotton samples from the

1999 crop, and the results seem to be useful for establishing new color classification methods with CIE *L*a*b** to solve cotton color grading problems associated with the Rd-b measurements. The distributions of cotton colors in the CIE *L*a*b** system using the USDA physical standards and samples collected from the 1999 crop. Samples of various official cotton color grades generally have good separability in two subspaces, *L*-b** and *L*-a**. When cotton colors are considered in the CIE *L*a*b**, data separability can be substantially enhanced because a* is also an independent and significant attribute. From the frequency distributions of sample data, it is evident that the probability density functions of individual color grades follow normal distributions. The distribution of adjacent color grades partially cross each other, and an overlapping region shows the probability that samples in one grade will be misclassified into another grade. A decision boundary between two adjacent distributions can be simply determined using the intersection of the two distributions where misclassification rates are minimal. These distribution models of color grades are essential to other classification methods to be developed in new color grading systems (18).

The visual grading of cotton was performed in the daylight conventionally. Visual measurement of the cotton color is an art which is performed under the universal controlled lighting conditions. The color quality of light source is very important. The cotton classer attempt to class the cotton on the basis of color of the sample and the standard would have in daylight. So, it is very important for a cotton classer if he is doing classification in the classing room to have constant color of the lighting as it has to replace the daylight. It shall make the color of the cotton appear as possible as it would in daylight. In USA daylight at about 7500K is what the cotton classer has found in practice to be the minimum color temperature of preferred daylight. The data for 400 to 700 nm are based on Table III of August, 1965, recommendations of the CIE colorimetry committee (E-1.3.1) for an international standard to represent typical daylight (300 to 830 nm) of correlated color temperature 7500 K. The tolerance for meeting these standards shown up for color quality is 200K correlated color temperature of color. And for the spectral quality the spectral distribution should be as close as possible. And the color rendering index should not be lower than 92 determined by the color rendering index recommended by 1965 by the international commission on Illumination. The optimum amount of illumination is unknown. For light sources that include the use of fluorescent lamp the USDA department of agriculture requires at the time of installation a minimum of 100 foot-candles (1076 1x) on the working surface. Studies show that illumination above 400 fc (4300 1x) may be considered “very poor. Optimum conditions lie somewhere between. Most recent installations are well above the minimum requirements, usually reaching a range of 150 to 200 fc (1614 to 2152 lx) on installation.

Lamps and equipment must be properly maintained in order to hold to proper and uniform levels of lighting. It is not enough to install good lighting; it must be maintained. The following routine should be followed:

- Daily inspection to check that all lamps are in good order.
- Prompt replacement of deficient lamps by the proper type of lamp.
- Use of a foot candle meter8 to chart and record foot candle levels throughout all classing areas. The level of these data should be watched throughout the year to determine changes in illumination. Records of this sort, kept over a period of years, are a help in setting up definite cleaning and replacement schedules.
- Regular cleaning of fixtures, recording foot candle levels before and after cleaning.

- In fixtures that include use of fluorescent lamps, regular inspection of ballasts, at least once each year. Low voltage or lack of ventilation above the lighting units tends to cause the ballast to overheat and bleed. In fact, ballast trouble can cause considerable variation in light output.

In 1914 the grades of cotton were made compulsory for the trade of the cotton. Till 1935 a class of cotton blue sample was also there in the classing format. Since it is the policy of the United States department of Agriculture to give the numbers to the cotton samples like 1 is for middling. For the highest grade no.9 is the good ordinary. Initially term middling was used for the middle grade but today the term middling is used for the base grade. Statistical analysis by methods of multiple curvilinear correlations used early in the cotton works showed that in the 9 grades of the white standards the correlation of three color factors and grade was .981 for the earliest measured standards. Since two of three color standards value and chroma accounted all the color values of cotton in 1930.

In order to have a grade diagram to which the color data might be referred and also comparison of several set of samples can be performed here. In the 1939 and 1946 the changes in the standards were too great to be rectified by slight changes. Measurements of these new standards presented in 1946 and also adapted. Comparison of these new standards shows that the results which actually shown in 1946 resembles the white standards of the 1936 standards. For comparison of the color of the standard with the color of the current crops the result of surveys for 1944 and 1945 crops. The color of the cotton crop from different areas in the cotton belt varies. Initially the hunter diagram was composed of straight lines which separated the samples from each grade. The initial colorimeter which was introduced in the 1946 was based on the munsell value and chroma. But later in the 1950s the new colorimeter was introduced and this was based on the Rd and +b values. The earlier colorimeter diagram was actually based on the disc colorimetry.

As far as the problem of raw cotton grading is concerned the new colorimetry device was quite satisfactory. Firstly, a graph was introduce in the cotton market for a limited range and without any kind of conversion. A chart was introduces which was very much similar to the long established readings similar to the munsell value and chroma chart. The color difference meter worked so well so the specifications were written for completely automatic conversions. This instrument was based on the photocell and based combination initially. This two dimensional diagram initially was able to measure grades automatically and shows grades simultaneously in the range of 40-90 (Rd) and 0-20 (+b).

This instrument was in use for the cotton grading for a long time and measured thousands of cotton samples. And on the basis of standard for cotton the operator was able to give the cotton grade based on its working (two filters).

The cotton color diagram which was used in the 1950 was actually based on the standards which were passed in 1946. A numerical code was introduced in the grading system for cotton classification or its equivalence grades. And the use of same codes was necessary for new instruments.

The first number used in the grading system is the grade number. If a precise number is needed then a code was introduced based on the reflectance and yellowness. For example for Rd=71 and +b=10 then the code is 71.10. It means that the reflectance number should precede the yellowness number in order to keep the words in the same order.

The grades of cotton depend on the color of the fiber, the amount of foreign matter present in the cotton, roughness and smoothness of the cotton and also ginning preparations. In those times the total grades of cotton which were actually presented were 33 and in these grades 13 grades were physically present. Earlier in 1930s the work on cotton color was based on the chroma and Hue value. So the chroma and Hue were the two parameters which were actually used for the cotton color and the correlation between these two was quite high as 98%. And these two factors contributed equally in the correlation. On the base of these correlations since that time the plotting of cotton color on chart was two dimensional. The contribution of three factors in the cotton color measurement is equal while representing the cotton color. So, the color represented the cotton is actually average of these three factors contribution. And these factors are discussed earlier color of cotton fiber, amount of foreign matters present in the cotton and ginning preparations.

Tolerance for the cotton samples is not the only factor which should be considered. It is possible to make immediate use of new instrument for such kind of the series. The conditions under which a sample can be measured should be same and if these conditions are not same then in that case we need to compare them. The classer have the ability to see the colors and can differentiate them from the other main classes like from white and light spotted or spotted. But he cannot differentiate in the subclasses and the instrument can help him to differentiate in the subclasses. This color range is actually prescribed for the cotton only.

In this study various complications of the cotton color measurement will be studied one by one. These problems are selected on the basis of the personal experience of the researcher working in the cotton procurement department in the spinning industry. Also the selection of these problems is based on the alternate methods proposed by the researcher to apply in the cotton color grading systems. Below given chapters deal all the problems and their solution step by step. In the first section of the study the use of a new light source is tried in the cotton color industry. Currently, two light sources Xenon and incandescent are used in the cotton color industry. In our study LEDs are used for the cotton color grading system. The use of LEDs is selected due the fact this light source is now used in different industries and possesses so many potential benefits on the conventional light sources which mentioned earlier. The results are far more satisfactory and the not only published but also presented in international conferences.

Second part of the research is focused on a new method used for the cotton color grading. This new method is known as non-contact method. Which is chosen to see whether the results obtain from this method is correlated with the other methods. This will confirm the applicability of this method in the cotton color industry.

Besides this process visual experiment for the cotton grading is also arranged, in which different group of people (professional and non-professional) were involved. These visual experiments were performed very under different viewing environment and some of the new techniques are suggested in this research on the basis of the experiments. And at the last but very major experiment was the trash segmentation from the cotton sample. Which allows the correct color measurement of the sample in the presence of the trash particles and these particles can be leaves, bur or any other foreign matters. This part of the study is a very crucial part because the visual color grading of the cotton is actually based on the fact that the trash particles will not be taken into consideration during the visual assessment and focused will be only those part are free from the trash. But in the case of the instrument color measurement the grading is different, as instrument consider it as spot inside the cotton and gives it a lower grade as compared to visual assessment although these particles can be removed by using different kind of instruments like Shirley analyzer.

2 Chapter 1

2.1 LEDs Utilization in the cotton color measurement

Incandescent light source is used for the cotton color measurement instruments but recently Xenon is used a light source in this process and reportedly it is observed that it has a precise measurements of color as compared to incandescent light source. The phenomenon of color measurement is a very simple and also dependable on certain things. When we see color there are three factors involved given as light, object and observer. In these factors light plays an important role in the color measurement phenomenon. Although the stability of color representation is observed with the use of Xenon flash illumination. But still there is always a space for the new things to take place and also for more precision.

Now, a day's LEDs as light source are taking place in every field. LEDs are more energy efficient light source and also long lasting as compared to the conventional light source. LEDs operate differently than the conventional incandescent light source and this property of LEDs makes it more rugged and durable than others. The major benefit of LEDs that it gives exceptionally longer life span (60,000) hrs and more energy efficient (90% more efficient). The maintenance cost and increases the safety (19). And now LEDs are replacing the conventional lightings in the different applications like, residential lighting, aerospace, architectural lighting, automotive aviation, broadcasting, electronic instrumentation and traffic and safety transportation. The reproducibility and repeatability of different HVI systems is also unsatisfactory. Some of the problems which are observed by the Commercial Standardizing of the instrument testing of cotton are:

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

- HVI malfunction.
- Sample Preparation

The discussion of these problems will be carried out in the research but the main focus is on the lighting so, the age of the lamps used by the HVI (900) is a major concerns in HVI malfunction. Currently, the basic component inside the colorimeter includes two incandescent lights and two photodiode detectors. *Rd* and *+b* are measured by measuring the color from the light reflected off of the cotton sample when placed over the colorimeter's nine square-inch observation window. In this research LEDs are used for the cotton color measurement and these LEDs which are used contain the full spectrum range (400-700) nm. Previously it was not possible to have full range of spectrum LEDs but the color temperature was same (6500K) which is required for the cotton color measurement. It is necessary to have not only color temperature at the desired level but also the full range of spectrum. The results and discussion part includes the results of cotton color measurement by using the LEDs and the comparison with the different color temperatures as well (5).

2.2 Theory

In the era of 1943 till 1967 Richard Hunter made some efforts to change the CIE XYZ color scale system into another form, which represents the better way for describing the human vision concept. In 1943, Rd, a, b scale was developed for the C/2 conditions. Here Rd is equal to the *Y* (brightness) and it represents the average reflectance or transmission of the object. It means that the higher the value of reflectance or transmission the higher the value of Rd, whereas, a_{Rd} and b_{Rd} represents the redness/greenness and yellowness/blueness respectively. The mathematical formula used here, is not the same which is used today in the Hunter a, b or CIE a*, b* color values. In 1948, Hunter developed a photoelectric reflectometer, which allowed direct measurement in terms of the L, a, and b values, contrary to tristimulus colorimeters that times. Two different circuitries were developed, one to yield L, a_L, and b_L values, and one to yield Rd, a_{Rd} and b_{Rd} values (20). Conversion of CIE tristimulus values measured with condition of CIE illuminant C and 2° standard observer (CIE1931) to Hunter L, a, b space is performed as follows:

$$L = 100\sqrt{Y} \quad (1)$$

$$a_L = \frac{175(1.02X - Y)}{\sqrt{Y}} \quad (2)$$

$$b_L = \frac{70(Y - 0.847Z)}{\sqrt{Y}} \quad (3)$$

And:

$$Rd = Y \quad (4)$$

$$a_{Rd} = 1.75 f_Y (1.02X - Y) \quad (5)$$

$$b_{Rd} = 0.70 f_Y (Y - 0.847Z) \quad (6)$$

$$f_Y = \frac{0.51(21 + 0.2Y)}{1 + 0.2Y} \quad (7)$$

The Rd value is used mostly as overall reflectance and brightness for limestone powders. The Y-value is equivalent to the Rd but there are some industries, which have notice the particular metrics, and they retain them to describe the color property of the products. In general, a limestone powder, which possesses a best color quality, is usually known as higher Rd value. The Hunter L, a, b system was came into existence for illuminant C and 2 degree observer in 1958. And in 1967 the Hunterlab also adopted some additional illuminants and also added the expansion factors Ka and Kb and von Kries adaptation of neutral point. Modified versions of equations (5) and (6) are as follows (21):

$$a_{Rd} = K_a f_Y \left(\frac{X}{X_0} - \frac{Y}{Y_0} \right) \quad (8)$$

$$b_{Rd} = K_b f_Y \left(\frac{Y}{Y_0} - \frac{Z}{Z_0} \right) \quad (9)$$

$$K_{ai} = \sqrt{\frac{X_{0i}}{X_{0C/2}}}.175 \quad (10)$$

$$K_{bi} = \sqrt{\frac{Z_{0i}}{Z_{0C/2}}}.70 \quad (11)$$

And subscript i means used illuminant and observer such as D65/10, A/2, etc.

Due to advance of Hunter reflectometer, colorimeter respectively, was starting from 1950 used. This device was based on two wide range color filters (green and blue) allowing measurement of two values: reflectance Rd and yellowness +b. Important advantage of that times was direct reading of above mentioned values. This concept was later followed in current HVI system.

In the CIE system of colorimetry the Y trstimulus values gives the luminance or luminance factor. Since luminance is intended to represent the effectiveness of various stimulus wavelengths in evoking the perception of brightness. Helmho tz is a one formula that confirms this error. Perceive brightness increases with increasing saturation. It also shows that the effect depends upon Hue.

Various approaches has been used to model the Helmholtz effect. One of the approach is using the involved Cowan and Ware equations. Correlation factors are calculated for all the stimuli in equations. The Ware and Cowan equations were derived for the unrelated colors.

A correlation to the CIELAB lightness L* was taken as a function of CIELAB Chroma C* and Hue angle h_{ab}. The predictor of chromatic lightness L* had the equation given as:

$$L \ = L + f.2(l)f.(hab)C \qquad (12)$$

This equation describes the Helmholtz effect by adjusting the luminance based predictor of lightness. The luminance value is constant while chroma is changing. It shows that the lighter chroma chips do appear brighter. Helmholtz effect shows that perceiving brightness is not a one dimensional effect of stimulus luminance. As the stimulus becomes more chromatic at constant luminance it appears brighter.

Careful observation of the visual world shows that the color appearances of objects changes significantly when the overall luminance level changes. Object appears vivid and contrasty on a brighter summer afternoon and more.

2.2.1 Stimulus

The stimulus is defined as the color element and for this it is necessary to measure the color appearance. Typically the stimulus is taken to be a uniform patch of about 2^0 angular subtense. The 1931 observer is considered to be best for the stimuli ranging from 1^0 to 4^0 in angular subtense. The inhomogeneity of the retina with respect to the color responsivity is a fundamental theoretical limitation to this definition of the stimulus.

It is a practical necessity that has served basic colorimetry well since 1931. A more practical limitation, especially in imaging applications, is that the angular subtense of image elements is often substantially smaller than 2°and rarely as large as 10°. Fortunately such limitations are often nulled, since in color reproduction, the objective is to reproduce a nearly identical spatial configuration of colors (i.e., the image). Thus any assumptions that are not completely valid are equally violated for both the origin l and the reproduction. Care should be taken, however, when reproducing images with significant size changes or when trying to reproduce a color from one scene in a completely different visual context (e.g., spot color or sampling color from an image).

The environment of the stimulus from 2^0 to the edge of the stimulus is called the proximal field. For the appearance modeling the proximal field is necessary. In some cases if the proximal field is not known then in these cases it is specifies as background. Background is known as the environment of the stimulus extending from 10^0 to the edge of the stimulus.

Specification of the background is absolutely necessary for the modeling of simultaneous contrast. And if the proximal field is different than the specifications can be used for more complex modeling. The background is usually made up of the surrounding area. Precise calculation of the background in any kind of image requires point-wise recalculation. If the chromaticity is constant and a luminance level is 20% then the background is considered constant. The need for precise definition of the background is minimized in most imaging application.

The field outside the background is known as surround. Sometimes the entire room is considered to be the surround in which the image is taken. Printed images are viewed in the dark surround and videos displays in dim surround. Various color appearance models uses more or less information on each component of the visual field. The adapting stimulus is sometime considered to be the background and sometimes it is considered to be the measure of the light source. So, it is necessary to describe the tristimulus values for each of the visual field. When measurement is made for each of the visual field then it is necessary to consider the standard observer 1931at 2^0 observer. And if self-luminance display is used then the determination of absolute tristimulus values can be accomplished by measuring it with spectrophotometer. Actually these kinds of materials are actually classified on the basis of its spectral reflectance and transmittance. And it is very rare that images are viewed under light source that closely meet the CIE illuminant. The difference in the color measurement made under illuminant and a real source is quite significant sometimes. F8 is specified as a typical fluorescent illuminant with a color temperature of 5000K and can be considered as of extremely high quality illuminant.

It is difficult to understand that especially for those people with the affinity for physical science the mode of appearance is and apparent color depends upon the stimulus color. There is one example which can be explained here is that a house which was pained yellow and the color of the door was also yellow. At some point later in the evening it appears that the color of the door is blue. A blue door on a yellow house was a perception which should be taken into consideration. On a very closer look it was seen that the door was illuminated by the sunlight from the setting sun and a brick wall was having the shadow on the wall that is why the door was illuminated only by the skylight and that is why the door appeared as more bluish than he yellowish. First look give perception that the house was yellow and the door was blue under the uniform illumination and actually the reality is that the door was illuminated by a bluish light that is why it was appearing more bluish. In another example a child was watching some photographic prints which were actually developed in the dark room under an amber safe light. Of course the print was completely achromatic and the illumination was a single and highly chromatic color. So the child insisted that she can realize the objects and when they took the prints out the color of the object was black and white. And the child was not able to recognize the object on the basis of the color. This is also a very important example of recognization objects on the basis of its color perception. This phenomenon is completely compatible compatible with the coganitive model with the color recognition. There are five main modes of viewing which are actually defined under.

The perception based on illumination is actually non-object mode and is mediated by the illumination and the presence of illuminated objects that actually reflect light.

The surface mode requires the presence of a physical surface and light being reflected from the surface. The volume mode of appearance is defined as the color perceived is belonging to a bulk of more or less uniform and transparent substance. For example the number of air bubbles in a block of ice increases and the lightness of block increases towards white while the transparency decreases towards zero. The volume more perception needs three dimensional structure. The film mode of appearance is defined as color perceived in an aperture with no connection to an object. If a surface cannot be shifted then the mode shifted from surface to the film. All other modes of appearance can be reduced to the film modes.

The two same patches with different backgrounds appear distinct. The black background makes the patch to look lighter while the white background makes the patch appear darker.

Contrast causes stimuli to shift in color appearance when the color of their backgrounds is changed. These apparent color shifts follow the opponent theory of color vision in a contrasting sense along the opponent dimension. In other words it can be said that a light background induces a stimulus to appear darker and a dark background induces a dark backgrounds.

2.3 Materials and Methods:

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 (2) and figure (3) and figure (4). 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

Figure 2. Representative Box containing (1-6) AMS cotton samples.

Figure 3. Representative Box containing (7-12) AMS cotton samples.

(20 ± 2 °C and 65± 2% RH).

Each sample, which is shown in the figure (2) and (3), 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.

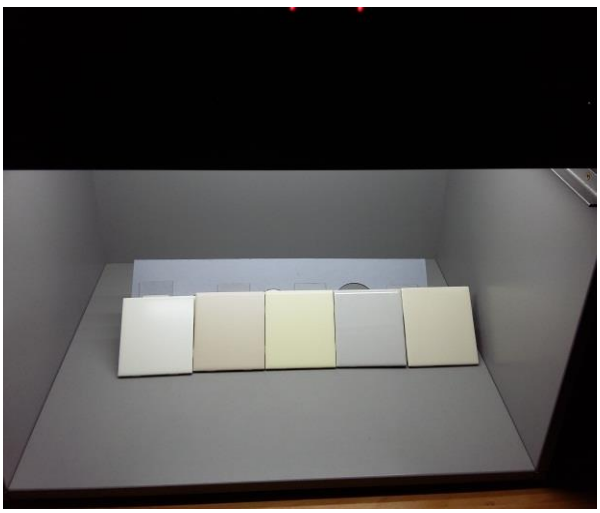


Figure 4. Representative set of Five AMS ceramic tiles.

Figure 5. 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 are shown in the table 15. CIE XYZ values are converted into Rd, a and b values by using Eqn (1) (2) and (3).

2.4 Results and Discussion:

12 cotton samples provided by the AMS are analyzed with two different light sources and compared with the known parameters of cotton fiber (Rd, +b) which reflect the color of the cotton fiber. Equations (2) and (3) is used here for the conversion of the CIE (X ,Y, Z) into (Rd , +b) system. A strong relationship is observed when the LEDs are compared with D65 for the cotton samples. Here, (X ,Y, Z) of D65 light source is obtained from the spectral data and then it is converted to the (Rd, +b) values. D65 represents the daylight with the correlated color temperature 6500K. Colorimetric values CIE (X,Y,Z) used are selected with respect to the standard illuminant(22). The temperature of the light source plays an important role in determining the color of the cotton sample. There are so many kind of daylight simulators are available in the market for the color measurement which can be compared for color measurement. That can be our future concern for the color measurement of cotton fiber. We will not only measure the cotton samples but we will also measure the cotton calibration tiles.

The spectral power distribution of the daylight simulator and also violet white LEDs is measured and compared in the below given diagram. These two light sources will also be used for the color measurement of cotton fiber. In the light cabinet we will use for the color measurement the different temperature of the LEDs are available which will actually help us to determine the exact cotton difference.

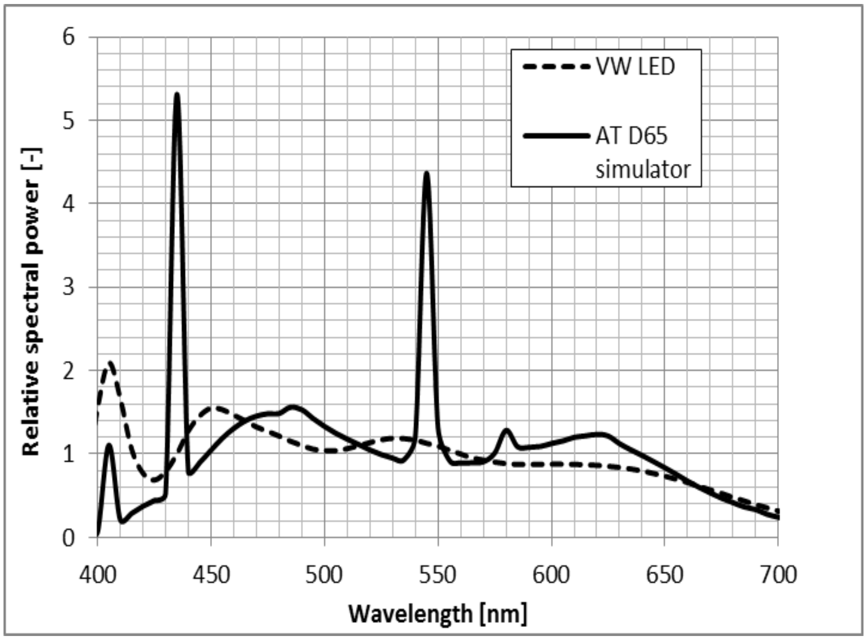


Figure 6. Comparison of Relative spectral Power obtained from the VW LEDs and the AT D65 simulator.

As mentioned above that this research was implemented to investigate the cotton color standard with by using LEDs as light source so, therefore the experiments performed on the cotton standards obtain from the AMS departments with the known Rd and +b values (23).

2.4.1 Spectral data of the calibration tiles:

As described earlier that the main focus of the study is to analyze the effect of light source used in the color grading of cotton. LED are used for the color grading of cotton fiber therefore, the spectral data of LED is compared with the D65 (Use of D65 is a common practice for the color grading of cotton fiber).

2.4.2 Color Tiles:

The color standard tiles examine on the HunterLab Miniscan XE and the L* a* and b* values obtained. The reflectance data for these ceramic tiles is also obtained, which is shown in the fig (7). The range of the wavelength is selected from (400-700nm). The colors of the representative tiles are white, brown, yellow, grey and central (24).

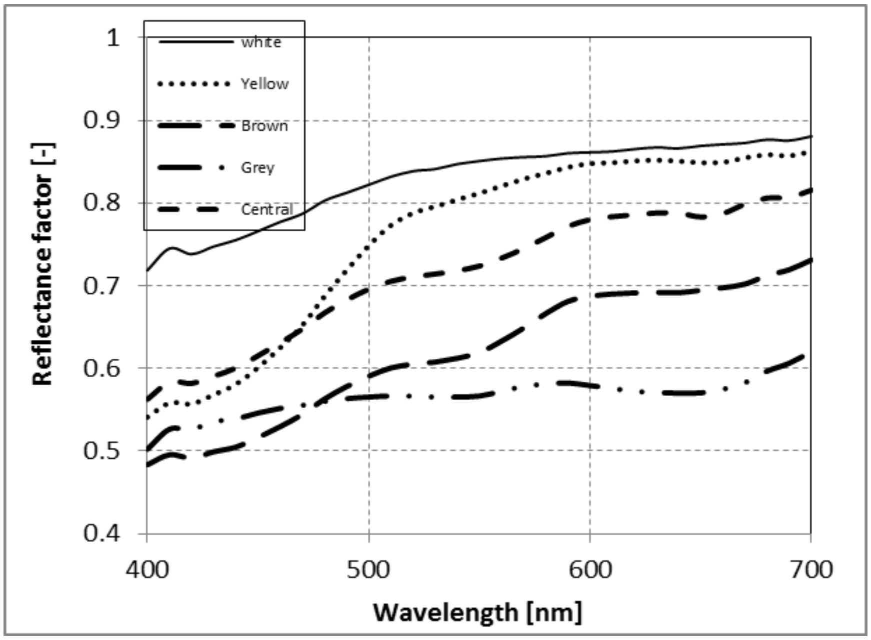


Figure. 7. Reflectance data obtained for color tiles from the HunterLab Miniscan XE.

The reflectance data is shown to provide the information of the reflectance at each wavelength ranging from 400-700nm. The five standard AMS tiles used are the tiles with incandescent light source used. The comparison of L*a*b* values with the HVI Rd and +b values is already performed in the previous work. The L* value of all the tiles is little high as compared to the Rd values of HVI.

The values measured with telescopic method are x, y and Lv. Then the conversion takes place. And the L* a* b* values obtained by using color space conversion. It is obvious that the illuminant used for the color measurement influence the color grading. As the AMS tiles possess smooth surface therefore the values obtained during experiment are very reliable. And a very strong relationship is seen between the HVI Rd and with the non-contact method Rd value and also with the HVI +b and non-contact method +b. The non-contact method Rd and +b values obtained by using color space conversions from x, y and Lv (Chromaticity and luminance).

2.4.3 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 Hunterlab 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.

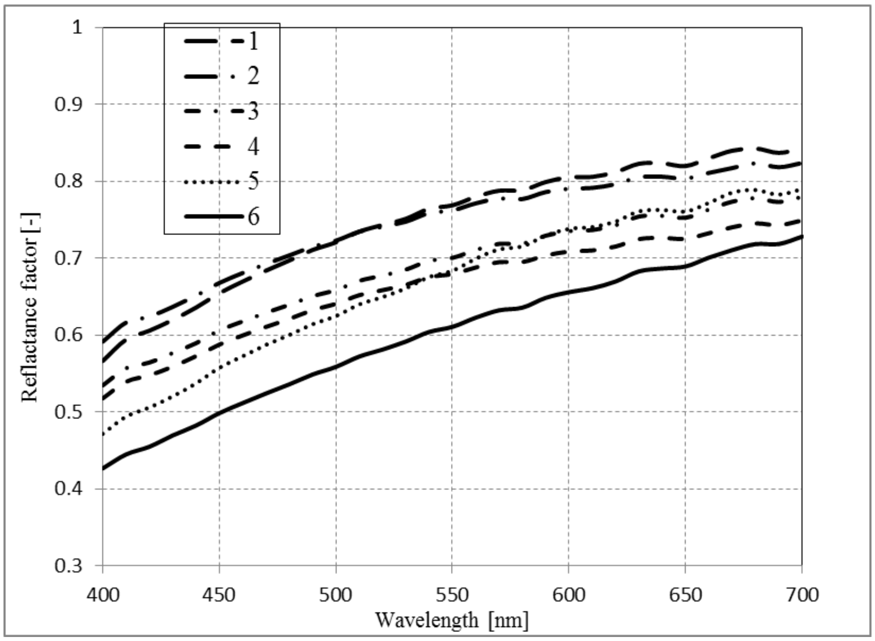


Figure 8. Reflectance data obtained from the HunterLab Miniscan XE for cotton samples 1,6.

The cotton grading system of the USDA is not taking into consideration the reflectance value of the cotton samples at each specific wavelength. And in our opinion it is also very important to consider the reflectance at each wavelength because it will enhance the possibility of the instrument to observe the color measurement more closely. The one more important thing is that the instruments color measurement is not the final grading of the cotton system. It is necessary to have visual classer to obtain the exact final precise grade.

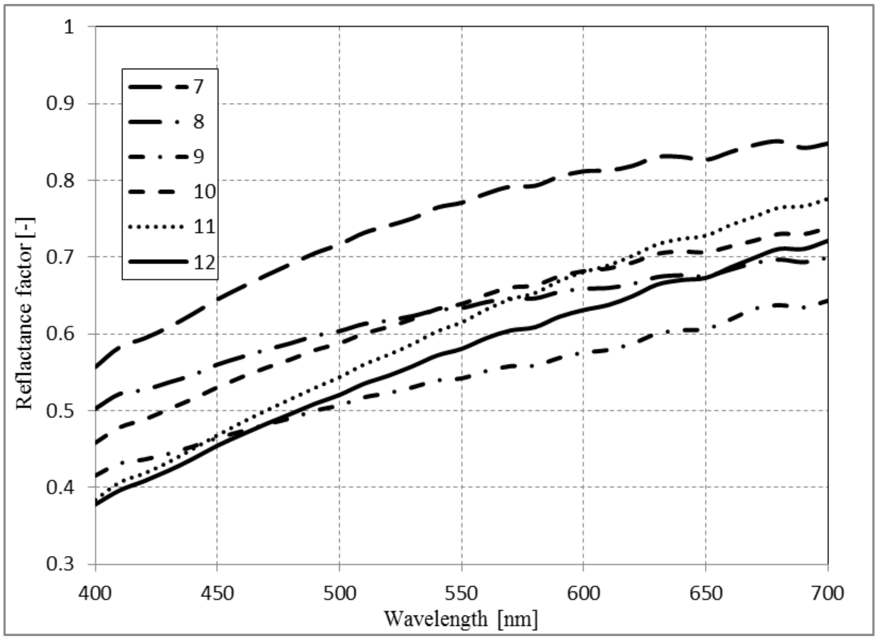


Figure 9. Reflectance data obtained from the HunterLab Miniscan XE for cotton samples 7, 12.

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. The current system which is in use globally will not provide us this kind values which are actually needed to express the color precisely. The idea behind this representation is that because the cotton color is a complex matter in which other the chance of error is more as compared to the other properties of the cotton fiber. This error which can actually be minimizes is not only in the cotton industry but also it is present in the paint industry, automobile industry and some of the other very important industries which are dealing with it also in the same manner by hiring visual inspectors.

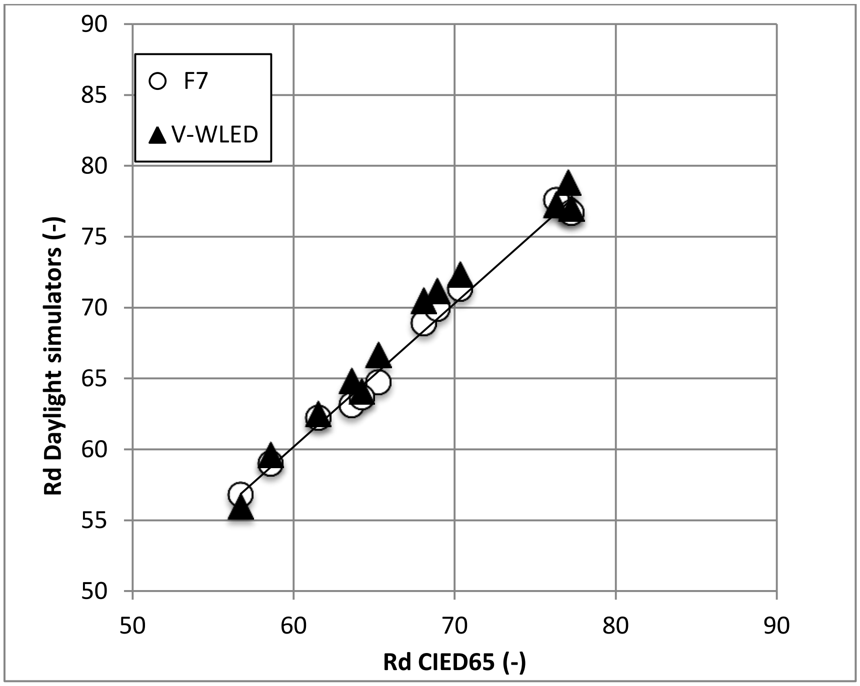


Figure 10. Comparison of Rd values between VW LED and AT D65 Simulator.

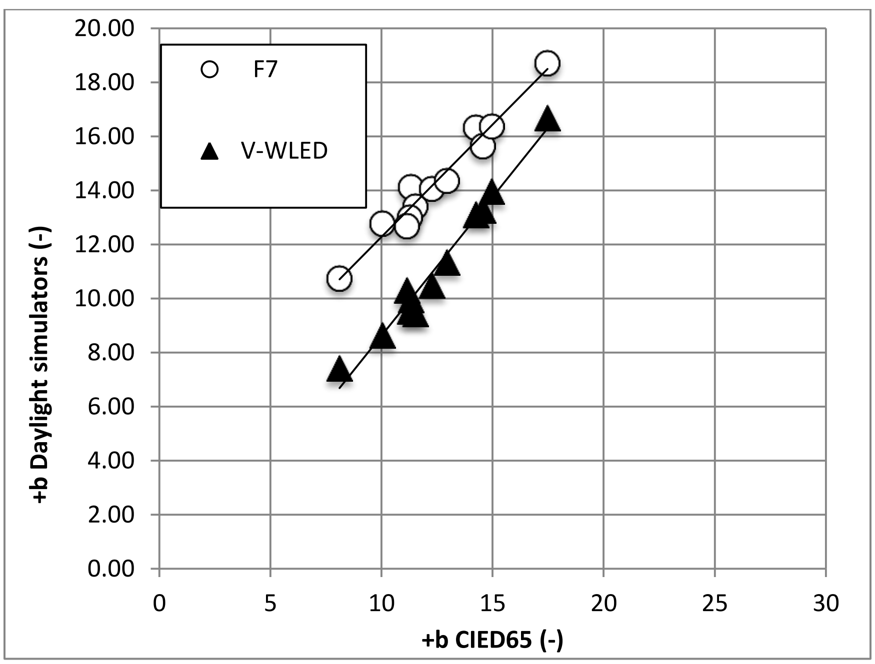


Figure 11. Comparison of +b values between VW LED and AT D65 Simulator.

Fig (10) and (11) 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.

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 (25). 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 (slope)	B (intercept)	R^2
AT D65 simulator	1.01	0.46	0.99
VW LEDs	1.03	1.48	0.98

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

	A (slope)	b (intercept)	R^2
AT D65 simulator	0.91	0.39	0.97
VW LEDs	0.94	3.76	0.98

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.

2.4.4 Comparison of the Rd values (USDA cotton samples) between the Miniscan and Labscan

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.

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	50.00	46.72	48.78	44.99
USDA 10	61.07	63.70	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 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.

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.

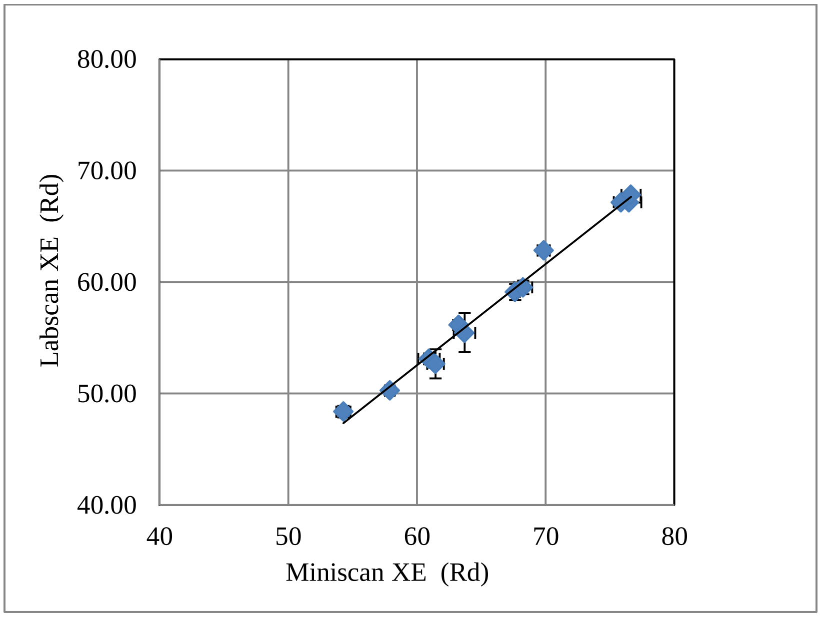


Figure 12. Comparison of USDA cotton samples Rd values between Labscan and Miniscan XE.

2.4.5 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.

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

2.4.6 Representation of cotton samples in Chromaticity diagram:

Although the light of different wavelengths are equal in power as far as physical standpoint are concerned but the visual system is not equally sensitive to them. Luminance and chromaticity is hypothetically a typical human visual system which is described in terms of equations relating its quantitative visual response to measurable physical statistics of light stimuli. By keeping in view the disagreement between the visual measurement of cotton color and the instrumental measurement of cotton color this phenomenon is used in this research for the color measurement because it represents the human visual perception. x , y and luminance fully capture the standard observer color match to the test light. The below given chromaticity diagram of cotton samples can be useful for the convenient representation of mixture of two light sources. Chromaticity of the two lights lies on the straight lines connecting the chromaticity of the two lights.

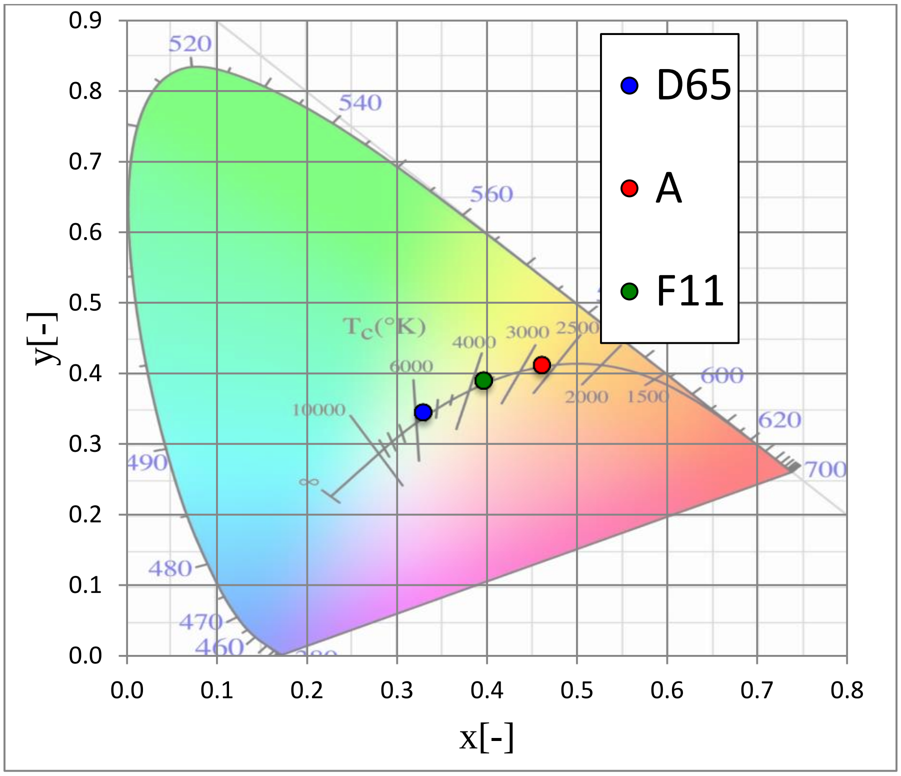


Figure 13. Representation of cotton samples in the x, y chromaticity diagram.

2.4.7 Representation of cotton samples in Hunterlab Color Diagram

The representation of the cotton sample in the Hunter lab color diagram is a very important part of the research because it helps to predict the color grades of the cotton samples. Same cotton sample sometimes graded differently due to the use of different light source. Below given color diagram is a perfect example of this argument. In this chapter we will not only discuss the color representation of cotton samples in the HVI diagram but we will also discuss the modification of the HVI diagram in some other #d color spaces, which will help us to determine the cotton grading in some globally recognized system and also this system will be more compatible as compared to Rd, a, b. This Improved colorimetry system will also give us the grading of the cotton systems in different region.

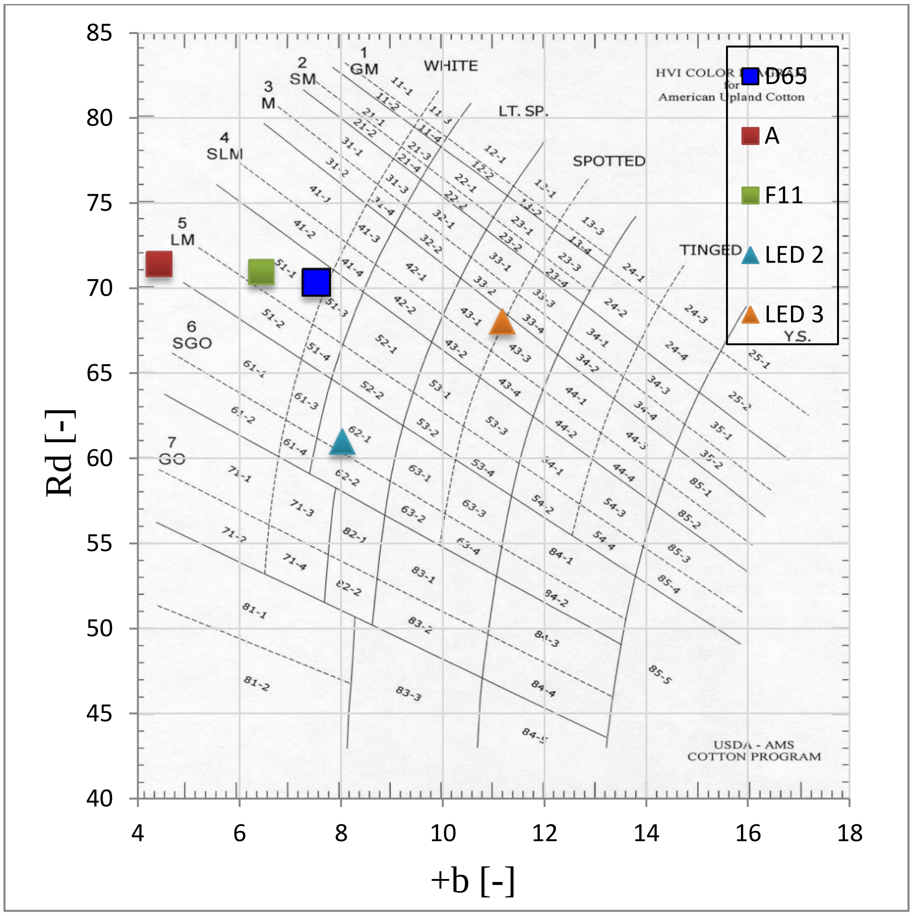


Figure 14. Representation of the cotton sample in HVI diagram.

The Cotton sample which is graded in the white category in the Hunterlab Color diagram is graded as spotted and light spotted in the LEDs as a light source. In the CIE D65, A and F11 the light source is based on the color temperature and also possess the range of 400-700nm in the visual spectrum. But in the case of LEDs it is different because the LEDs used here do not have the full range of spectrum.

2.4.8 HVI Diagram

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.

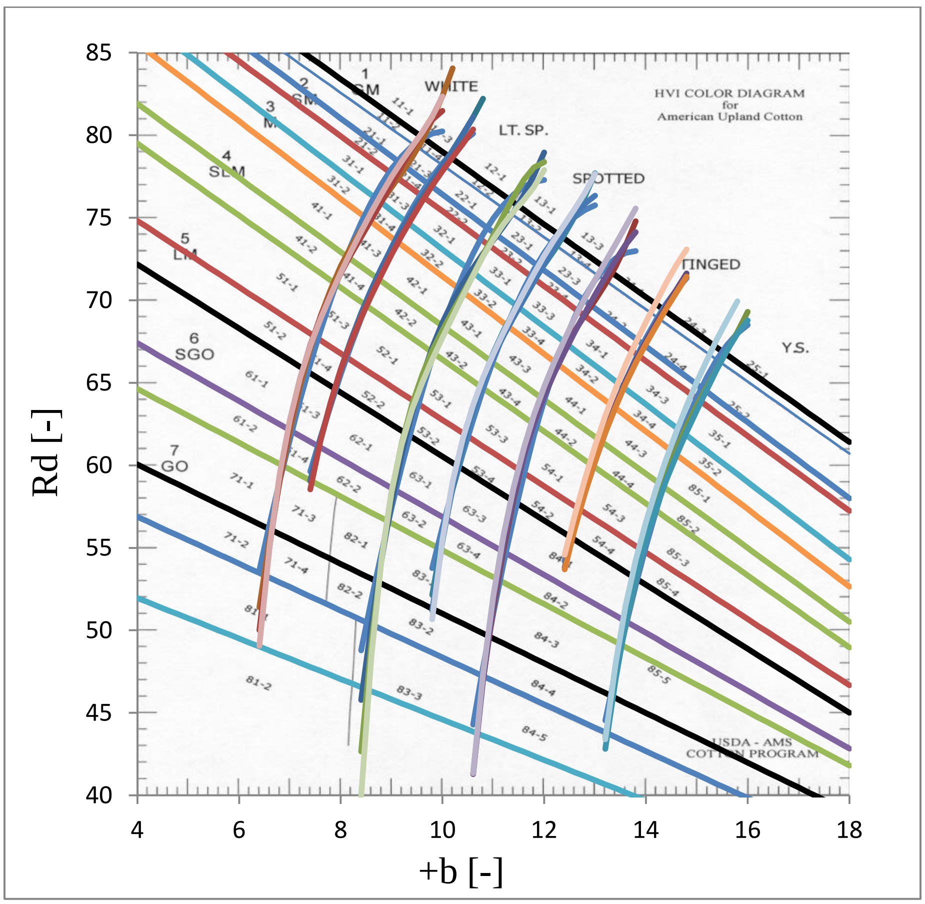


Figure 15. HVI diagram shows comparison of the different polynomial functions.

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. 4th 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. 4th degree polynomial function is best fit for all the lines shown in the vertical direction of the graph.

Table 10. Straight line for HVI diagram horizontal lines.

	Intercept	Slope
GM	100.05	-2.18
SM	98.10	-2.27
M	94.95	-2.35
SLM	88.21	-2.18
LM	79.93	-1.94
SGO	71.15	-1.63
GO	62.56	-1.42
GM dotted	101.00	-2.20
SM dotted	99.42	-2.30
M dotted	96.57	-2.34
SLM dotted	90.86	-2.24
LM dotted	82.85	-2.01
SGO dotted	74.41	-1.75
GO dotted	66.06	-1.50
dotted	56.86	-1.22

The above given table indicated the slope and intercept for the horizontal lines shown in the HVI diagram. As these lines which are horizontal are actually straight lines and only two points are considered on these lines and by taking the equations from these points the straight lines are taken to show the grades on the HVI color diagram. These horizontal lines are basically straight and these lines intersecting the curved lines to give the color grades which can be seen in HVI diagram.

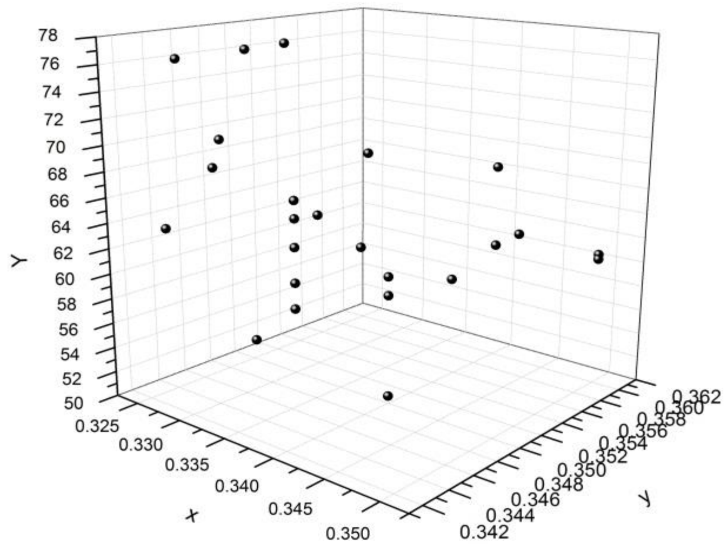


Figure 16. Color representation of the cotton samples with chromaticity values and Y tristimulus.

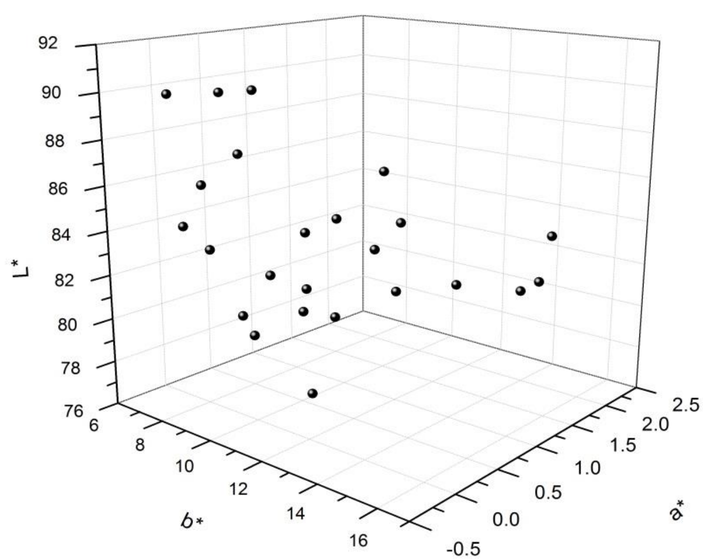


Figure 17. Color representation of the cotton samples in CIE L,a,b system.

The color of cotton is represented in two different color spaces Like CIE L, a, b system and also in x, y, Y chromaticity values. In the previous polynomial fitting we have seen that the fourth order is used best fit for the HVI diagram and in the fig (16) and (17) it is quite obvious that with the help of these best fit polynomial fitting we can represent the cotton color in different color spaces. The Origin Pro statistical software is used for the analysis. So, till now the color of the cotton is only represented in Rd and +b system which is not globally recognized. And now it is quite possible to represent the system in different system which are globally recognized also used worldwide for the color representation and are traceable color standards.

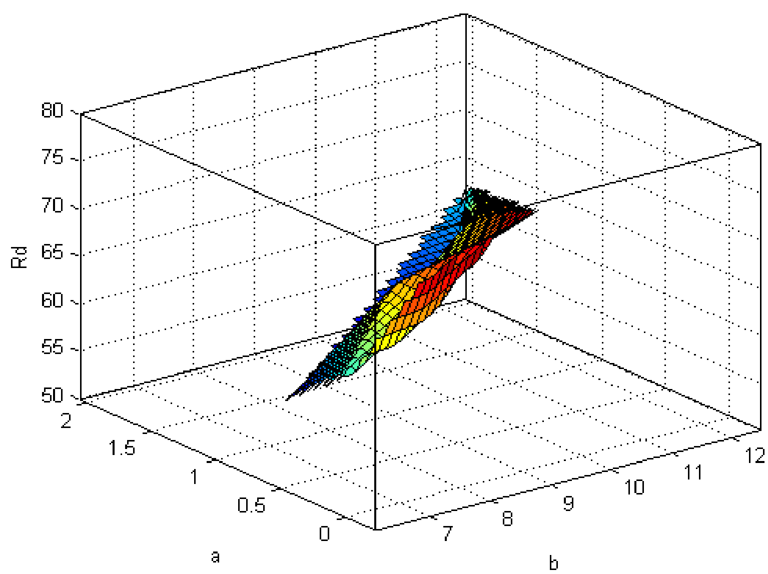


Figure 18. Representation of USDA cotton samples in 3D Rd, a, b systemwith linear interpolant.

In Linear interpolant of the up given graph f(x,y) = piecewise linear surface computed from p where x is normalized by mean 8.746 and std 1.866 and where y is normalized by mean 0.6067 and std 0.7153

Coefficients: p = coefficient structure

Goodness of fit: SSE: 0 , R-square: 1

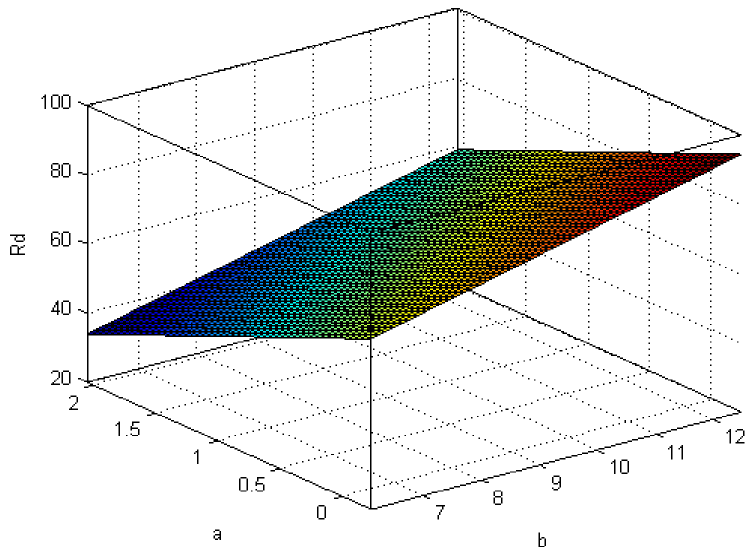


Figure 19. Representation of USDA cotton samples in 3D Rd, a, b systemwith 1st degree polynomial function.

Linear model Poly11: f(x,y) = p00 + p10*x + p01*y

Coefficients (with 95% confidence bounds): p00 = 41.64 (27.4, 55.88) ,

p10 = 3.96 (2.095, 5.826)

p01 = -15.48 (-20.35, -10.62)

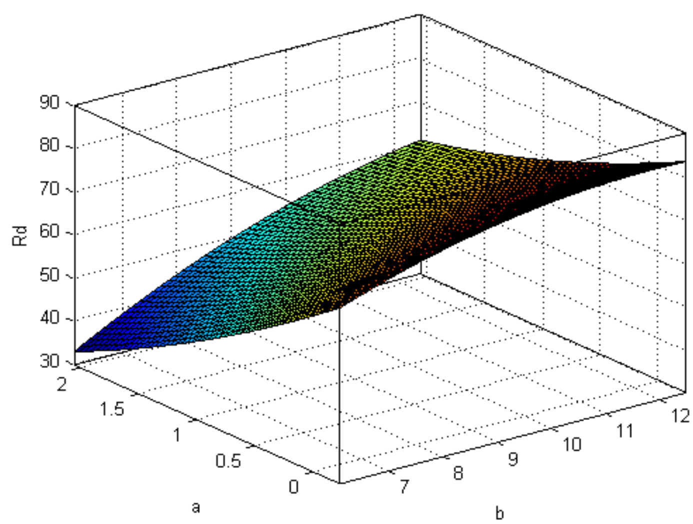


Figure 20. Representation of USDA cotton samples in 3D Rd, a, b system with 2nd degree polynomial function.

Linear model Poly22:

f(x,y) = p00 + p10*x + p01*y + p20*x^2 + p11*x*y + p02*y^2

Coefficients (with 95% confidence bounds):

p00 = 22.92 (-118.9, 164.7)

p10 = 9.476 (-27.56, 46.51)

p01 = -26.11 (-76.19, 23.97)

p20 = -0.3898 (-2.789, 2.01)

p11 = 1.038 (-5.641, 7.716)

p02 = 1.786 (-12.2, 15.77)

Table 11. Goodness of fit comparison of linear and different polynomial functions in statistical analysis.

	SSE	R-Square	Adjusted R-Square	RMSE
Linear Interpolant	0	1	Na	Na
1st degrre Poly.	87.54	0.85	0.82	3.11
2nd degrre Poly.	70.04	0.88	0.78	3.41
3rd degrre Poly.	42.52	0.92	0.60	4.61

The USDA cotton standards are represented in 3D diagram and the fitting surface is obtained by best fitting model. The color values of these standards are represented before In CIELAB system and in the chromaticity values x, y, Y. Now, this color representation allow us to determine the best fit surface and also it allows us to see that how the prediction of a value can take place in the region which was ignored previously. This prediction also gives us the satisfaction to measure color of cotton in the recognized system of color space. The USDA standard samples are represented in 3d diagram because in past the (a) value is ignored while representing cotton color. Initially, when the HVI diagram was made it was suggested that it was based on the visual values and still same is the case. In the previous figures it can be seen that the color of the cotton standards is used to predict a best fit model for the representation of cotton color and also for prediction the (a) value in the Rd, a, b system. In the results it is observed that on the basis of SSE values which are shown in the respective tables the first degree polynomial function is best fit. All of these models have good R-square value but on the other side in some cases the predicted (a) value is way beyond limits which is not so much useful. Matlab software is used for these models for predicting the best model for this color representation. The calculation of a value by using these functions is quite complicated and this problem is basically due to the eigen vectors. The determination of eigen vectors is very important in the physics and engineering. Where it is equivalent to matrix diagonalization. And it arises in such common application as stability analysis. Each eigen vector is paired with a corresponding so called eigen value.

2.4.9 Improved HVI diagram:

Table 12. The limits points of the region between white and light spotted is represented in these three different color regions based on the previous analysis.

	Rd	**a**	**b**	**X**	**Y**	**Z**	**x**	**Y**	**Y**
1	59.05	1.08	7.40	58.68	59.05	53.41	0.34	0.35	59.05
2	61.54	1.01	7.60	61.05	61.54	56.29	0.34	0.34	61.54
3	63.77	0.95	7.80	63.19	63.77	58.83	0.34	0.34	63.77
4	65.78	0.90	8.00	65.11	65.78	61.06	0.34	0.34	65.78
5	67.58	0.86	8.20	66.84	67.58	63.02	0.34	0.34	67.58
6	69.20	0.83	8.40	68.40	69.20	64.74	0.34	0.34	69.20
7	70.65	0.81	8.60	69.81	70.65	66.24	0.34	0.34	70.65
8	71.97	0.80	8.80	71.08	71.97	67.56	0.34	0.34	71.97
9	73.16	0.79	9.00	72.24	73.16	68.73	0.34	0.34	73.16
10	74.26	0.79	9.20	73.31	74.26	69.78	0.34	0.34	74.26
11	75.28	0.79	9.40	74.31	75.28	70.73	0.34	0.34	75.28
12	76.26	0.79	9.60	75.27	76.26	71.61	0.34	0.34	76.26
13	77.20	0.80	9.80	76.19	77.20	72.46	0.34	0.34	77.20
14	78.13	0.80	10.00	77.10	78.13	73.29	0.34	0.34	78.13
15	79.07	0.81	10.20	78.03	79.07	74.15	0.34	0.34	79.07
16	80.06	0.81	10.40	78.99	80.06	75.05	0.34	0.34	80.06
17	81.09	0.81	10.60	80.00	81.09	76.03	0.34	0.34	81.09

In the up given table the line which actually divides the two regions white and light spotted is shown in the three different color spaces. The (a) value of the Rd, a, system is also calculated on the basis of model used for the surface fitting. This line will be shown now, in the 3d graphs in three different color spaces. Total 17 no. of points are taken first on the HVI colorimetry diagram and by using the USDA cotton standards we developed the best fit model for representation. Now, this model helps us to predict the a value which is neglected previously and also it confirm the color values in the different known regions.

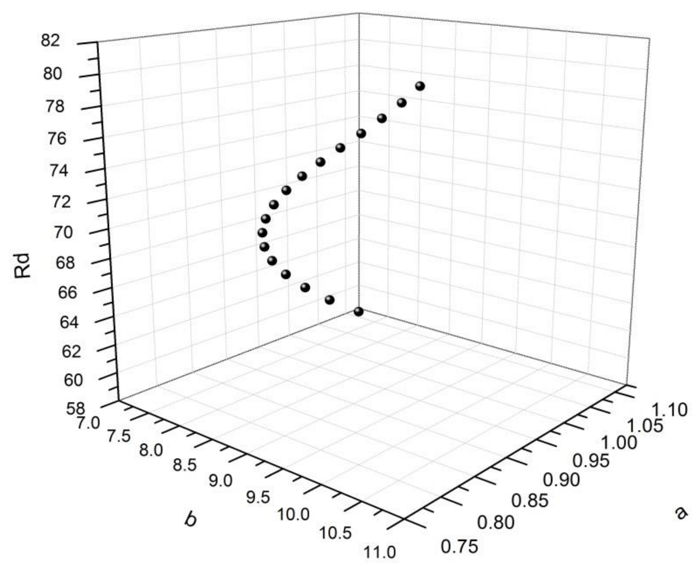


Figure 21. Line representing White and light spotted region is represented in Rd, a, b color space.

In the above figure the line which actually causes a major disagreement between the white and light spotted category is represented in the Rd,a,b system. This curved line trend show us that this 3d diagram is totally capable to distinguish the cotton color into the white and light spotted category. Similarly the other lines can be drawn also to distinguish the regions like spotted, tinged and yellow stained. The horizontal lines can also be drawn on the 3d graph to distinguish the sub-categories as well.

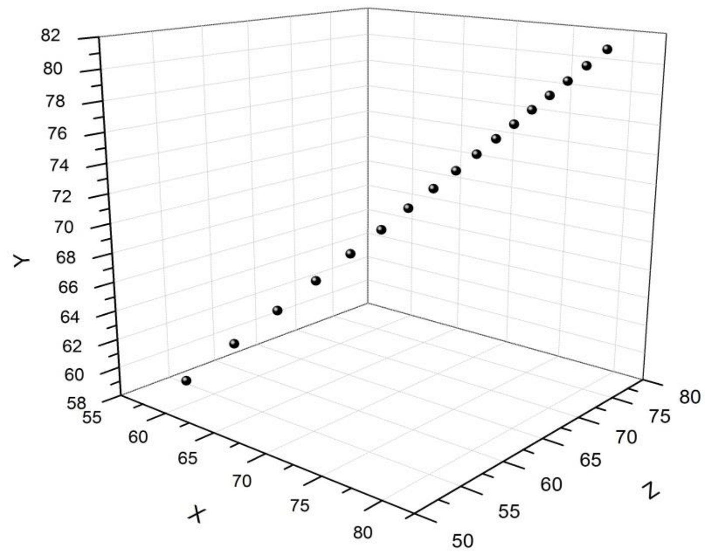


Figure 22. Line representing White and light spotted region is represented in CIE XYZ color space.

In the figure (22) the projection of the 3d image is used to show the curve trend of the line which can also be seen in all the color spaces.

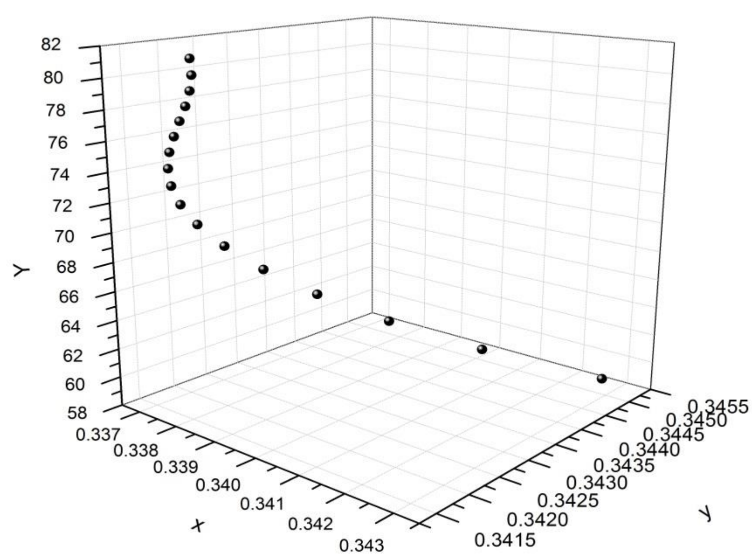


Figure 23. Line representing White and light spotted region is represented in x, y, Y color space.

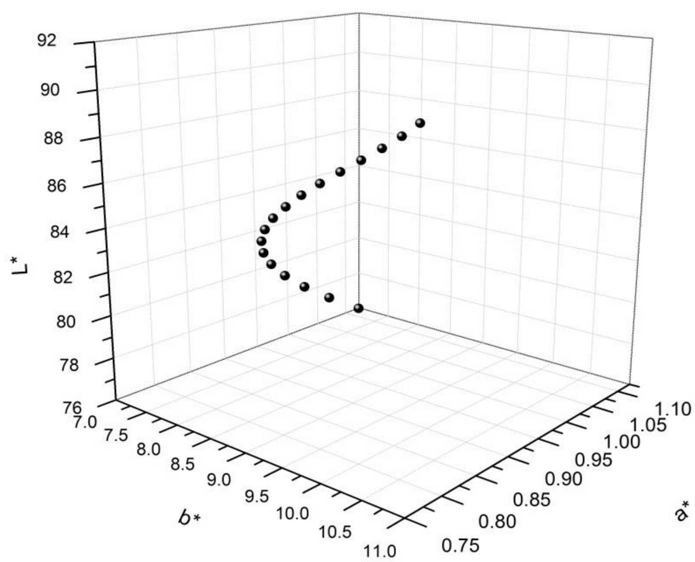


Figure 24. Line representing white and light spotted region is represented in CIE L, a, b system.

The line which is represented in the above given three graphs shows that how the limit boundaries which are created inside the HVI diagram can be drawn in the other color spaces as well. The other vertical lines like light spotted, spotted, tinged, white dotted has shown in same color and can be seen in the appendix. In the recent times there is such work is performed on the basis of cotton grading. Similarly, as we have drawn this line here in these color spaces the other limits lines of the HVI diagram can also be drawn inside these color spaces. And the grading of cotton can also be performed in different color spaces.

2.5 Conclusion:

On the basis of this research it was observed that the LED can be used as a light source in the cotton grading system. As 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 characterize 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. Improved HVI diagram is used here for the purpose of predicting the right color values without any errors in it. The color representation in different color spaces is also a very big achievement in the cotton grading on the basis of HVI diagram. Now the cotton color can be expressed in two different color spaces in 3D diagrams. In these color spaces the third parameter which is redness and greenness is taken into consideration while color representation.

3 Chapter 2

3.1 Cotton color measurement with telescopic (Non-contact) method:

The precise color measurement of cotton fiber possesses great importance because the color has deep impact on the yarn processing. In the 1930s when instrumental color measurement of cotton fibre took place Rd and +b became the color parameters of cotton with the evaluation of Hunter colorimeter in 1950s. In 1970s colorimeter technology was brought into use for classification and was fully integrated into HVI (High Volume Instrument) by the end of 1970s. And these parameters of cotton do not relate to the other well-known and globally recognized color systems like CIELAB, where L* is the lightness, a* is the redness/greenness and b* is the blueness/yellowness of the sample. As a two wavelength based system the HVI does not include information about other regions of the color space, which might play a vital role in the cotton color measurement (4).

And the values of the specific wavelengths used are proprietary to USTER and it was not possible for the others to have access to these values. If these improvements can be added into the HVI then this system will be much improved color analysis system for the color evaluation of the cotton fibre. Modern spectrophotometers and colorimeters include diffuse reflectance measurements of the sample over the full visible spectral region of the electromagnetic spectrum (at a minimum, 400-700 nm) use globally recognized color systems and units, and use an NIST traceable white standard.

So, the direct use of color spectrophotometer for the cotton color measurement parameters Rd and +b is not that much simple because the advances spectrophotometer is capable to examine the entire visible region (400-700 nm) while on the other hand the HVI is only two filters colorimeter as we mentioned earlier. So, direct measurement of Rd and +b is not possible so, the internationally recognized three dimensional color systems have been used. Primarily the color system based on tristimulus color (XYZ) (26).

There are some problems connected with color measurement using the HVI, which uses a two-dimensional system: the (Rd) and (+ b) to assess the color of a sample and the color grade. However, the HVI approach is insufficient in comparison with visual human perception. HVI color results are correlated with the visual grading, but an agreement between the HVI and the classer grading is not satisfactory (8). Although the HVI is used all over the world for the grading of cotton whether is it color property or other properties of the cotton fibers but as far as the color property is considered the final grading of cotton was performed by the grader till the end of 2000 (13).

The Rd, a, b scale is an industry specific color scale that was developed as early version of the Hunter L, a, b scale. Rd is used to represent lightness and is the same as the CIE Y Brightness/ Luminosity value. Sometimes the Rd, a, b is expressed as L_{Rd}, a_{Rd}, b_{Rd}. Color metrics and color science are in use since 1900s with some objectives to measure the values of color on the basis of human perception; to represent the color values in the words used by humans to differentiate the colors (27).

In 1931, the CIE tristimulus values X, Y, Z that actually was based on the reflectance and transmission spectral data. And these values were used to quantify the perception of a color made by human on any object. Human normally uses lightness, saturation and Hue to describe the color but, these CIE tristimulus values X, Y, Z does not describe well these terms (3)(28).

3.2 Theory:

Testing of raw cotton in the spinning mills before going into the process for yarn manufacturing is a very common phenomenon. Normally, two or three random samples are taken from the cotton bale (160-220) kg which represents the properties of the whole bale of cotton. In the recent years, lot of work is done to improve the overall color grading system of cotton sample (29). Most commonly used method for the cotton color measurement is colorimeter and this method is not capable to give the information of color variation within the sample. As the cotton samples represents a major part of the cotton bale so, it is necessary to measure the color variation within the sample as it represents the whole bale of the cotton (30). Color of cotton is a combined property of individual fibers. Uniform color property is very necessary for the desirable quality of the processing (31).

The variation in the properties of cotton fiber should be in the narrow range. Normally cotton color assessment is performed by instruments but the final decision about the color grade of the cotton is taken by the cotton classer till now due to the disagreement between the instrumental measurement and the visual measurement. Although the sample of the cotton has its own average value of the color but the variation within the cotton sample exists (32). Color space system which should be linear and should be able to give the improved perception of the color is highly needed in cotton color grading system and which should led to a non-linear transformation of the CIEXYZ color space system (33). Most recognized color space system in the world is CIELAB system which is 3 dimensional system and commonly known as L*a*b* system (34). In this system L* represents lightness or darkness, a* represents redness or greenness and b* represents yellowness and blueness of the sample (35).

Colorimeter method which is used for the color measurement of cotton fiber is very old and it shows a great disagreement when it is compared with visual grading system of the cotton. In recent times cotton color is measured with in so many different ways. Cotton color measurement by spectrophotometer is one of those methods. The strong L*↔Rd and b*↔+b was observed. The use of L*a*b* for cotton grading system and relating them with the global color parameters of the cotton is a great achievement (36). During the HVI measurement the variable which has negative impact on the cotton color measurement is the glass in front of the cotton sample (17). The use of image processing technique for the cotton color measurement is also enhancement to measure the exact color of the trashy cotton as the HVI is not capable to predict the precise color parameters of the cotton (37). This research enables to remove the effect of trash on the color measurement of the cotton fiber (38).

So, there is always a space for a new method for the color determination of cotton fiber. The color parameters (Rd, +b) used for the cotton color grading are in use since 1950s and these parameters are not globally recognized for the color measurement (34). Some of the studies previously show that the variation within the sample exists as compared to the variation between the samples (32). HVI color measurement system comprises of two broad band filters for color grading. In which one filter is responsible for the luminance (Rd) and the second filter is responsible for the yellowness (+b). And these two filters are not enough to cover the full spectrum and this problem affects the color grading system (39).

The main focus of the research is to use a unique method known as non-contact method to measure the color variation in the cotton sample. In which, LED are used for the color measurement (40). Digital imaging processing technique is also used for the measurement of color variation within the sample (41). By using this technique data of scanned cotton images were also examined and the results were compared with the HVI and the Non-contact method to check the color variation in the cotton sample (34).

3.3 Material and methods:

3.3.1 Color Tiles (Ceramic):

The samples used for the experiment are the standards tiles and the standard cotton samples which are obtained from the AMS (Agriculture Marketing Services) department USDA (United States department of Agriculture). A set of 5 ceramic tiles of color white, brown, yellow, grey and central respectively with the smooth surface and known Rd (degree of reflection) and +b (yellowness) values.

3.3.2 USDA Cotton samples:

AMS standard cotton fibers (2 boxes contain 12 samples). An example of the samples is given in the figure (2). 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. The tiles set mentioned above is very well prepared and possess a smooth surface for the evaluation. White, Brown, Yellow, Grey and central are the colors provide with the 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 the 12 cotton samples with different values of Rd and +b. The laboratory conditions used for the color measurement are (70 ± 2 °F and 54 ± 2% RH).

3.3.3 Pakistani cotton samples:

Pakistani cotton samples (12) are taken from the CCRI (central cotton research Institute) Multan, Pakistan. The HVI values of the samples are provided by the CCRI department. The cotton samples are tested with the non-contact method as well as contact method.

3.3.4 Turkish Cotton samples:

12 turkish cotton samples are used. These samples are actually the color standards of the cotton in turkey. And for the color measurement of Turkish cotton these standards are used for the calibration purpose.

Figure. 25 . 12 Turkish cotton samples.

3.3.5 Experimental:

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. In the fig. (26) 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).

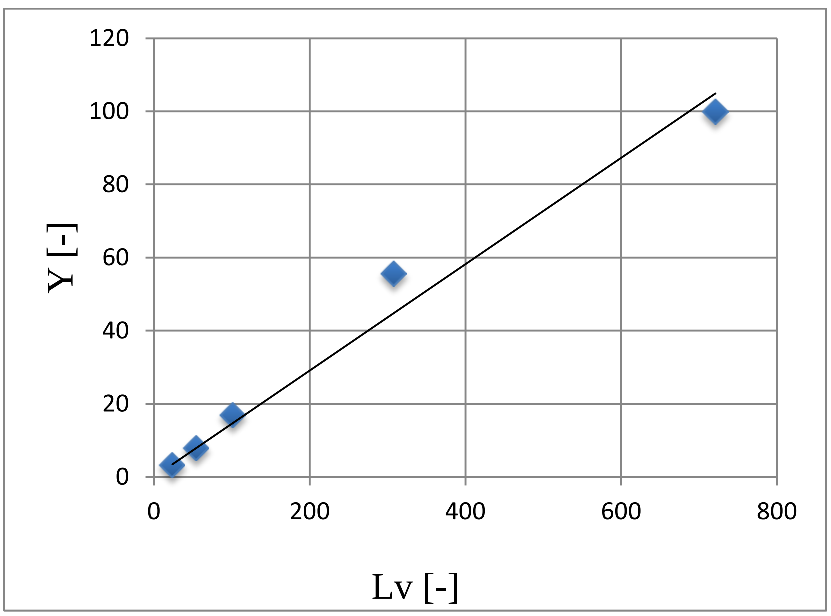


Figure 26. Relationship between the Lv (Luminance) value and the Y value of CIE XYZ.

In the below given table the line eqn. of the above table is presented which shows a great relationship between the luminance values taken from the non-contact method and the Y values.

Table 13. Equation of the trend of the line between the L_v (luminance) and Y values.

a (slope)	b(intercept)	R^2
0.27	1.87	0.99

3.3.6 Contact method:

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.

3.3.7 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 Figure (27). The images are cropped in order to include 700x700 pixels.

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

Figure 27. Original samples

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

Figure. 28. 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. Color images in RGB space can be converted into the CIE L*a*b* space with the help of the following conversion equations.

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

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

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

Where $f(t) = t^{1/3}$ if t > 0.008 856, else

3.4 Results and Discussion:

The color tiles used for the color calibration of HVI are used for the Comparison of contact and non-contact method.

Table 14. . Comparison of Non-contact method and contact method with calibration tiles.

Color Tiles	Contact method			Non-contact method		
	X	Y	Z	X	Y	Z
White	79.06	83.61	82.14	79.76	84.41	82.71
Central	69.88	73.20	67.04	69.65	72.98	66.82
Grey	53.87	56.89	58.46	53.98	57.00	58.59
Yellow	74.91	79.79	66.23	75.09	79.95	66.14
Brown	60.50	62.93	56.29	60.54	62.97	56.27

Hunter lab Miniscan XE portable spectrophotometer is used for the spectral data and to obtain the L*a*b* values. All the tiles and the cotton color standards were measured by placing directly the samples in front of the port of the spectrophotometer (42). The HVI results provided by the AMS department USDA are measured with the HVI instrument. The objective of the "HVI" is to measure the fiber length, fiber strength, Micronaire, trash and color. The results provided by the AMS department are respectively for two illuminants. For the sample color measurement HVI uses two wavelength band system to measure the Rd value as well as +b value (29). Our primary motive is to correlate the HVI provided results with the non-contact method (telescopy measurement) results. And to analyze whether is it possible to use Non-contact method in the cotton color measurement (43).

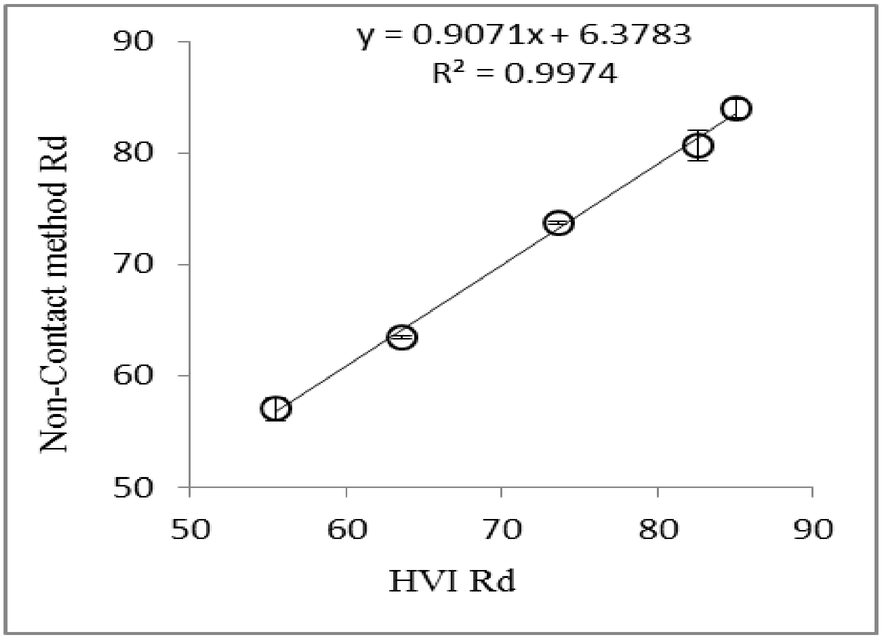


Figure 29. AMS standard ceramic tiles (xenon). HVI Rd Vs Non-Contact method Rd.

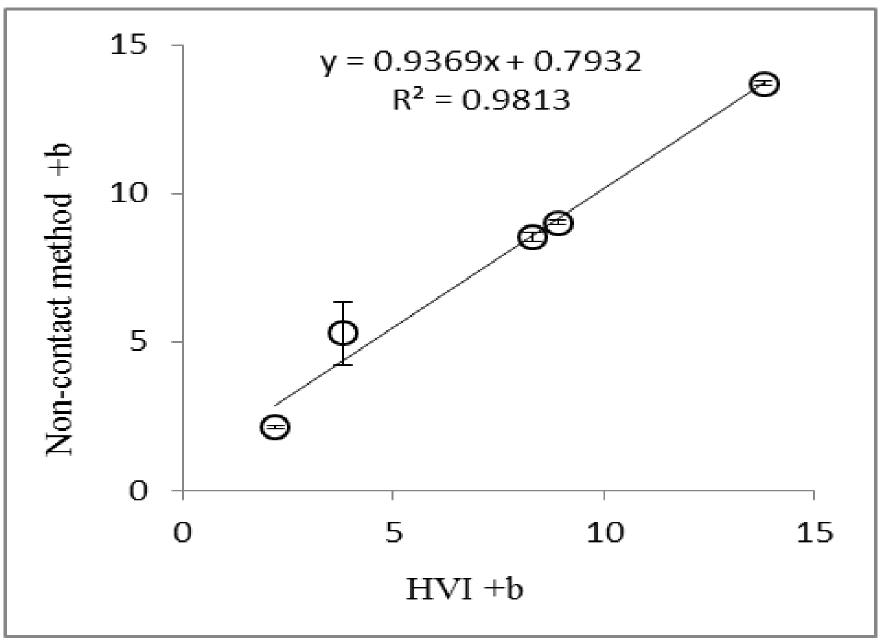


Figure 30. AMS standard ceramic tiles (xenon). HVI +b Vs Non-Contact method +b.

The HVI colorimeter uses two filters to measure the samples diffuse reflectance at the two visible spectrum regions and the value of Rd and +b obtained from the Uster algorithms. In the Laboratory of Color and Appearance measurement in the Technical University of Liberec, two sets of tile were measured again with the Non-contact method. One set for incandescent and the second with the xenon light source. Then the value of Rd and +b were compared between the HVI-1000 and with the Non-contact method. In the table it is clearly visible that there is a strong relationship between the HVI measurement and with the Non-contact method measurements. In both the parameters (Rd, +b) the values are very close to each other with R^2 value of (0.99, 0.98) respectively.

Table 15. x, y, Lv values obtained through non-contact method.

USDA Cotton	x	y	Lv	X	Y	Z
1	0.336	0.366	234	76.70	78.80	64.70
2	0.338	0.366	230	74.70	77.30	65.10
3	0.338	0.365	215	69.80	72.40	59.60
4	0.338	0.366	210	68.20	70.50	57.80
5	0.346	0.376	212	69.60	71.20	53.70
6	0.336	0.376	186	60.80	62.50	46
7	0.332	0.378	229	74	77	62.30
8	0.334	0.378	193	63	64.80	55.30
9	0.346	0.372	187	54	56	43.90
10	0.349	0.369	198	64.50	66.70	52
11	0.342	0.377	191	61.10	64.10	43.10
12	0.346	0.378	177	57.10	59.60	42.70

3.4.1 USDA Cotton Samples:

Table (15) shows that the cotton samples from the USDA are measured through non-contact method and the values then converted from the luminance to the CIE XYZ values. Then the comparison of the non-contact method is made with the CIE values under the illuminants (D65, A, F11) (44). Comparison between CIE (D65, A, F11) and the non-contact method (D65, A, F11) is shown in figure (31)(32)(33). The CIE data is obtained from the spectral data which was taken from the Hunter-Lab miniscan XE. And the B W-LED data is obtained from the telescopic method (45). A strong co-relation is observed between the values obtained from the CIE spectral data and non-contact method.

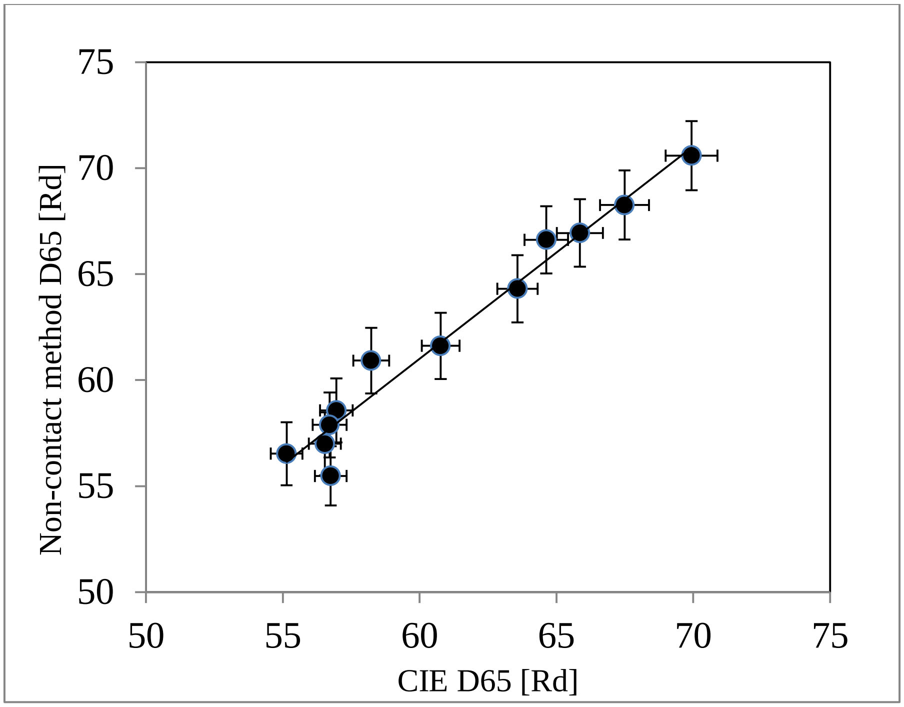


Figure 31. Rd values comparison between CIE (D65) and Non-contact method (D65).

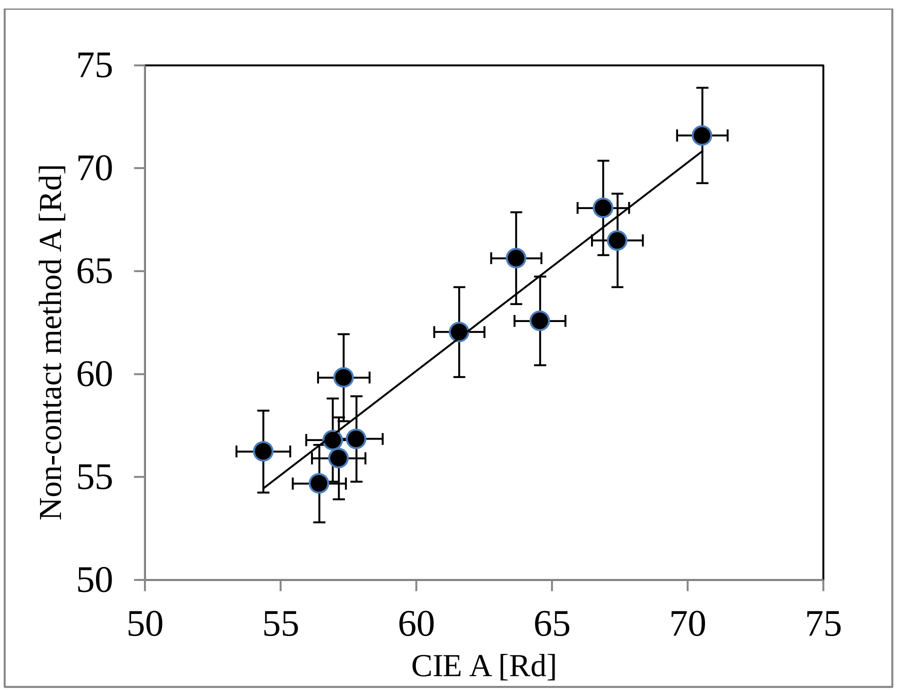


Figure 32. . Rd vaues comparison between CIE (A) and Non-contact method (A).

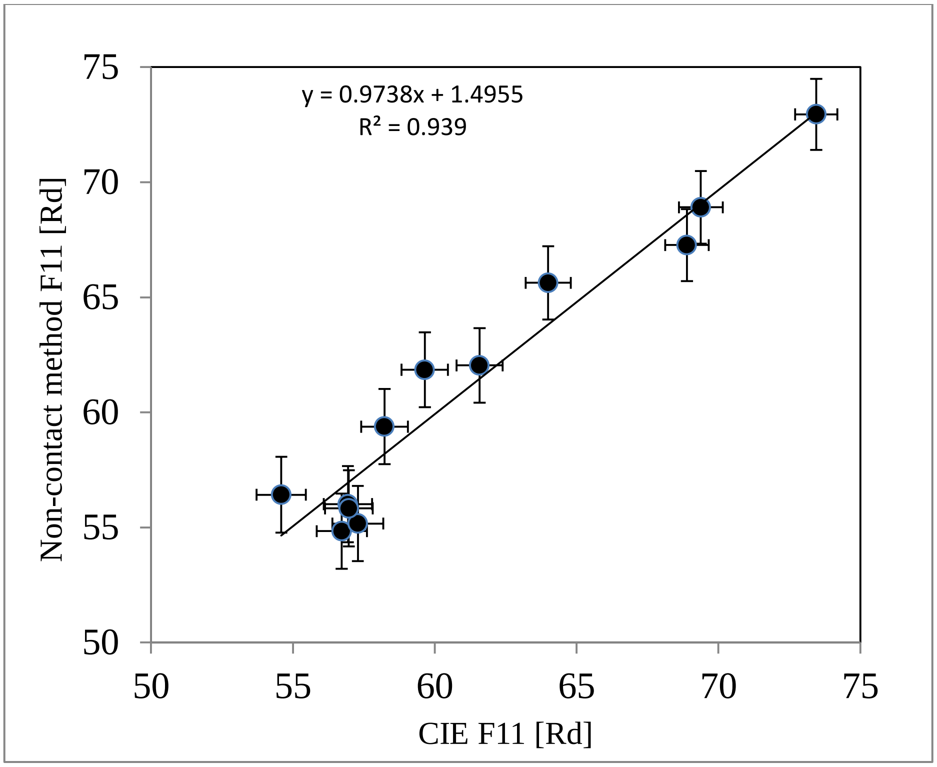


Figure 33. Rd values comparison between CIE (F11) and Non-contact method (F11).

Table 16. Equation of line for different illuminants.

Illuminants	a (slope)	b (intercept)	R^2
D65	0.89	1.09	0.96
A	0.54	1.01	0.92
F11	1.49	0.97	0.93

3.4.2 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 17. . 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 (46). 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 (20) (47).

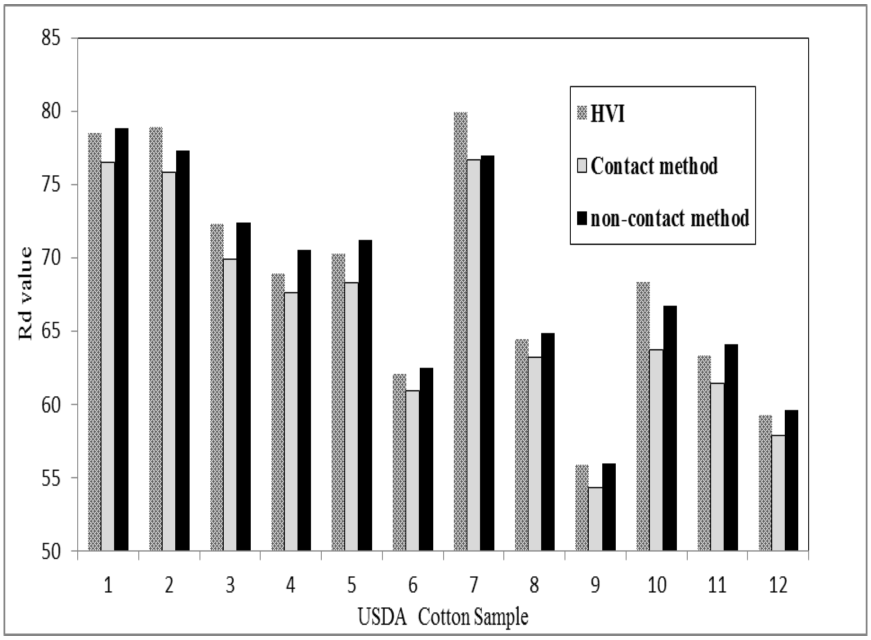


Figure 34. Comparison of Rd values of non-contact method with the HVI and contact method.

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 globally for the cotton color measurement (48).

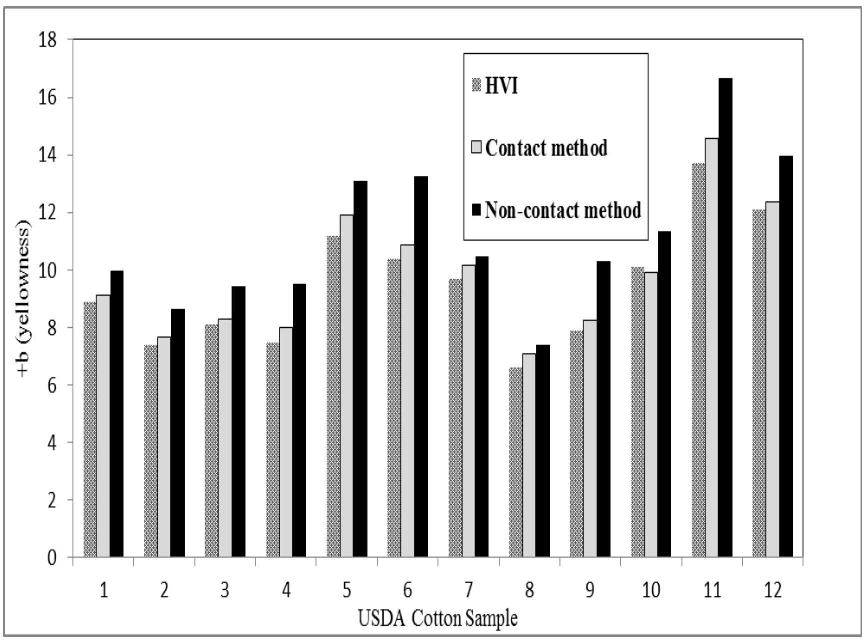


Figure. 35. comparison of +b values of non-contact method with the HVI and contact method.

3.4.3 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 (31). The properties of the cotton samples measured with the HVI are given below:

Table 18. 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	23.80	23.92	6	5.40	60.60	9.10
2013/2 CCRI	25.40	27.35	5.80	3.80	64.90	11.60
2012/3 CCRI	26.60	27.55	6.30	3.70	71.50	12.70
131 CCRI	24.90	27.65	5.40	3.80	66.10	8.40
2014/1 CCRI	24.70	26.37	6.10	4.50	68	13.60
2014/3 CCRI	26.40	28.63	5.90	3.50	74.70	8.90
117 CCRI	24.60	24.61	5.20	4.90	53	10.60
149 CCRI	25.20	25.20	5.30	4.80	68.20	8.80
156 CCRI	25.20	28.04	5.40	3.80	62.30	9.60
143 CCRI	27.30	29.31	6.30	3.90	64.40	9.60
2014/2 CCRI	26.80	26.86	6.10	3.80	76.40	12
109 CCRI	25.40	30.98	6	3.20	58.50	8.90

Each sample was analyzed by non-contact colorimeter CA-210 (Minolta, japan) from a controlled distance of 30 cm (49). As basic set calibration samples were used grey scale samples from X-Rite Color Checker standard (50). 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.

Table 19. Transformation of the value x, y and Lv values into CIE XYZ system.

Pakistani Cotton	X	Y	Z	x	y	Lv
159 CCRI	56.08	59.48	50.69	0.337	0.358	176
2013/2 CCRI	56.91	61.73	49.28	0.343	0.360	177
2012/3 CCRI	58.91	68.76	47.16	0.351	0.368	183
131 CCRI	59.57	63	53.77	0.338	0.357	187
2014/1 CCRI	57.60	64.05	45.98	0.352	0.367	178
2014/3 CCRI	64.23	67.83	57.40	0.339	0.358	201
117 CCRI	39.54	48.74	34.13	0.342	0.362	124
149 CCRI	58.15	61.42	52.47	0.338	0.357	182
156 CCRI	57.13	60.39	50.27	0.341	0.360	179
143 CCRI	53.66	56.76	47.75	0.339	0.359	168
2014/2 CCRI	66.21	69.86	55.84	0.345	0.364	207
109 CCRI	53.13	56.22	48.27	0.337	0.357	167

$$Lv \cong Y \qquad (15)$$

Resulting values were subsequently compared among itself and with contact method using correlation plot. It is also shown that the results of telescopic color measurements represent very strong relationship with the HVI color measurements. This non-contact method is capable of measuring color from different points of the sample so that measurements are more reliable unlike averaging the color of the measuring area as is applied with HVI system(51). Therefore this method is used for color analysis of cotton samples in this research .

This part of research investigates the variation in the cotton color standard with a new method (non-contact method) by using LEDs as light source. Standard samples obtained from the AMS department with the known Rd and +b values are used for experiments (52). The results obtained from this new method will be compared with the other image analysis as well as

HVI results. And the spectral data obtained of these samples with the help of Hunter lab Miniscan XE is also used to compare the results with the spectrophotometer.

Y values of the sample 159 CCRI measured through non-contact method varies between 56.02 and 61.42, sample 2013/2 CCRI varies between 53.62 and 59.87, sample 2012/3 CCRI varies between 57.16 and 64.71, sample 131 CCRI varies between 60.92 and 69.38, sample 2014/1 CCRI varies, between 56.79 and 60.27 Sample 2014/3 CCRI varies between 62.21 and 71.86 Sample 117 CCRI varies between 41.5 and 53.8, sample 149 CCRI varies between 57.6 and 66.87 sample 156 CCRI varies between 56.62 and 66.87 sample 143 CCRI varies between 49.63 and 58.17 sample 2014/2 CCRI varies between 53.4 and 59.9 sample 109 CCRI varies between 51.62 and 59.94 .while the calculated means of samples are shown in the table no.20 respectively.

Similarly +b values of the sample 159 CCRI measured through non-contact method varies between 6.08 and 8.4, sample 2013/2 CCRI varies between 9.10 and 14.76, sample 2012/3 CCRI varies between 9.16 and 11.21, sample 131 CCRI varies between 6.92 and 9.32, sample 2014/1 CCRI varies, between 11.97 and 14.41 Sample 2014/3 CCRI varies between 6.21 and 9.86 Sample 117 CCRI varies between 8.5 and 9.8, sample 149 CCRI varies between 7.6 and 10.57 sample 156 CCRI varies between 6.21 and 10.75 sample 143 CCRI varies between 7.6 and 11.17 sample 2014/2 CCRI varies between 9.4 and 13.9 sample 109 CCRI varies between 5.61 and 9.49 .while the calculated means of samples are shown in the table no. 21 respectively.

Histograms of b* and L* values obtained from digital images in CIE LAB space are shown in figure (36) to figure (41) respectively. The b values correspond to the color attribute of the sample and more uniform; whereas L values are highly affected by the sample preparation and the lighting angle due to the fact that these effects cause shadows and light shines. Digital image analysis method can be used for the investigation of variation within cotton color sample

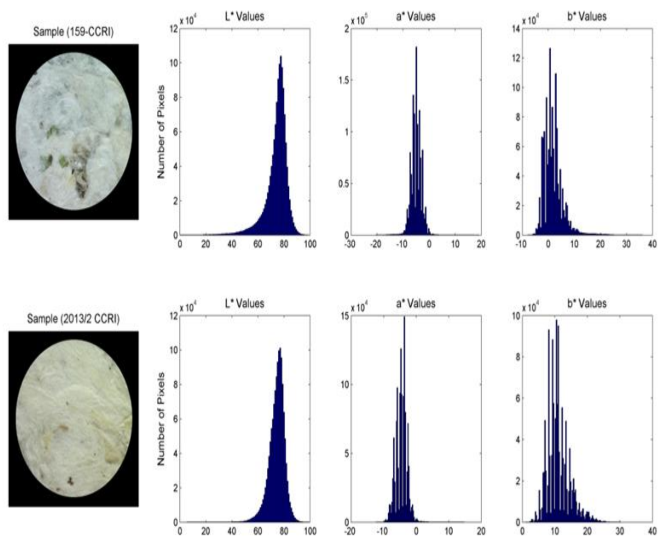


Figure 36. Histograms of L*a*b* values for cotton sample (159 CCRI) and (2013/2 CCRI).

These histograms images which are shown in the respective figures are very important in the sense that they show actually the variability of the cotton sample in all the color channels L*, a*, b*. In our next chapter we will discuss the trash segmentation from the cotton surface. And it is also observed that the color channels which will be used there for color measurement will be lightness and chroma. The cropped images which is shown in the is taken under a controlled ambience inside of the light cabinet. The temperature of the light source used is 6500K which is necessary to cotton color measurement. The images which contain trash particles on the surface of the cotton can clearly see in the lightness values with respect to their pixels.

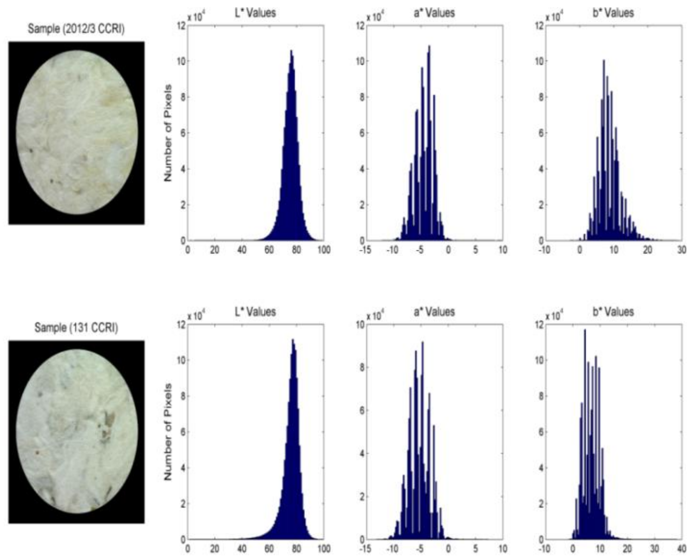


Figure 37. Histograms of L*a*b* values for cotton sample (2012/3 CCRI) and (131 CCRI).

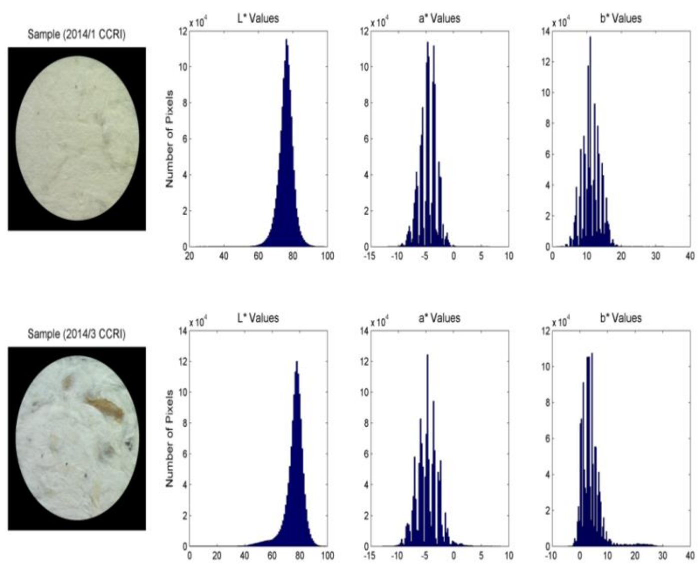


Figure 38. Histograms of L*a*b* values for cotton sample (2014/1 CCRI) and (2014/3 CCRI).

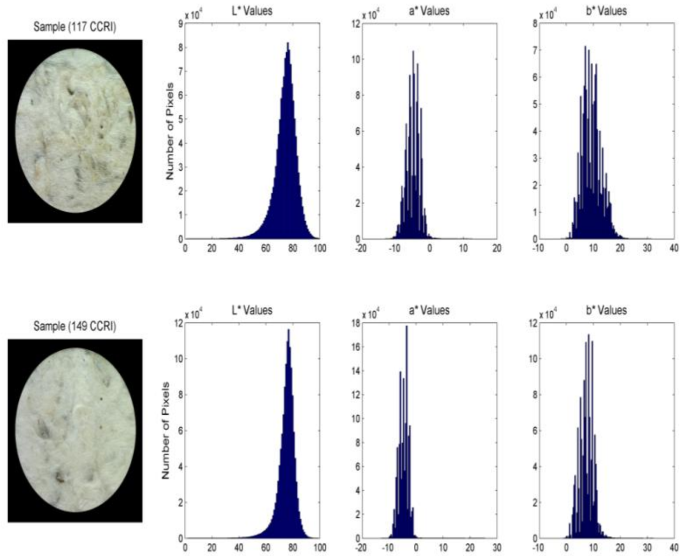


Figure. 39. Histograms of L*a*b* values for cotton sample (117 CCRI) and (149 CCRI).

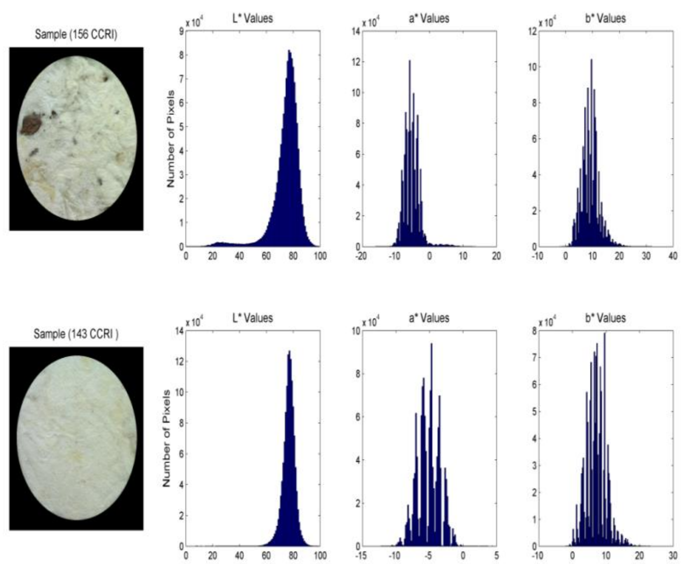


Figure. 40. Histograms of L*a*b* values for cotton sample (156 CCRI) and (143 CCRI).

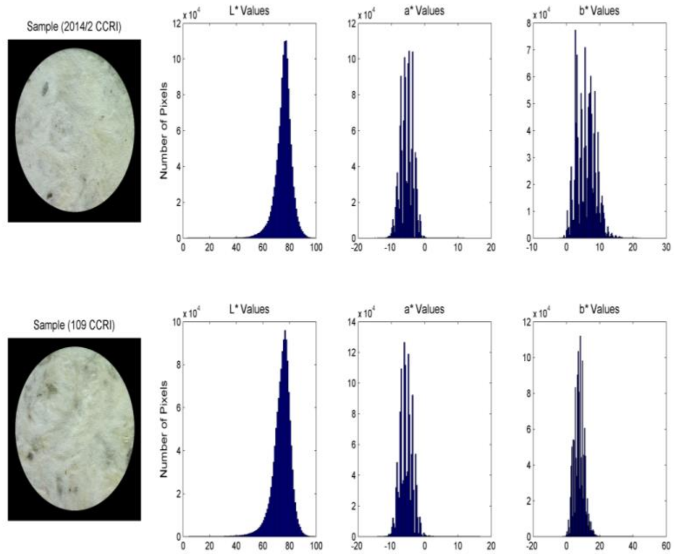


Figure 41. Histograms of L*a*b* values for cotton sample (2014/2 CCRI) and (109 CCRI).

Table 20. Descriptive statistics of the measured values by using digital camera is summarized.

	Cotton Samples	159 CCRI	2013/2 CCRI	2012/3 CCRI	131 CCRI	2014/1 CCRI
L*	Min	0.36	2.18	13.61	0.99	18.04
	Max	98.95	99.12	98.48	99.07	98.66
	Mean	73.73	74.91	74.79	74.41	75.53
	Median	75.44	76.13	75.36	76.04	76.09
	Std.Dev.	8.78	7.38	5.39	8.06	4.86
a*	Min	-16.76	-12.12	-12.44	-13.21	-12.13
	Max	12.93	13.10	6.76	10.25	6.24
	Mean	-4.89	-4.16	-4.37	-4.86	-4.45
	Median	-4.92	-4.19	-4.31	-4.83	-4.37
	Std.Dev.	2.01	1.84	1.69	1.87	1.66
b*	Min	-7.92	-2.91	-3.45	-1.83	-0.73
	Max	31.60	31.03	27.72	36.93	27.13
	Mean	2.43	8.18	7.49	7.62	10.00
	Median	2.21	7.84	7.39	7.44	9.88
	Std.Dev.	3.10	3.43	3.15	3.04	2.78

Table 21. Descriptive statistics of the measured values by using digital camera is summarized for cotton samples.

	Cotton Samples	2014/3 CCRI	117 CCRI	149 CCRI	156 CCRI	143 CCRI
L*	Min	3.94	0.71	3.17	1.78	10.94
	Max	98.66	99.34	98.84	99.06	98.57
	Mean	76.51	73.90	75.93	74.99	76.82
	Median	77.35	75.39	77.07	76.36	77.16
	Std.Dev.	6.14	9.46	7.02	8.28	4.85
a*	Min	-12.56	-14.28	-13.46	-14.58	-12.45
	Max	10.06	12.40	12.29	12.54	6.77
	Mean	-4.72	-5.31	-5.03	-5.20	-5.00
	Median	-4.77	-5.33	-5.05	-5.21	-4.98
	Std.Dev.	1.92	2.09	1.83	2.01	1.73
b*	Min	-5.60	-1.77	-1.58	-2.13	-2.67
	Max	25.51	44.55	31.66	31.46	24.73
	Mean	3.17	9.15	7.89	8.08	7.07
	Median	2.88	8.94	7.81	8.09	6.93
	Std.Dev.	2.97	3.70	2.84	3.19	3.05

Table. 22. Descriptive statistics of the measured values by using digital camera is summarized.

	Cotton Samples	2014/2 CCRI	109 CCRI
L*	Min	4.19	1.55
	Max	98.93	99.13
	Mean	75.61	75.59
	Median	76.24	76.96
	Std.Dev.	6.09	7.98
a*	Min	-15.13	-14.27
	Max	9.57	12.55
	Mean	-5.45	-5.09
	Median	-5.51	-5.14
	Std.Dev.	1.83	1.94
b*	Min	-2.59	-3.91
	Max	30.84	32.30
	Mean	5.85	6.09
	Median	5.68	5.98
	Std.Dev.	2.71	3.09

Table (20) and Table (21, 22) summarizes the comparison of values obtained by Non-contact method, image analysis method and standard HVI values derived for Rd values and +b values. It can clearly be seen from the tables that all values show similar tendencies. Although further analysis of the noncontact method and image processing method reveals that color variations exist even with the standard cotton samples prepared for calibration and must be as homogenous as much possible. Cotton is a natural fiber and the color of the fiber cannot be controlled fully like manmade fibers. Therefore color variation must be an expected property while it must be taken into account while classifying the cotton grades (32).

3.5 Conclusion:

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.

4 Chapter 3

4.1 Visual Grading of cotton and Comparison with different methods

Visual classification of cotton sample is an art of presenting the color of cotton by taking into means the international standards of cotton. As described in the previous chapter the color of cotton is an important factor to figure out the price of cotton. By keeping in view the quality of light used for the precise measurement is very important. The visual classification of cotton color is performed by the cotton classer by taking the reference of cotton standards in the daylight. For classification of cotton in the classing room it is very important to have lighting in the room same as in the daylight. Different parts of the world the daylight temperature of the light is different. In USA the temperature of the daylight is 7500K. The act of identifying a specimen by a color grade or color score that is specific to the color and the material graded is known as the color grading. Illumination is the density or the flux of light on a unit of the surface (53).

For the visual color grading of cotton there are different factors which can affect the phenomenon of color grading. It is not all about the quality of the illumination but the viewing conditions, age of the classer, experience of the grader, the table on which sample is placed (color of table top) and viewing angle these things are very important in point of view of cotton color assessment (54). All of these things will be discussed in this chapter and will be taken into consideration for the discussion point of view (55).

In the previous chapter we discussed the non-contact method and its use for the cotton color grading. It is necessary to analyze that the non-contact method can be used to minimize the dis-agreement between the visual and instrumental color measurement. And the grade assigned by the grader to the cotton is it close to the grade assigned by the non-contact method.

4.2 Theory:

According to young Helmholtz theory the photo receptor cells in the human eye makes the color vision. There are different kinds of receptors in the eye and these receptors are called cones. And each of the cones is sensitive to visible light at a particular range. The human eye is an organ that reacts with the light on the basis of several purposes. Rods and cone cells in the retina allows conscious light perception, vision, color difference and perception of depth. Human eye has the capability to distinguish 10 million colors and it is also capable to detect a single photon.

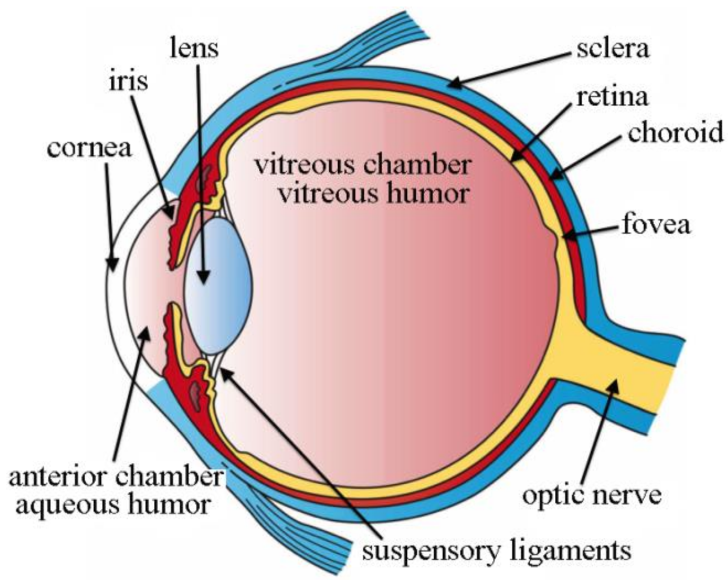


Figure 42. The structure of the human eye.

According to the research the mammalian eye consist of three types of photoreceptors which are rods, cones and photosensitive retinal ganglion cells. The two classic photoreceptors cells are rods and cones. The visual system of human works mainly due to these photoreceptor each of the photoreceptor carries the information which is useful for the visual system (56).

Basically the rods are narrower than the cones and they are distributed across the retina but the chemical process in each that supports photo transduction is similar to each other. A third class of the photoreceptors was also discovered in the last century which does not contribute directly into the sight but are thought to support circadian rhythms and pupillary reflex (36).

As far as the functionality of the rods and cones is concerned there are extremely major differences between these two photoreceptors. The rods are extremely sensitive and can be triggered easily with the help of a single photon. At the very low level of light the visual system of the human eye is solely based on the signals of the rods signal. So, at the low level of light the color cannot be seen and the major reason is that only one photoreceptor is active (57).

On the other hand the cones need relatively brighter light or a larger number of photons to receive signals from the eye. In the human eye there are three different types of cones cells which are distinguished according to their response to the different wavelength of light. So, actually the color difference is calculated on these three distinct cones signals. The firing of the cells depends on the number of photons absorbed. Three types of cone photoreceptors could be classified as short-preferring (blue), middle-preferring (green), and long-preferring (red), according to their response to the wavelengths of light striking the retina. The relative strength of the signals which is received by these three kinds of cones is utilized by the brain as different colors. This is the basic structure of the human eye and its working (58)(1).

Colorimetry is a technology which is quite similar to the spectrophotometry. But, it reduces the spectra to its physical correlates of color perception. Light sensation normally is created by the visible radiation. Electromagnetic radiations are falling within the range of (380-780) nm. Radiations of the short wavelength produce the blue color and the radiation of the normal range (520-550)nm are seen as green color and the radiation of the long wavelength are seen as red color. There are two different methods of producing color stimuli (59).

One of the methods is the additive color mixing and the other one is the subtractive color mixing. In the additive color mixing the lights are mixes in our eye. The color which we see through our eye is basically the mixture of the blue, red and green light. Here the spots are so near that our eye is not capable to differentiate between them. But if we will change the intensity of light then mixed colors will be produced. But in the subtractive color mixing the colorants remove some part of the visible spectrum which is based on the different concentration (60)(61).

Generally the laws of the additive color mixing are simpler than the subtractive color mixing. The general laws for the additive color mixing are given below,

- Every impression of the color is analyzed into three mathematical determinable elements the Hue the brightness of the color and the brightness of the intermixed white (62).
- If two lights are mixed and one of light between them is continuously altered then the impression of the mixed light is also continuously changed.
- If two colors have same hue and same portion of intermixed white it also gives identical mixed colors. Independent from the fact that which kind of homogeneous color is involved in their composition.
- The total intensity is always the sum of the intensities of the mixed lights (63).

CIE colorimetry stands on these laws that hold a comprehensive reason as long as observation condition of the observer eye (64). The color stimuli can be matched by the additive color mixing of three properly selected stimuli. No stimuli can be matched with the other two stimuli which are also involved in the additive color mixing (65).

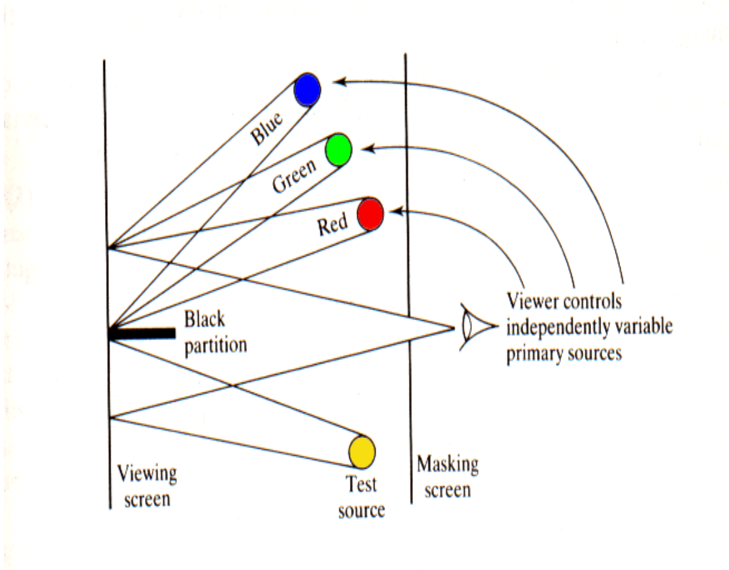


Figure. 43 . Basic experiment of color matching.

The test stimuli are subjective to the one side of the screen and the additive mixture of the three matching stimuli is placed on the other side of the field. Light flux of the three matching stimuli are adjusted to obtain a color appearance and when this is reached then the test stimuli can be characterized by three luminance values of the matching stimuli reaching the observer eye (66). The spectral power distribution of the test stimuli and the additive mixture stimuli are entirely different from each other. In such case we speak about metameric where the color look alike to the observer but their spectral power distribution is different. To obtain the colorimetry system one has to define the matching stimuli. Specifying both their spectral composition and the units in which their amounts are measured (67).

For the cotton color grading it is very obvious to know that the standard of the quality of color of illumination is the color and spectral quality of daylight of a moderately overcast northern sky.

As taking into consideration the 1965 CIE recommendation the data from 400 – 700 nm .. The tolerance of the color for meeting the color standards is 200K. And as far as spectral power is concerned the spectral distribution should as close as possible (68). And the color rendering index should not be less than 92 as recommended by the 1965 committee of international illumination. The optimum amount of illumination is unknown. If the light source is based on the fluorescent tube then according to the USDA the time of installation should be 100 foot candles at the surface. It is also seen that the illumination above 400foot candles ia considered as very poor. So, the optimum condition lies somewhere between them. Now a day's most recent installation are above the minimum requirement 150-200 foot candles approximately.

The geometry of the illumination is based that the lighting which is going to be installed should be diffuse so that when the observer looks at the sample he should have the perception at the depth. And this arrangement should be uniform at the whole room or in the whole working area it should be uniform. There should be no glare and also no cross-lighting and the brightness contrast of the light source should be held at minimum. Lighting should be able to provide the required amount of color from end –to-end on the table uniformly. Installation should be based on the pattern illumination provided by the pattern illumination. It is also recommended that the air conditioning should be specified with the lighting conditions as well. In the cotton classing rooms the lighting which fulfills these recommendations is widely used. And it is a common practice in the cotton classification. The use of spectral diffusing glass is common in this practice because it allows the low brightness of the color but also use to diffuse the color. Diffusing glass at the bottom of the units is set 10 ft (3m) from the floor and parallel to it, in rows centered 6 ft (2.1 m) apart. A minimum of four rows are recommended for an average sized room. For the full use of the room the lighting unit should be extended from 3-4 ft units (69).

For a single table for classing there should be three units and for the classing room the two rows of for units each should be installed.

The color of the walls, ceiling, floor and the cotton itself has a very considerable effect on the lighting units used. Classing rooms should be of neutral color so, that no chromatic color should be enhanced or discounted more than another. Neutral colors cover a range from series of white to black. All the grey colors which are used should of neutral so; any trace of hue should be avoided. So, the lightness of the grey should depend on the amount of light which is coming into the room and reaching the classing surface. For rooms with artificial lighting, such as those lighted with wall-to-wall lighting units, the surroundings should be a very light neutral gray, no darker than Munsell Neutral 8.5/, in order to conserve the lighting and to reduce brightness contrasts as much as possible (70).

The following color specifications are those used by the U.S. Department of Agriculture for surroundings in cotton classing rooms.

- Walls, no darker than Munsell Neutral.
- Ceilings, white, or as near white as possible, in no case darker than Munsell Neutral.
- Mats on which a classer stands should be black.
- Tables for Classing, light gray, with black top.

The papers which are used for the sample should not cover the large area of the view. The lighting should be properly maintained and a consistent routine should be followed which is given below,

- Daily inspection to check that all lamps are in good order.
- Prompt replacement of deficient lamps by the proper type of lamp.
- Use of a foot candle meter8 to chart and record foot candle levels throughout all classing areas. The level of these data should be watched throughout the year to

determine changes in illumination. Records of this sort, kept over a period of years, are a help in setting up definite cleaning and replacement schedules.

- Regular cleaning of fixtures, recording foot candle levels before and after cleaning.
- In fixtures that include use of fluorescent lamps, regular inspection of ballasts, at least once each year. Low voltage or lack of ventilation above the lighting units tends to cause the ballast to overheat and bleed. In fact, ballast trouble can cause considerable variation in light output.

Cotton color indicates other quality parameters of the cotton and it is also important to have a uniform color of cotton in order to obtain the uniform color after dyeing. In point of view of the spinning it is also of great importance to have precise measurement of the cotton bale color so that the blending of cotton should be of less complicated process. The need of the automatic colorimeter brought about the Nickeron and a photoelectric direct reading device was introduced. It was also known by the Nickerson that the instrumental measurement is not the replacement of the human classer (56).

The color represents the average of the contribution made to the color of a sample by the color of a fiber. The colorimeter has become almost grader not the almost (71). Previously research showed that the instrument developed by the Nickerson cannot be replace the visual classification. The reason that it cannot replace is that the instrument sees only one thing. It sees the average color of whatever appears on the face of the sample placed over its sample window. The instrument, whether this one or any other, cannot tell whether the color it reads is the color of spots or the color of foreign matters or it is a general background (14).

The presence of the dark particles on the surface of the cotton fiber would impart an overall darker color to the cotton sample. A study shows that the increase in the color grade after cleaning from the Shirley analyzer (which is a mechanical device used for the cleaning of the foreign matters present in the cotton fiber. Other study has also revealed that the value of Rd increases after cleaning with the Shirley analyzer. A negative correlation between trash content and Rd and between trash content and +b and an average increase of 4.4 Rd units and 0.5 +b units with the addition of lint cleaning. The problem further by examining the color of a constant sample face before and after meticulous removal of trash particles by hand (72).

The work involved both seed cotton and lint samples on which no seed cotton cleaning or lint cleaning had been performed; thus, a relatively large amount of foreign matter was present. Hand-cleaned samples had higher values of Rd, while the change in +b was unpredictable. There was significant correlation between the amount of trash removed and the change in Rd, and the R^2 value was relatively high (approximately 0.8) for the seed cotton samples. These results confirmed that non-lint material, by itself and without regard to machinery effects, affects color. Improving cotton color measurement is necessary to improve accuracy at the classing office, and so process control in ginning can more accurately route cotton through the most profitable sequence of machinery. An experimental cotton color/trash meter was developed for the purpose of improving color measurement on trashy cotton (12).

4.3 Material and methods:

24 cotton samples are used here for the visual classification. In which USDA standard cotton samples and also Pakistani cotton samples are included. The visual classification process involves the measurement of comparative grading of cotton with different methods. The process of visual classification involves group of people. People are professionally trained people of cotton classing. Which grade the cotton according to the USDA specified standards and the

second group of the classed is the group which does not have that much of experience of cotton classing but they possess enough knowledge of the cotton classing.

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. W_{CIE} (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 t-test is applied in the research for the statistical analysis between the visual grading as well as instrumental grading. The trilobite QC expert software is also used here for the analysis of the data. 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, which affect the color of the cotton samples.

4.4 Results and discussion

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 (73). 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 (74). 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.

Table 23. 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	68.90	109 CCRI	68.30	109 CCRI	64.40
117 CCRI	68.30	117 CCRI	55.90	117 CCRI	55.90
131 CCRI	64.40	131 CCRI	62.10	131 CCRI	68.30
143 CCRI	68.90	143 CCRI	68.90	143 CCRI	68.30
149 CCRI	78.50	149 CCRI	68.30	149 CCRI	68.90
156 CCRI	62.10	156 CCRI	68.30	156 CCRI	59.30
159 CCRI	55.90	159 CCRI	68.90	159 CCRI	68.30
2012/3 CCRI	63.30	2012/3 CCRI	59.30	2012/3 CCRI	63.30
2013/2 CCRI	59.30	2013/2 CCRI	62.10	2013/2 CCRI	59.30
2014/1 CCRI	63.30	2014/1 CCRI	63.30	2014/1 CCRI	63.30
2014/2 CCRI	70.30	2014/2 CCRI	70.30	2014/2 CCRI	70.30
2014/3 CCRI	79.90	2014/3 CCRI	78.50	2014/3 CCRI	79.90

While giving cotton a grade the cotton observer is asked to rank the cotton sample according to the degree of the whiteness (75). Then by using statistical software trilobyte QC expert the observation were analyzed with and the given results are examined.

Table 24. Anova table for the Different background observation.

Anova table for Rd values								
Source of variability	Sum of squares	Mean squares	Degree of freedom	St. Deviation	F-statistic	Critical quartile	Conclusion	p-value
Background	18.87	9.44	2	3.07	0.35	3.44	Insignificant	0.70
Cotton samples	705.67	64.15	11	8.01	2.42	2.30	Significant	0.04
Interaction	5.82	5.82	1	24.13	0.21	4.32	Insignificant	0.65
Residuals	576.35	27.45	21	5.24				
Total	1306.71	37.33	35	6.11				

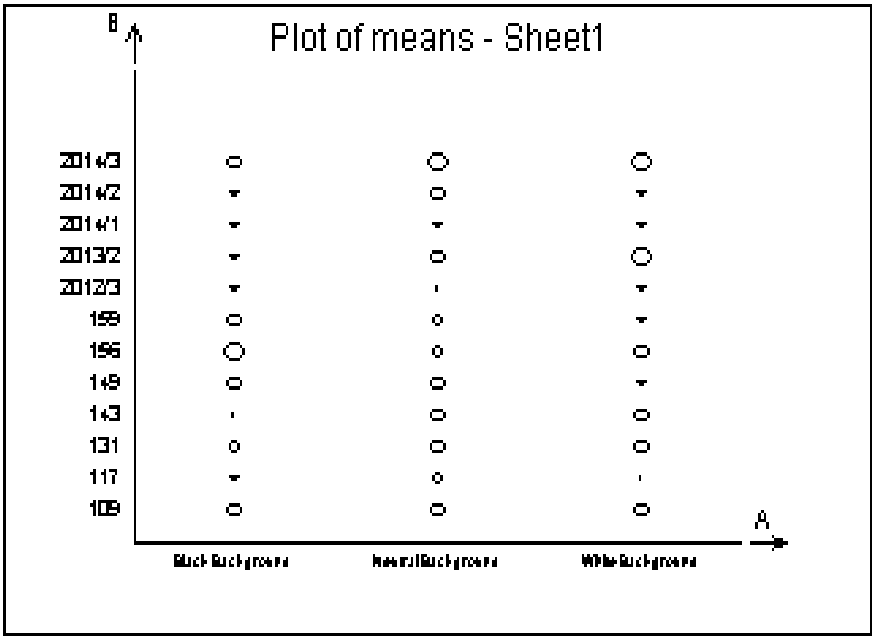


Figure 44. Plot of means with different background effect.

Table 24. shows that the analysis of variance for the different background observation. And in fig (44) it can also be observed the plot of means which is actually developed by the software used for the data evaluation.

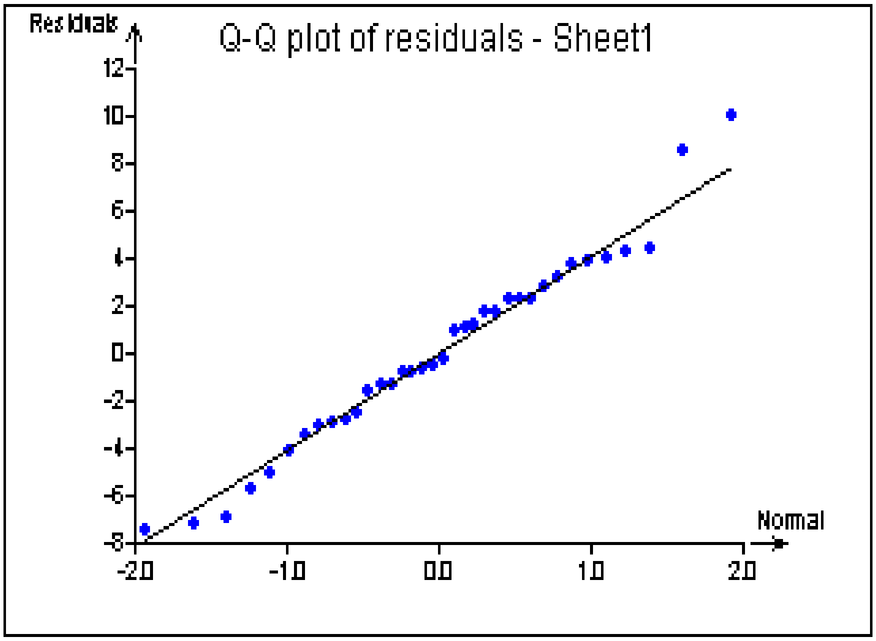


Figure 45. Q-Q plot of residuals.

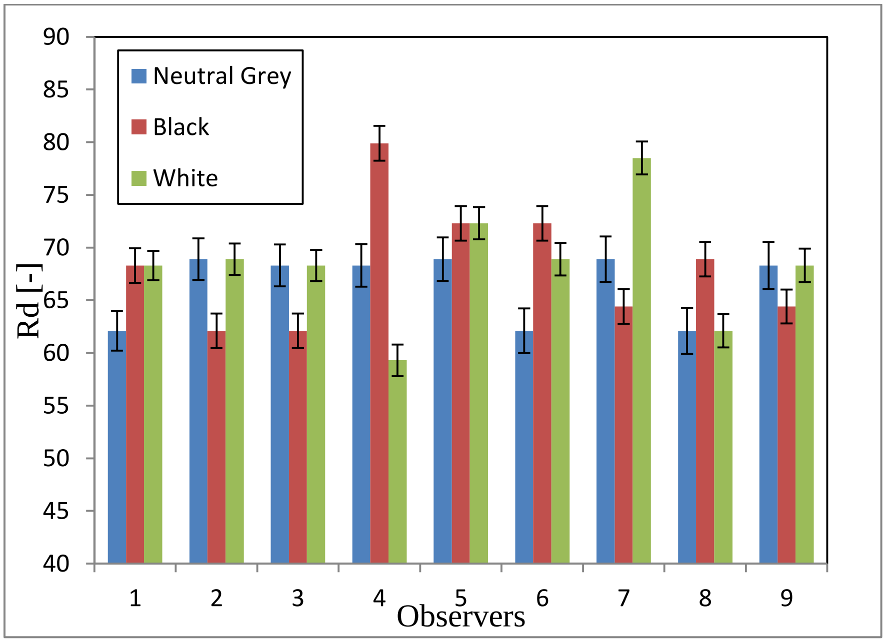


Figure 46. Effect of different backgrounds on the Rd values.

Fig (46) and fig (47) represent that how the observer grade cotton Rd and +b values in different backgrounds (neutral grey, black and white). The conventional system of grading the cotton visually is based on the black background on the table.

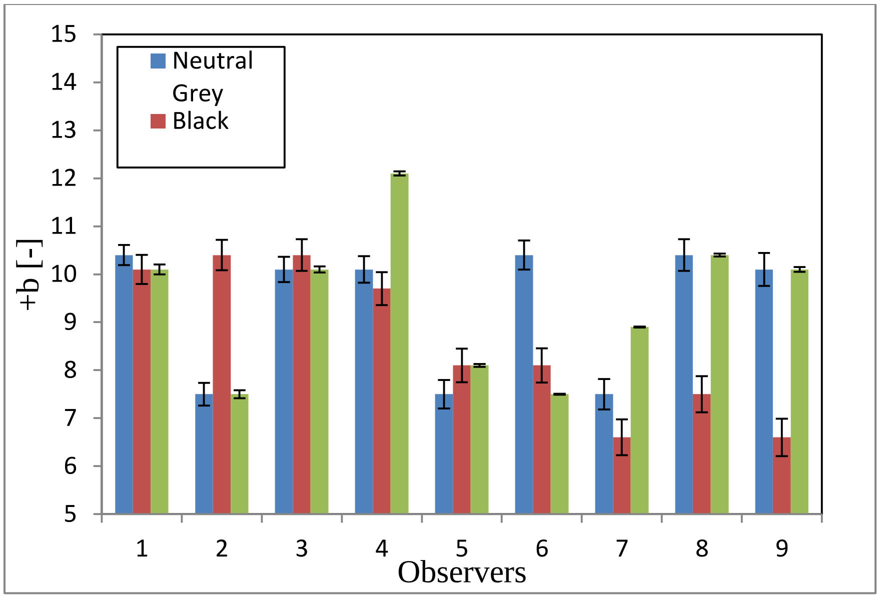


Figure 47. Effect of different cotton samples on +b values.

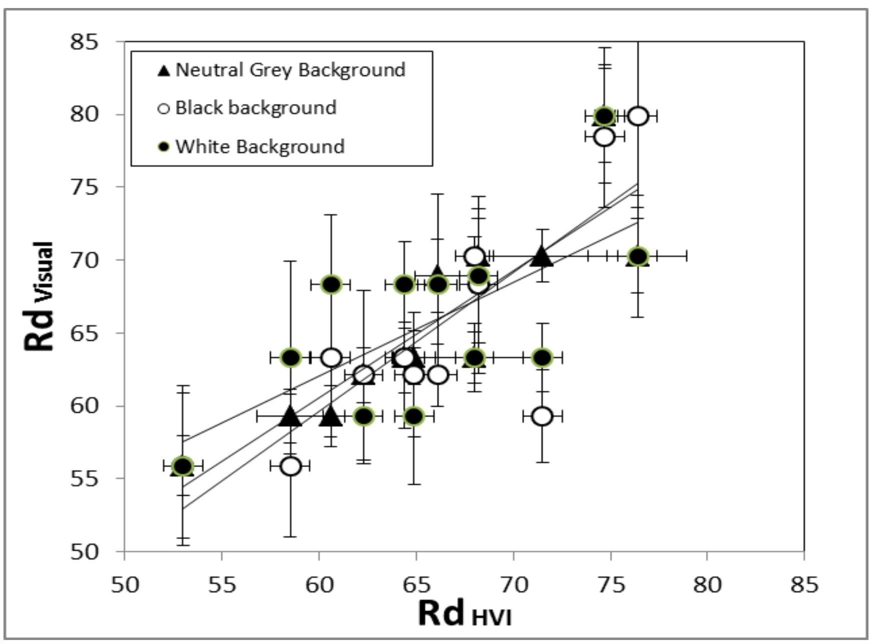


Figure. 48 . Rd values comparison between HVI and visual inspection.

Figure (48) shows that how the results of HVI correlates with the visual grading system. The correlation with the neutral grey background shows good compatibility with the HVI results as compared to the black backgrounds.

Table 25. Equation of the line for different backgrounds.

	a (slope)	b (intercept)	R^2
Neutral Grey Background	0.87	8.1	0.78
Black Background	0.95	2.37	0.66
White Background	0.64	23.3	0.45

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 (34). 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 (76).

Table 26. 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 (77).

The below given table indicates whiteness index measurement with comparison to the visual ranking of the observer (78). 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 (79).

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

The x, y chromaticity values can be obtained in different ways. As in our previous research we use a method called non-contact method and in this method we obtained luminance values as well as chromaticity values. Now, it is necessary to discuss that the chromaticity values can also be obtained by using CIE XYZ values. In our research the consider values are calculated from both methods. Although there are also different formulas for whiteness measurement which can be used but he CIE whiteness formula is used more frequently in whiteness measurement.

Table. 27. Whiteness index measurement for cotton sample.

Sample	Y	X	y	W_{CIE}	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 shows that the whiteness values measured with CIE whiteness formula and also measured with observer ranking. The Spearman rank correlation is used for the analysis and it was observed that the spearman rank co-relation is (.75). This is actually quite enough to show that there is a strong relationship between the visual relationship and with the CIE whiteness.

Besides this experiment one more experiment is performed with the same cotton samples and with recommended background from the USDA and it was seen that the spearman rank correlation was quite good. In this experiment almost 15 people were used for the experiment and they were asked to perform the experiment independently and rank the cotton according to its whiteness. The visual evaluation of the samples is also dependent on the observer age its color perception ability. The observer is called upon more than once in the classing room for evaluation and it is make sure that the ambience of the classing room is kept constant. There are some other factors also which can affect the cotton classing a great deal inside the cotton classing room.

Table 28. Use of spearman rank co-relation betweenvisual experiment and CIE whiteness.

Cotton Samples	Observer	CIE Whiteness	d	Σd^2
117 CCRI	8	9	-1	1
109CCRI	6	4	2	4
159CCRI	7	5	2	4
156CCRI	5	6	-1	1
143 CCRI	2	7	-5	25
131 CCRI	4	2	2	4
149 CCRI	3	1	2	4
2014/1CCRI	12	11	1	1
2013/2CCRI	9	10	-1	1
2012/3CCRI	11	12	-1	1
2014/3 CCRI	1	3	-2	4
2014/2 CCRI	10	8	2	4
			0	54

$$r = \frac{1-6\Sigma \boldsymbol{d}^2}{n(n^2-1)} \qquad (17)$$

The above given equation is used for the spearman rank correlation. And The value obtained from this formula is (.81). This is quite enough to show the strong relationship between the visual experiment and instrumental measurement. Previous relationship was not quite high but in this experiment it is improved upto a considerable limit.

4.5 Conclusion:

The research shows the factors which should be taken into consideration for visual grading of cotton and these factors affects the visual grading of cotton. The disagreement of the visual and instrumental grading is reduced by making some changes in the visual process. It clearly shows that the instrument measurement of color and visual grading of cotton have some differences due to the presence of the trash particles of the surface of the cotton samples. The instruments consider these particles as spots on the sample. This is the reason why a sample which is graded as white by the cotton classer will be considered as light spotted by the instrument grading.

The comparison between the non-contact method and visual classification shows that due the small measurement area of the cotton sample in non-contact method is quite helpful to reduce the disagreement. As HVI required the large area of the sample so it is not possible for HVI to check the variability of cotton sample and also it enhances the chances of disagreement between the HVI and visual grading of the cotton.

A question arises here that a method for instrument measurement should be introduced which like visual inspection should not take into consideration the trash particles while the color measurement. Such kind of process is introduced in the next chapter and the comparison is made that this method is valid to reduce the disagreement between the visual classification and instrument classification.

5 Chapter 4

5.1 A unique method for the trash Segmentation from cotton sample

In this approach mainly it is intended to detect and exclude the irregular regions in cotton image by using image processing methods in order to obtain the color of raw cotton sample. This will be realized by acquiring digital images of cotton samples in a pre-organized scene/state and detecting irregular regions in the cotton sample images using image processing methods in order to exclude these irregular regions while obtaining color information of raw cotton sample afterwards. Although researchers in image processing community often are not aware of the origins of the images they work with and simply work on their algorithms to consider the image as a multivariate function, it is important to determine image acquiring scene and know the entire processing steps applied to an image after being captured when the color measurements are involved in research (80)(29). In view of this information the process applied in this research can be summarized as follows:

1- Obtaining the RGB image

2- Obtaining color corrected images (Characterization)

3- Detection and exclusion irregular region using image processing methods

The process of detecting the irregular region through image analysis process is quite complicated process (81). To detect the irregular region one must have the information that which part should be considered as irregular region because the cotton possess no of trash particles of different kinds (82). The motivation of this study is to detect the trash particles and then removal of these particles from the surface while measuring the cotton color. In this way it will be possible to reduce the disagreement between the instrument and visual measurement (83)(84).

5.2 Theory

A light source to eliminate the object, a CCD camera which can also be called as sensor system and an interface between computer and a sensor system are actually involved in the image processing system. The working of interface is to convert the analogue to the digital system because the computer cannot understand the analogue system. So, interface transformation into digital system helps computer to read the digital information. And there is a part name as frame grabber which actually stores the image. There are different kind of frame grabbers in the market which can be used to which can run the programmes in the time-efficient way. Even though these programmes are involved I n calculation intensive part image. The result of an image processing can be transferer to the outer side by using more than one interface. New techniques are able to integrate the image processing system into camera. In this part of the theory we will try to discuss the hard components of the image processing system.

5.2.1 Illuminating the object:

One of the important part of image processing is to select the light source which will be used to enlighten the object. A good and wise decision should be required for the selection of light source because it can give us the best image under the desired circumstances. And when the restoration of the image is done the number of steps can be minimized. The features of the radiation can be select properly according to the surface of the object. So, the maximum number of intensity level is required actually for an image capturing technique. And it should have maximum level of contrast with its background.

Daylight usually is not suited in the image processing technique and the reason behind is that the color of the light and the intensity of the light is actually strongly dependent on the timing of the day and also on the weather conditions. So, places where the daylight cannot be ignored are not appreciated well in the image processing technique.

Similarly, tungsten light sources are not suitable actually for the image processing if the frequency of the camera is not a multiple of the net frequency. In this case light frequency and the image readout frequency differ and resulting in undesired interference.

Fluorescent lamps have large homogeneous illumination field. By using frequency rectifier these light source can be used. They also have one advantage that they do not get very hot. But one of the major disadvantages is that they have the spectral limitation. So, fluorescent lamps are very often used for the image processing technique.

Quartz tungsten lamps have one major advantage that they do not have problems with frequencies. Normal halogens lamps have tungsten filament inside. But, these lamps are filled with rare gas.

Discharge lamps have very high radiation densities. Certain kinds of flashlights can be used for stroboscopic illumination but these are expensive as compared to the others.

Light emitting diodes are actually suitable for the stroboscopic (flashlights). LEDs actually are not capable to control the inertia of the light intensity over a wide range of light intensity. LEDs also possess a good monochromatic nature. They are cheaper smaller and also light weighted they also offered long working hours. In past few years the use of the LEDs has dramatically increased. And the 100000 working hours have made them almost maintenance free. This shows us that why the LEDs are used now a days everywhere in the industrial sectors image processing.

Lasers have high radiation power which is actually focused on the small area. Laser light is highly coherent and also chromatic. Laser diode modules are now replacing the laser which was used previously for scan scene due to the safety measures. Laser diode module is actually of thumbnail size and like LEDs. It helps to project lines circles and also matrices of the points.

If it is impossible to eliminate the unwanted effect of the surrounding then infrared lasers can be used. Daylight blocking filter can also be used to completely eliminate the surrounding effect. If the constant intensity is required for a long period of time then the ageing process can take place. Ageing process can decrease the intensity and also the spectrum of the frequency can be shifted to the longer wavelength.

If the camera and the object both are on the same side of the object then it is called incident light illumination. If the camera and object are on the opposite side of the object then it is called transmitted light illumination. In the light field illumination the light source and the camera which are placed on the same side of the illumination and the part of light which is directly reflected into the camera will be used for the imaging process. Dark field illumination produces a dark background with light objects. If the surface of an object is need to be illuminated reflect strongly then direct lighting cannot be applied and diffuse light can be used instead. The direct light is actually focused on a diffuse surface. Structural illumination is needed if we want to illuminate a three dimensional object. The curvatures of the projected lines influence greatly by the position of the camera.

If we are using word “image processing” then it is considered that it is captured by the camera. Various image processing systems are used and they are dependent on their usage like

- Acquisition principle
- Acquisition speed
- Spatial resolution
- Sensor system
- Spectral range dynamic range

The apparatus are very costly now a days. More accuracy u need more powerful software is used in the image processing system. The systems which are used electronically in the image capturing systems are given below,

- Area scan camera
- Line scanner
- Laser scanner
- Computer and nuclear magnetic resonance
- Thermo graphic sensor system
- Ultrasonic devices

CCD sensors plays important role in the image processing systems. Theses sensors are actually part of complex systems and these sensors can be categorized like according to their sensitivity:

- Gamma radiation
- X-ray radiation

- The visual spectrum
- The infrared spectrum
- The radio wave range

These sensors are sensitive to a certain range of electromagnetic radiation. And other sensors like

- Ultrasonic sensors
- Magnetic sensors

Theses sensors do not work according to the CCD principals.

There are not so many complex mechanical parts in the CCD. The light falls on (charged coupled device) which has so many semi-conductors which are light sensitive and also called as pixels. The image sensor is the heart of the digital camera. In its basic principle the incoming electrons produce photons by using semi-conductor materials. The capacitors act like a light switch. If this switch is open the charges will be collected in the capacitor and also they will be transported when the switch is closed. The exact number of the electrons which are collected is proportional to the light reaching the light sensitive.

CCD areas are actually available in several CCD sensors. The term architecture shows the information of individual pixels and their bundle integration into a serial data stream. Numerous electromagnetic and some ultrasonic sensing devices frequently are arranged in some different array format. This is also predominant arrangement which is also used in digital cameras.

It is always wanted that the relationship between the input physical signal and the output physical signal is linear. If a and b are the two images and w1 and w2 are the arbitrary constants then we have a linear camera response like

$$C = R\,\{w_a + w_b\} \qquad (18)$$

Here R represents the camera response and c represents the camera output. The offset is never zero and thus we must compensate for this if the desirable result is to get intensity measurement.

The sensitivity can be described in two ways. Firstly, by describing the minimum number of photoelectrons. This is actually known as absolutely sensitivity. And the number of photoelectrons necessary to change from one digital brightness level to the other level. This is commonly known as relative sensitivity.

For measurement of the absolute sensitivity we need a characterization of the camera in terms of its noise. The minimum detectable signals are 300 photoelectrons. The absolute sensitivity of less than 10 photoelectrons is achievable with modern technology.

The relative sensitivity can be obtained by two different ways in first method the input signal a can be controlled by time of intensity then the gain can be estimated of the resulting straight line curve. The quantum efficiency refers to how many photo electrons are produced. And the number of photons which are going to perceive on the camera sensor should be done by using some standard source for emitting the photons.

SNR noise is used here such as:

- Amplifier noise in case of the color cameras.

- Thermal noise.
- Photons noise which is limited by photons.

In the range of temperature (230-250K) chip measurement is required. This shows that how thermal electrons produce photons. We also can see the number of thermal electrons which travel from one brightness level to another in the absence of photoelectrons. Due to the thermal noise at the general room conditions the camera requires more 20 seconds to produce one ADU. So, the integration rate at 25-30 images per second the thermal noise is negligible.

By increasing the integration time the SNR time can be increased and thus capturing more photons. The pixels in CCD cameras have finite capacity. Note that the certain cameras the measured SNR achieves the theoretical, maximum indicating that the SNR is, indeed, photon and well capacity limited. The CCD technology and the depth of a CCD pixel is constant at about 0.7 ke/um.

All the imaging systems produce shading. So if the physical input image is constant then the digital version will not be constant. The source of the shading might be outside the camera such as in the scene illumination. The source which actually causes shading can be outside the camera such as in the scene illumination. Shading can be removed by using different techniques.

In images the pixels appear to be square and to cover the continuous image it is necessary to understand the geometry of the given camera. The parameters X and Y are the spacing between the pixel centers and also shows the sampling distances. So, they possess different values foe X but also have same value for Y.

5.2.2 Square Pixels

With the non-square pixels there is a greater risk involved. So if isotropic objects are scanned with non-squared pixels might appear isotopic on a camera compatible. But analysis of the objects will yield non-isotropic results.

Fundamentals of the digital image processing can be divided into four major categories

- Histograms
- Simple mathematics
- Convolution
- Mathematical morphology

In histograms the point operation is actually based on the manipulation of the image. Important examples are such that if an image is scanned in such a way that the resulting brightness values do not make full use of the available dynamic range. So this can be seen in the histograms of the image. By stretching the histogram over the available dynamic range. This situation can be corrected by stretching the histogram over a wide range.

When one wish to compare two or more images on a specific basis which can be texture then so it is common to first normalize the histograms to a standard histograms. This method is very much useful if the images are taken under different conditions. The most common normalization of the histograms technique is histogram equalization. Where one attempt to change the histograms through the use of the function into a histogram. This will correspond to a brightness distribution. But in case of the arbitrary image we can only estimate the results. The quantized probability distribution function normalizes from o to 2^b-1. And the process of histogram equalization can be applied on the regional basis. The histograms derived from local regions can also be used to derive local filters which need to be applied to that region. For example minimum filtering, median filtering and maximum filter. There is a difference between binary arithmetic and ordinary arithmetic. In the binary arithmetic there are two brightness values 0 and 1.

In the ordinary case we begin with 2B brightness values or levels but the processing of the image can easily generate many more levels. For this reason many software systems provide 16 or 32 bit representations for pixel brightness in order to avoid problems with arithmetic over flow.

Operations based on binary (Boolean) arithmetic form the basis for a powerful set of tools that will be described here and extended in Section 9.6, mathematical morphology. The operations described below are point operations and thus admit a variety of efficient implementations including simple look-up tables.

The main purpose of the image characterization is to automatically characterize all pixels into land cover classes. The term classifier is actually representing a computer programme which selects the image classification. There are many classification strategies which have been used for past several years. At the moment it is difficult to say that which classifier is the best. It is compulsory that the analyst understand the classifier. The conventional methods mainly use two approaches. In which one is unsupervised and the second is supervised. When the spectral grouping is used for nuclear meaning it is called unsupervised approach. In the supervised approach the analyst supervised the pixels categorization process by specifying to the computer algorithm.

Various kind of algorithms are used to give an unknown pixel to one of number of classes. The decision of specific analyst depends on the input data and also on the desired output. Non-parametric classification logarithms make no such kind of assumption.

Among the most frequently used classification algorithms are the parallelepiped, minimum distance, and maximum likelihood decision rules.

Parallelpiped classification alogaritham is used is actually a computational compact method the remote sensing data. It is possible that a unknown pixel have the possibility to satisfy criteria. Minimum distance to mean classification algorithm is a very simple and commonly used it requires that the user provide mean vector. To provide a minimum distance the programme must calculate the distance to each vector.

The application of the CIE colorimetry to imaging system became more familiar as the digital imaging system prevailed and also with the use of computer system to generate and proof content ultimately generate for the other media. There are some other problems which are generated by the open digital system and these problems are actually color production problems which can be solved by the CIE colorimetry to specify image across the various devices.

5.3 Materials and methods:

5.3.1 Obtaining RGB Image from Raw File

In order to determine a color for a pixel in an image can be possible only by knowing three color values of that pixel location. Although every pixel needs to have three color values for determining color, often digital camera sensors use Bayer CFA sensors (although some sensors work in different principles as Fovea Sensors). This type of sensors use one layer of photosites where each photosets measure the amount of only one primary color component (Red, Green and Blue) of the hitting light (85). Bayer sensors are arranged in a 2x2 mosaic pattern called a CFA (Color Filter Array) repeated all over the sensor surface where the number of green channel photo sites are twice due to be able to mimic the human eye response because the human eye is more sensitive to green than the blue and red channels. In the figure it is shown a typical Bayer sensor photosite arrangement (10).

As mentioned before, color of a pixel can be determined only by three values of color channels. Therefore missing color channels must be estimated based on the raw data of the color mosaic In order to produce a full RGB image. This process is generally referred as ”demosaicing”. The simplest demos icing method is linear interpolation, ie interpolating the color values of neighbor pixels for determining the missing color information. When the camera acquires an image it saves a “RAW” file which contains the sensor pixel values as well as meta-information. In order to view the image acquired by the camera, RAW files needed to be further processed. These steps can be done in the camera itself or afterwards using some commercial software (86). Generally the processing steps are not known by users and the main aim of these steps is developing an image looking good (87).

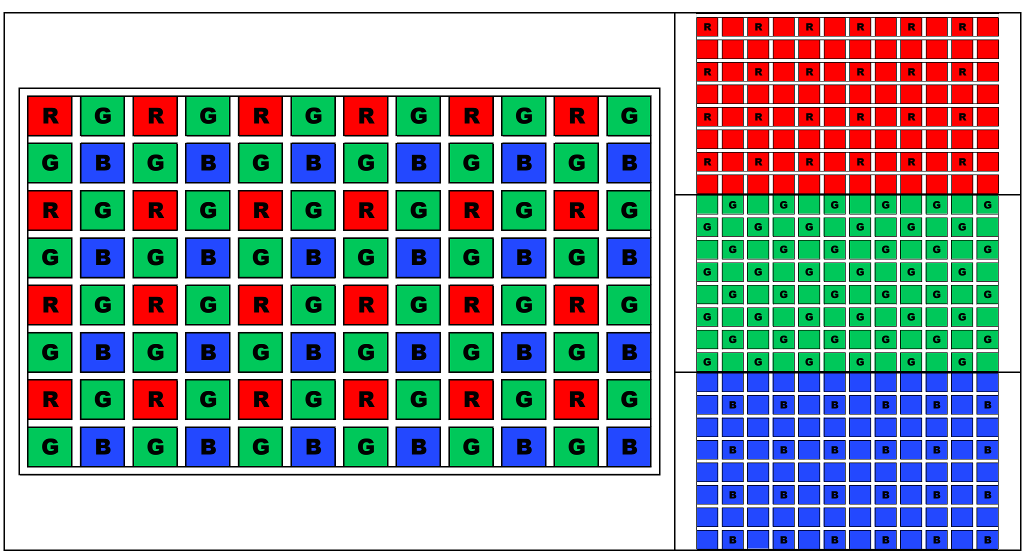


Figure. 49. CFA Bayer Sensor Pattern.

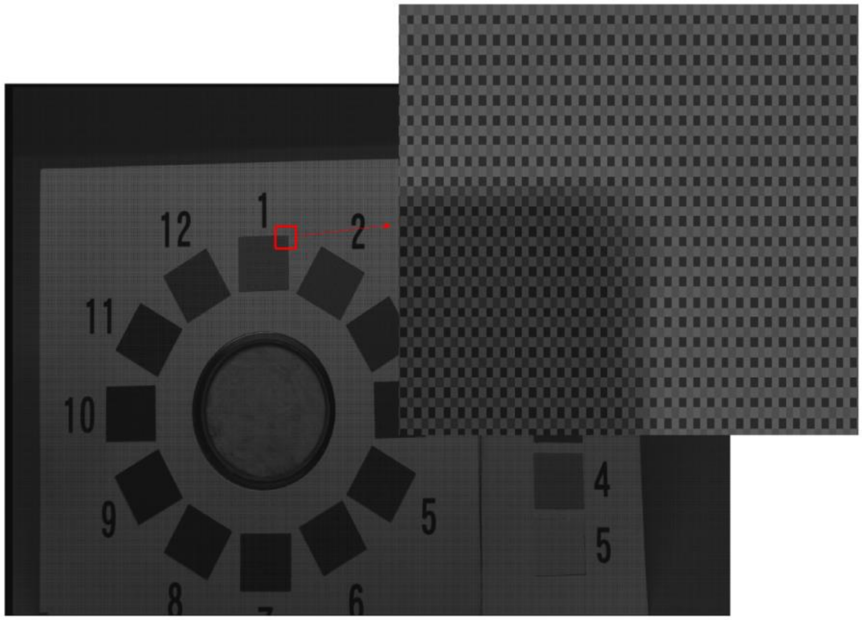


Figure. 50. Raw image and a zoomed small region with raw sensor data (Bayer CFA)

Image processing methods will be applied in MATLAB environment, therefore it is needed to be able to open the data file in Mat lab environment. Unfortunately reading raw data file is not simple as reading a normal RGB images. Therefore images needed to be converted to a form called Digital Negative (DNG). Main steps to convert the RAW data to RGB image is as follows

1-Cropping Active Area

2-Black subtraction

3-White Balance correction

4-Demosaicing

5-Color Scaling

5.3.2 Characterization Methods (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. In every acquired image there are standard color samples whose colorimetric values are known (17)(11).

5.3.3 Linear least-squares regression

Figure. 51. Cropped Standard Color patches regions and Neutral gray regions.

The circle which can be seen on the surrounding of the cotton samples are basically used to control the environment. The positioning of the samples can also be controlled with these samples and also the color values of the samples are known and they can also be used as reference points around the sample.

Table 29. Colorimetric values of the surrounding colors of cotton samples .

	L	a	b
A1	85,57	2,56	83,06
A2	76,25	-24,26	68,20
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

Table 30. Colorimetric values of neutral grey samples.

	L	a	b
N1	22,79	0,71	-0,33
N2	40,89	-2,40	2,04
N3	59,07	-1,46	3,15
N4	76,48	-1,46	2,67
N5	92,82	0,92	0,50

Figure 52. Standard Colors.

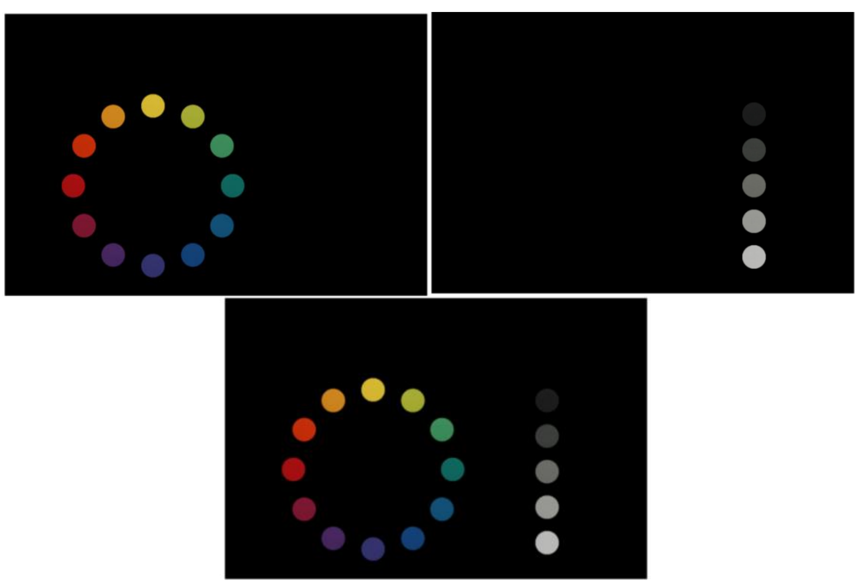


Figure 53. Standard color regions from the image.

General formula is as follows

$$X = \sum_{i=0}^{3}\sum_{j=0}^{3}\sum_{k=0}^{3} w_{X,l} R^i G^j B^k \tag{19}$$

$$Y = \sum_{i=0}^{3}\sum_{j=0}^{3}\sum_{k=0}^{3} w_{Y,l} R^i G^j B^k \tag{20}$$

$$Z = \sum_{i=0}^{3}\sum_{j=0}^{3}\sum_{k=0}^{3} w_{Z,l} R^i G^j B^k \tag{21}$$

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. The known color values are related with these pixel values by polynomial weights.

$$\begin{bmatrix} X_1 & Y_1 & Z_1 \\ X_2 & Y_2 & Z_2 \\ \vdots & \vdots & \vdots \\ X_N & X_N & X_N \end{bmatrix}_{(Nx3)} = \begin{bmatrix} 1 & R_1 & G_1 & B_1 & R_1G_1 & G_1B_1 & R_1B_1 & R_1^2 & G_1^2 & B_1^2 & R_1G_1B_1 \\ 1 & R_2 & G_2 & B_2 & R_2G_2 & G_2B_2 & R_2B_2 & R_2^2 & G_2^2 & B_2^2 & R_2G_2B_2 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & R_N & G_N & B_N & R_NG_N & G_NB_N & R_NB_N & R_N^2 & G_N^2 & B_N^2 & R_NG_NB_N \end{bmatrix}_{(Nx11)} \begin{bmatrix} W_{X0} & W_{Y0} & W_{Z0} \\ W_{X1} & W_{Y1} & W_{Z1} \\ W_{X2} & W_{Y2} & W_{Z2} \\ W_{X3} & W_{Y3} & W_{Z3} \\ W_{X4} & W_{Y4} & W_{Z4} \\ W_{X5} & W_{Y5} & W_{Z5} \\ W_{X6} & W_{Y6} & W_{Z6} \\ W_{X7} & W_{Y7} & W_{Z7} \\ W_{X8} & W_{Y8} & W_{Z8} \\ W_{X9} & W_{Y9} & W_{Z9} \\ W_{X10} & W_{Y10} & W_{Z0} \end{bmatrix}_{(11x3)}$$

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

$$[c][A]^{-1} = [p][A]\,[A]^{-1} \qquad (22)$$

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.

5.3.4 IMAGE PROCESSING

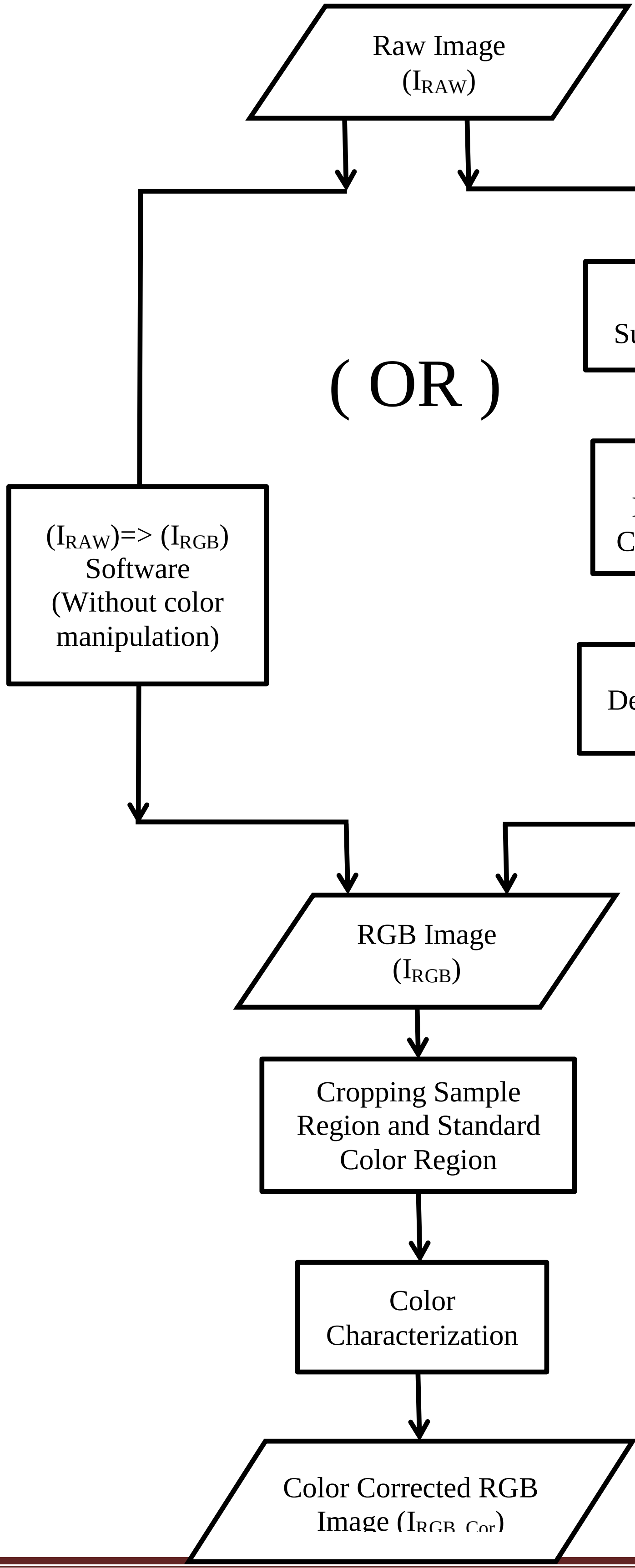
Generally raw cotton samples may lose brightness and have a yellow color due to different disturbances although cotton is expected to have a bright white color. Raw cotton also may contain thrash particles in addition to color varieties which are imposing problems for color measurements of raw color samples (88). 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.

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.

The below given diagram shows us that how the process of trash segmentation works. As we have different kind of software which can also be used to convert the rawimage into RGB image. We also used the software to convert the raw image to RGB image. After obtaining of the RGB image the cropping of the cotton samples is used. It is necessary to obtaine the color values and color characterization.

After the color corrected RGB image is obtained the then it is necessary to perform the color transformation in the LCH color space. Then the L channel and C channel gives us the cotton region and the irregular region. The irregular region means the trash particles.

In the end the irregular region can be subtracted from the image and we obtain only the cotton region which gives us the color of cotton fiber by excluding the trash particles. Then the color transformation can take place and the values of L and b can measure which will help us to grade the cotton and also to compare the cotton color with the visual classification and other instrumental classification.


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

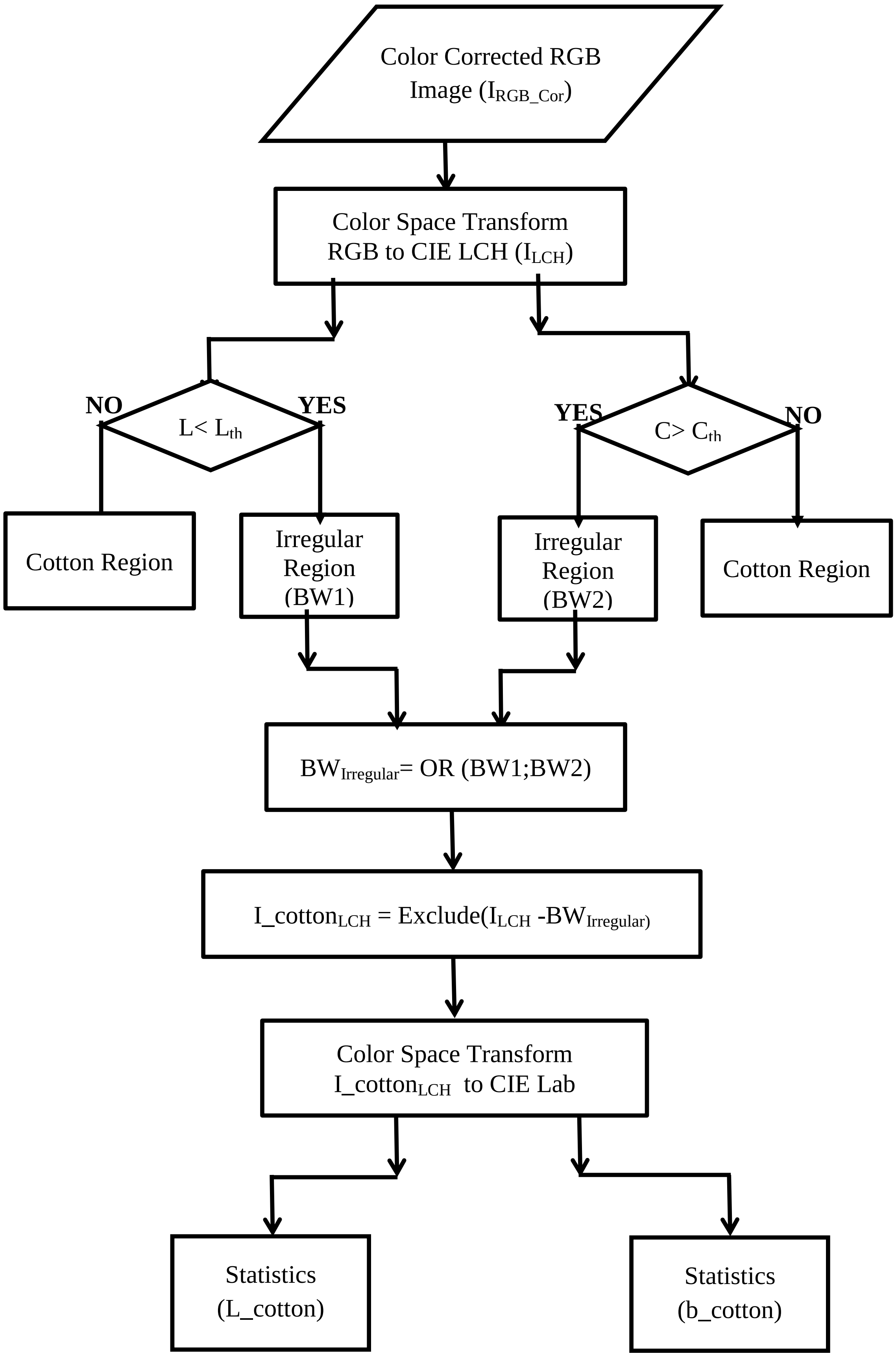

Color Corrected RGB
Image (I_RGB_Cor)
Color Space Transform
RGB to CIE LCH (I_LCH)
NO
L< L_th
YES
YES
C> C_th
NO
Cotton Region
Irregular
Region
(BW1)
Irregular
Region
(BW2)
Cotton Region
BW_Irregular= OR (BW1;BW2)
I_cotton_LCH = Exclude(I_LCH -BW_Irregular)
Color Space Transform
I_cotton_LCH to CIE Lab
Statistics
(L_cotton)
Statistics
(b_cotton)

Figure 54. Captured image

5.3.5 Obtaining the center coordinates of cotton sample

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 (89)(90).

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.

$$D= [(L-L_0)^2+(a-a_0)^2+(b-b_0)^2]^{(1/2)} \qquad (23)$$

Where, D is the distance, L, a, b are the obtained pixel color values from the image and L_0, a_0, b_0 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.

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 regions (91).

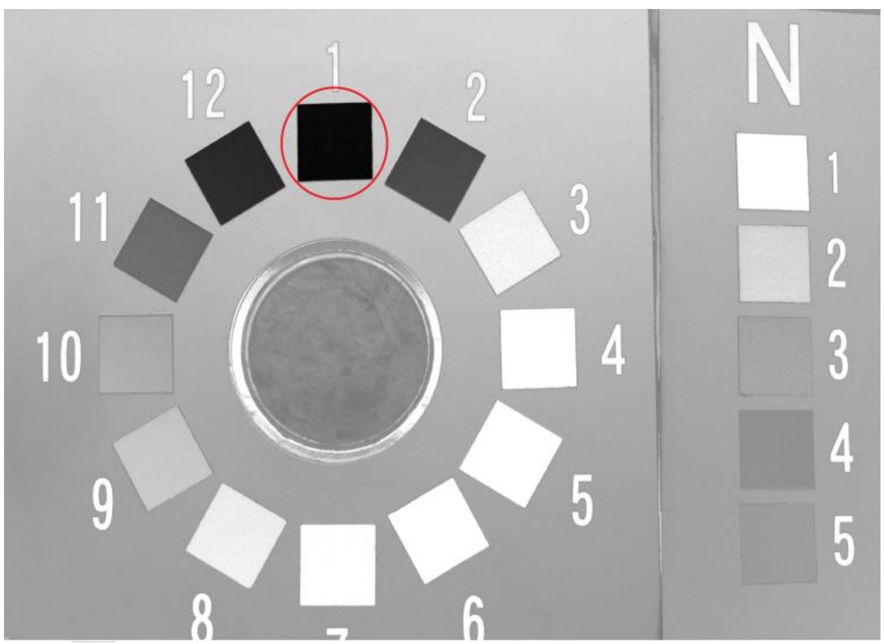


Figure. 55. The calculated distances shown as a gray scale image.

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.

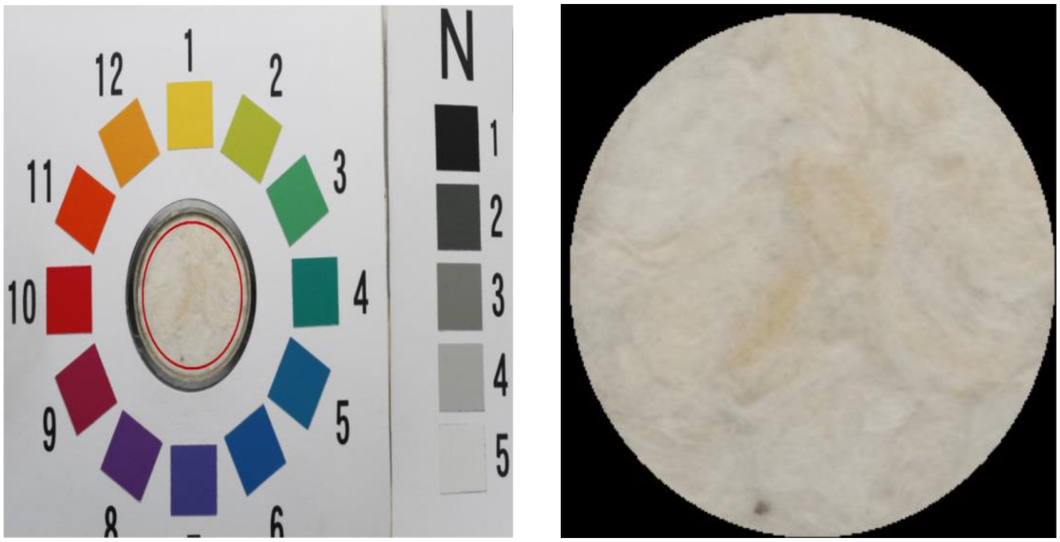


Figure 56. Cropped Cotton Sample Region.

5.4 Results and discussions

5.4.1 Identifying Irregular Regions

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 (92). Figures show the every channel values of the LCH and CIE Lab color spaces of ten different cotton sample images (159 CCRI) shown in Figures. The LCH color space is actually a polar form of the Lab system. In most cases either Lab or LCH are used for the evaluation. But, in our research we used both color spaces because in the further analysis of our study we will compare our results with the visual experiments and in human color vision the chroma plays an important role so, it is necessary to use the entire color channel which can truly represent the color perception of human being. In the below given figures all the color channels are shown for different cotton samples. And these cotton samples are already used in our research so, the color values of these samples are known.

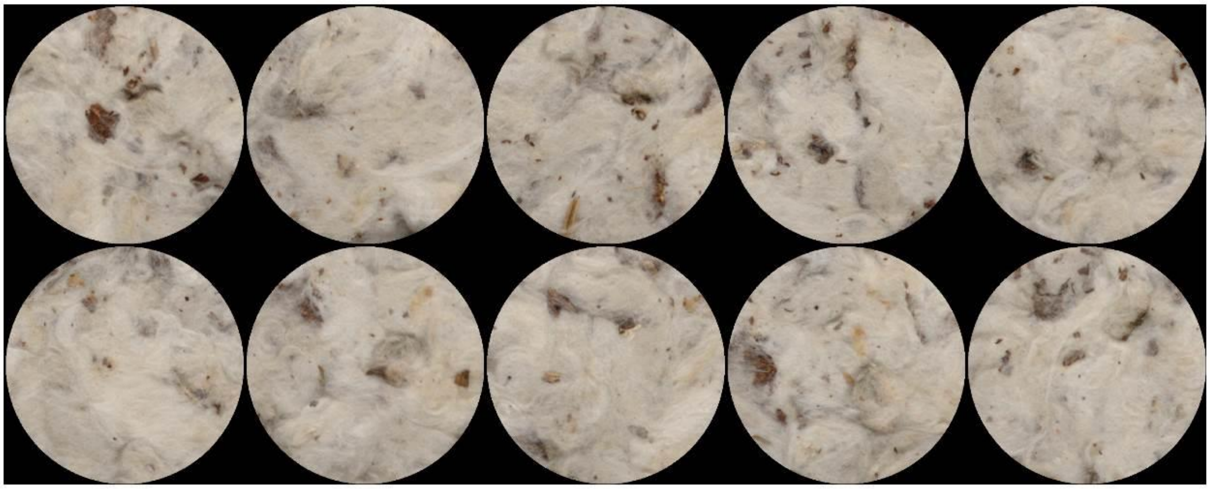


Figure 57. Original samples.

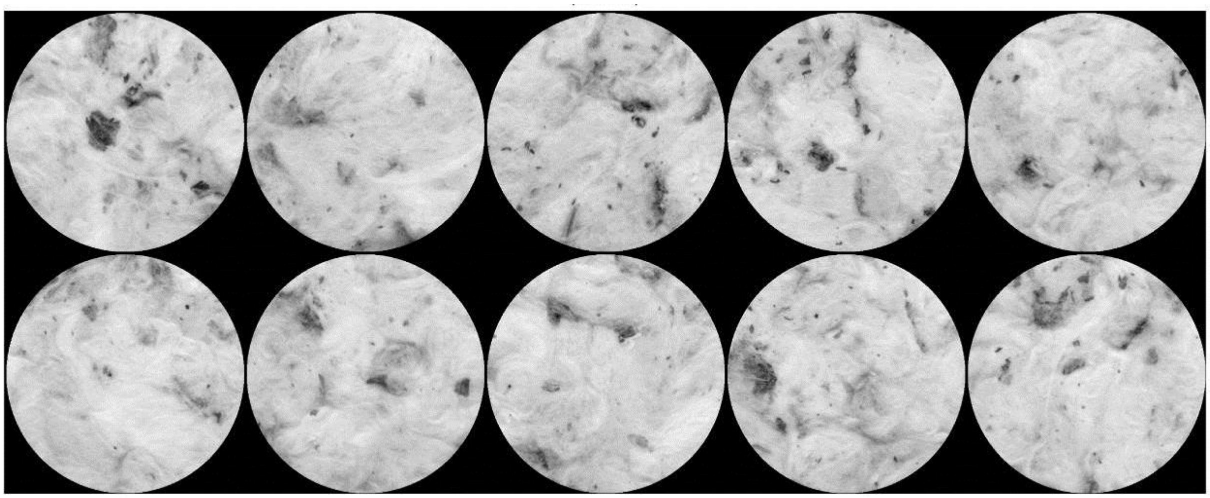


Figure 58. LCH-L.

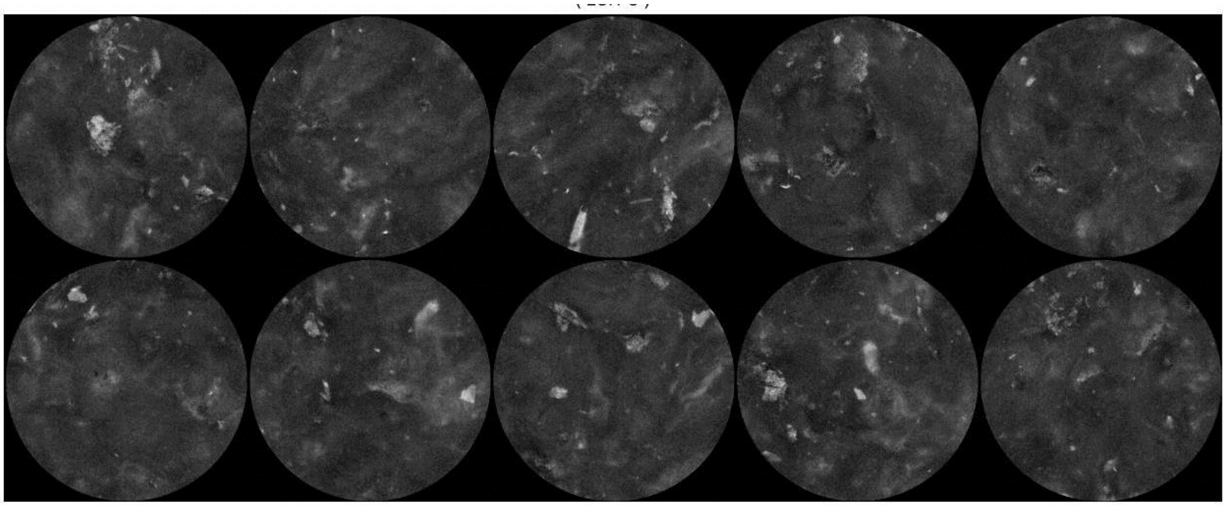


Figure 59. LCH-C.

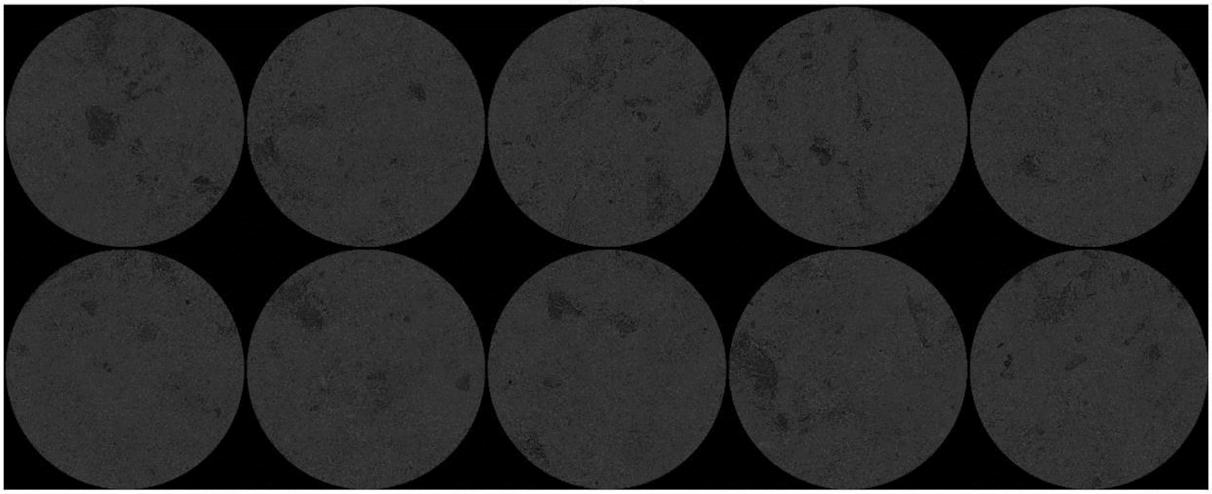


Figure 60. LCH-H.

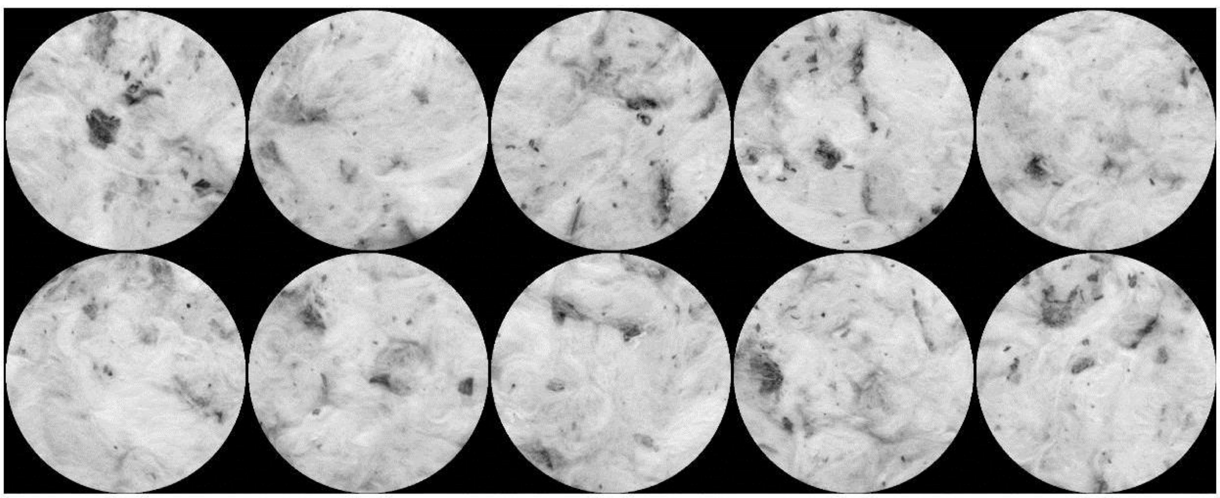


Figure. 61. CIE Lab-L.

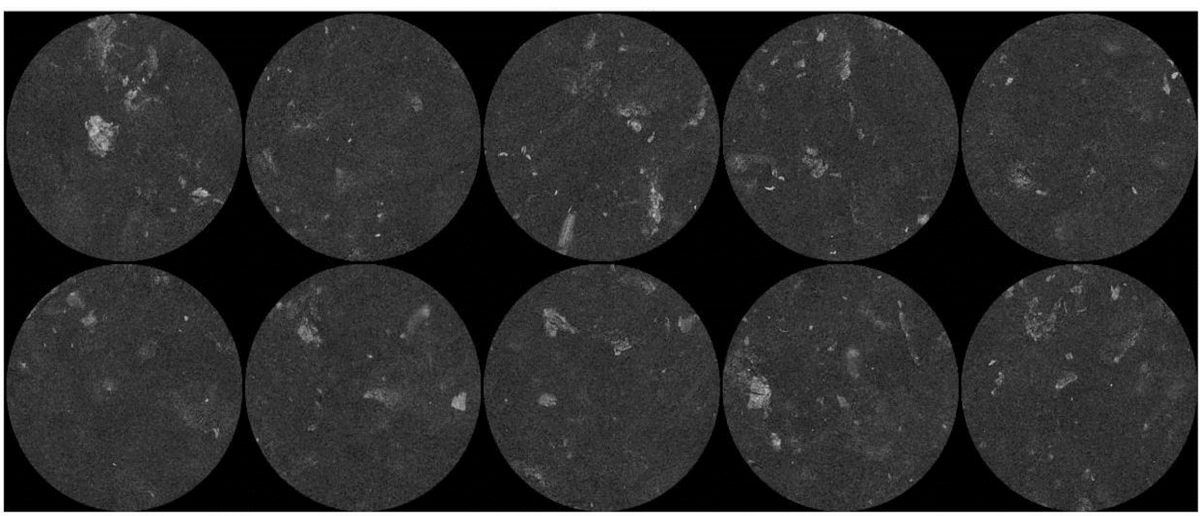


Figure 62.CIE Lab-a*.

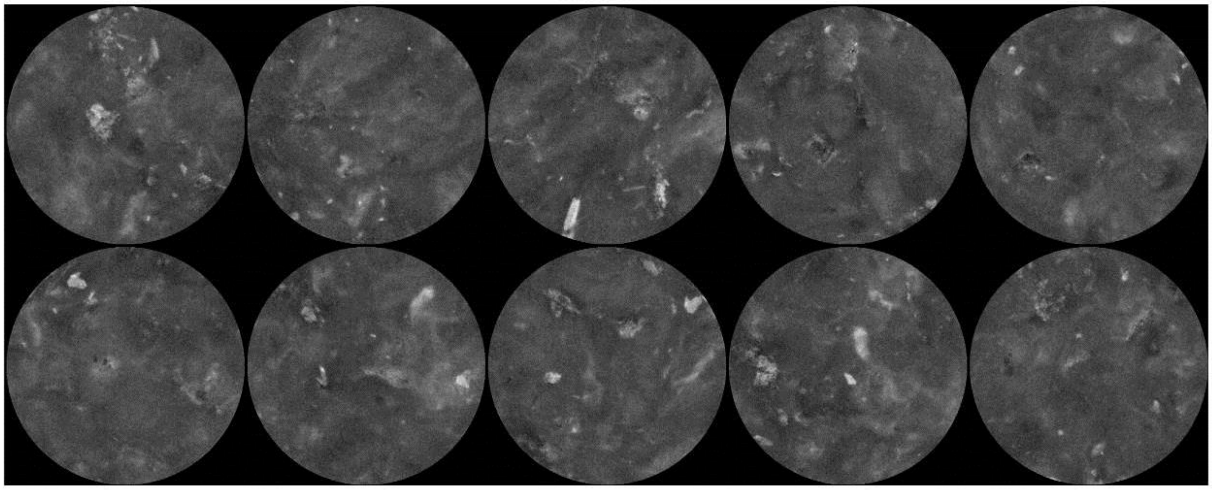


Figure 63. CIE Lab-b*.

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 (83).

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:

$$B_{i,j} = \begin{cases} 0 & if \quad I_{i,j} < T \\ 1 & if \quad I_{i,j} \geq T \end{cases} \qquad (24)$$

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 (93). 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 (94). 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 64. Sample image.

Figure 65. LCH_L (L < Lth).

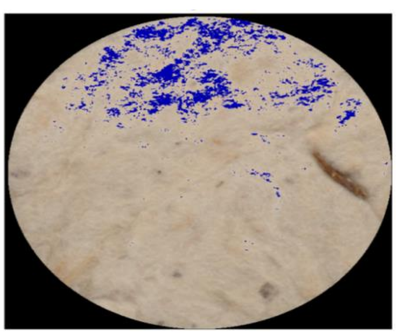


Figure 66 . LCH_L (L > Lth)

Figure 67. LCH_C ($C < C_{th}$).

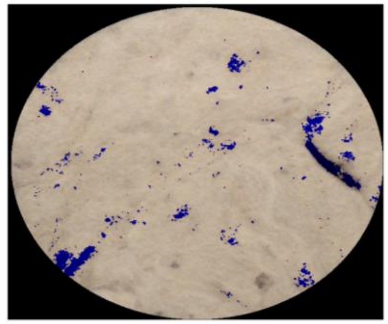


Figure 68. LCH_C ($C > C_{th}$).

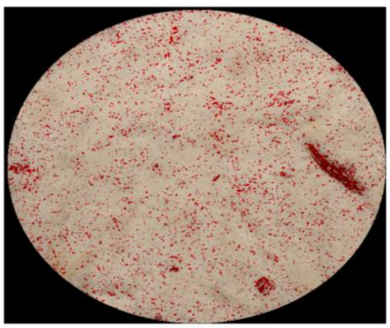


Figure 69. LCH_H ($H < H_{th}$).

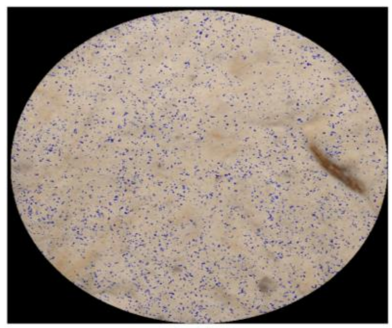


Figure 70. LCH_C ($H > H_{th}$).

Figure 71. Lab_L ($L < L_{th}$).

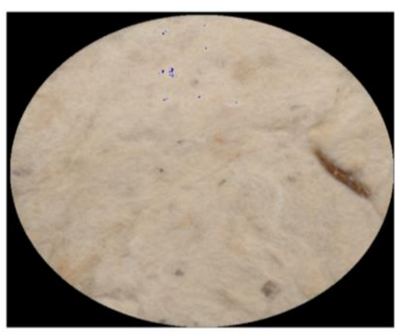


Figure 72. LabL ($L > L_{th}$).

Figure 73. Lab_a ($a^* < a^*_{th}$).

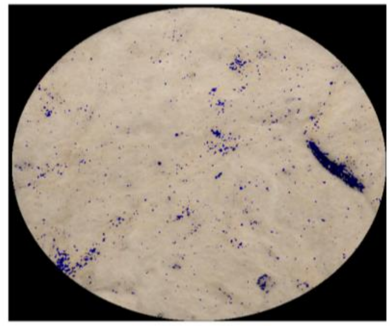


Figure 74. . Laba (a* > a*th).

Figure 75. . Lab_b ($b^* < b^*_{th}$).

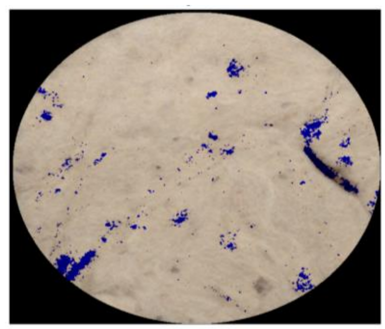


Figure 76. Lab_b (b* > b*th).

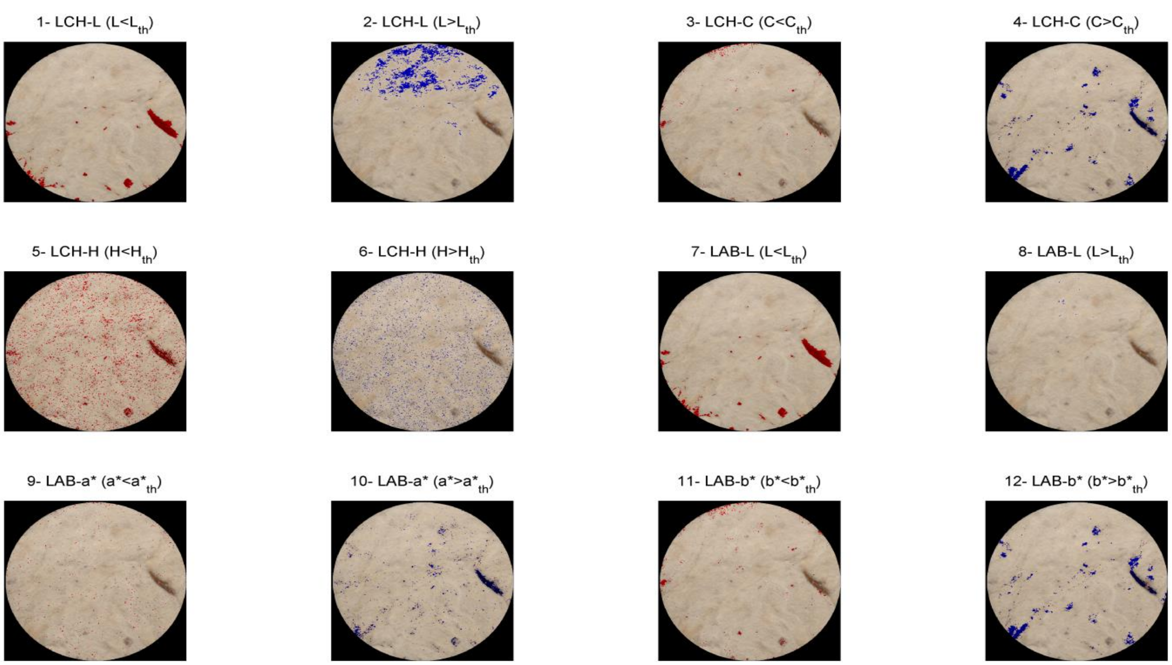


Figure 77.

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. 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 (95).

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 (96). In order to determine the threshold values(97) suggested to obtain the average values of irregular region color values manually and using these as thresholds for the segmentation process.

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:

$$T_1 = \mu_L - 2\sigma_L \qquad (25)$$

$$T_2 = \mu_C + 2\sigma_C \qquad (26)$$

Where σ_L is standard deviation and μ_L is the mean of L channel values, similarly σ_C is standard deviation and μ_C is the mean of C channel values of LCH color space.

These two criteria must be used in connection with each other 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.

5.5 Logical "AND" or "OR"?

Figure 78. Sample image.

In the image blue regions are obtained using the C>T2 criteria and red regions are L<T1. The black regions are the intersection regions which means when the AND operator is used these regions will be detected only. Following images also show these applied logical AND and OR operators (10).

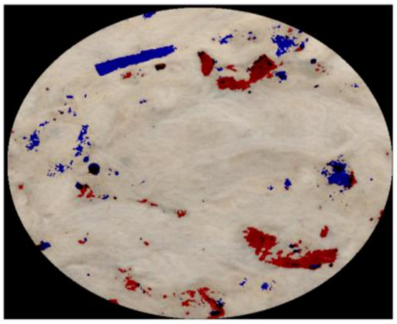


Figure 79. ($L < L_{th}$) ($C > C_{th}$).

The identification of the trash particles is very complicated and in our future work we suggest to measure the color values of the trash particles and also the nature of the trash particles which can be present in the cotton surface. This process enhances the possibility to measure the color more precisely.

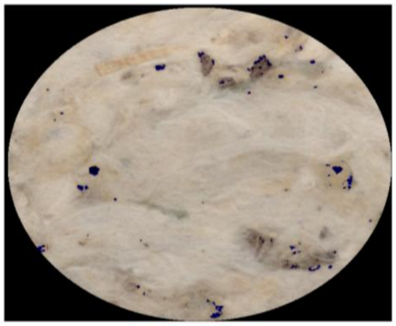


Figure 80. ($L < L_{th}$) AND ($C > C_{th}$).

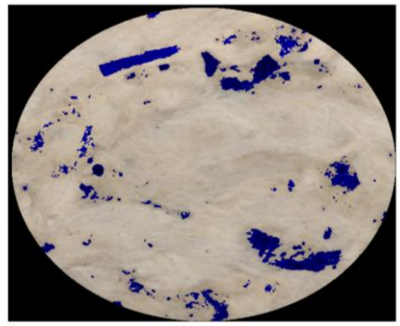


Figure 81. ($L < L_{th}$) OR ($C > C_{th}$).

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

$$L^* = 116 f(Y/Y_n) - 16 \quad (27)$$

$$a^* = 500[f(X/X_n) - f(Y/Y_n)] \quad (28)$$

$$b^* = 200[f(Y/Y_n) - f(Z/Z_n)] \quad (29)$$

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

(Xn, Yn, Zn) are the (X, Y, Z) values for the reference white point.

Matlab Image Processing Toolbox transforms color images in RGB space into CIE L*a*b* space using a CIE illuminant D50 white point as default (98).

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:

$$X = 0.412453R + 0.357580G + 0.180423B \quad (30)$$

$$Y = 0.212671R + 0.715160G + 0.072169B \quad (31)$$

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

Table 31. 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 32. 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

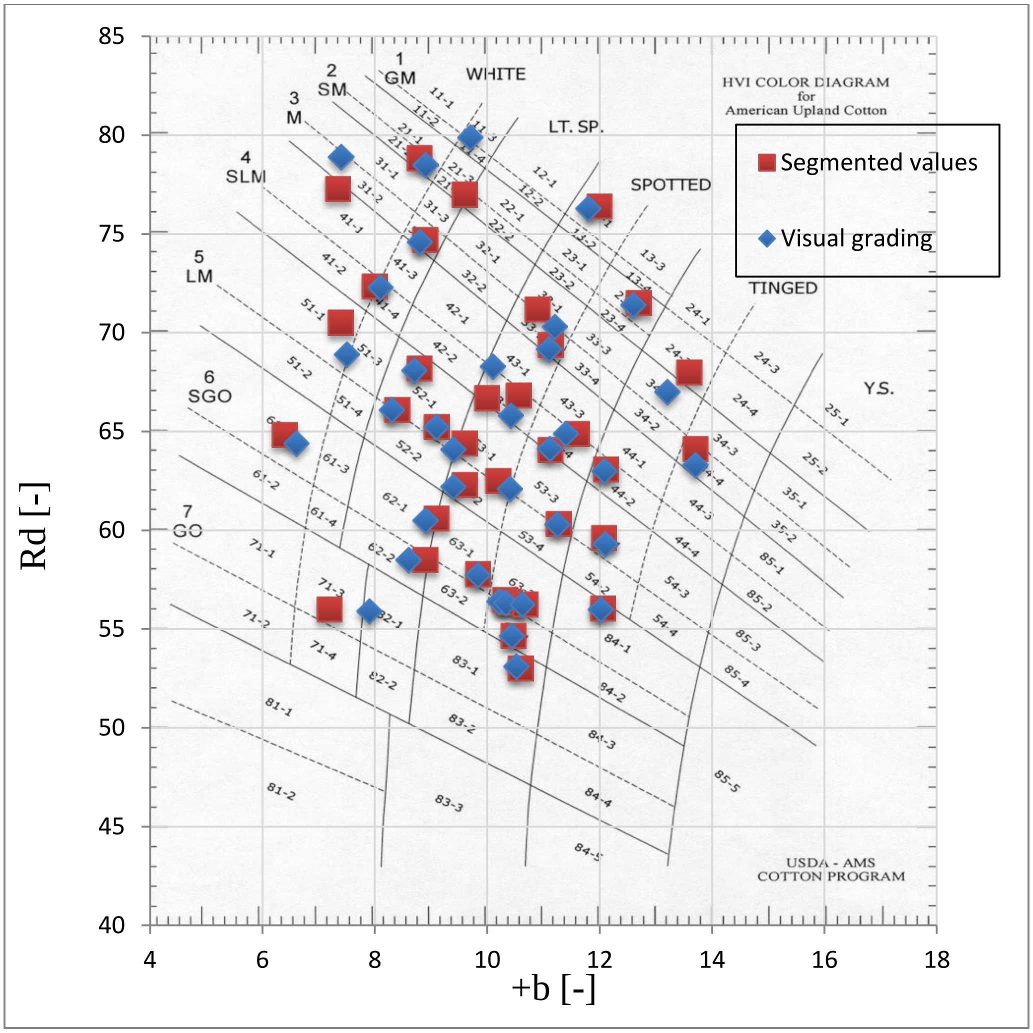


Figure 82. HVI Color Diagram representing Segmented and visual inspection values.

Fig. 82. 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 (99). 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. 83 and 84 the linear relationship between two color parameters Rd and +b is shown.

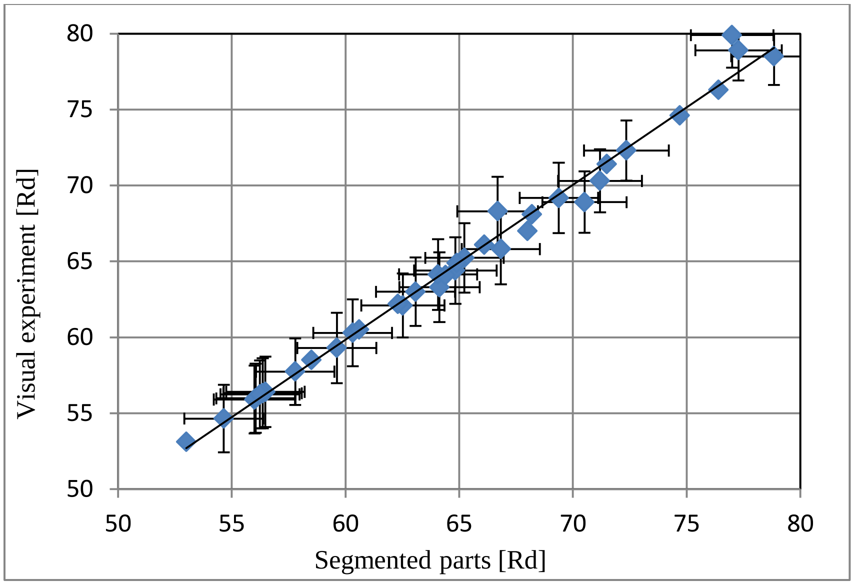


Figure 83. Comparison of Rd values between visual assessment and segmented parts.

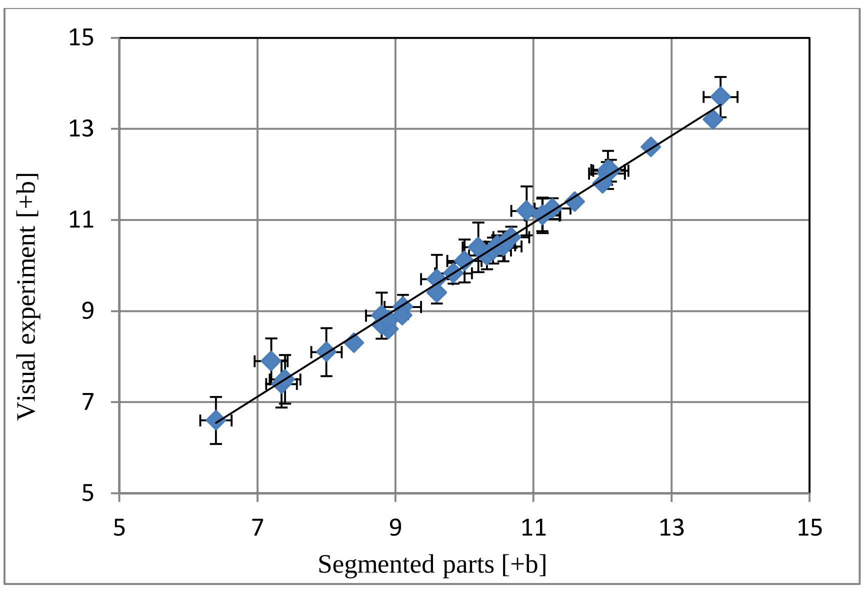


Figure 84.Comparison of +b values between visual assessment and segmented parts.

Table 33. Regression values for Rd and +b values.

	Slope	Intercept	Correlation Co-efficient
Rd	1.02	1.36	0.98
+b	0.95	0.43	0.98

5.6 Analysis of the histograms

The system which enables us to differentiate the cotton color and trash color is capable to show the color of trash particles and cotton separately in the shape of histograms. Three different types of histograms actually can be generated from the system. In the first histogram the CIE L, a, b values of the cotton and trash are shown while in the second histograms the L, a, b values of the cotton region only can be seen and in the third histogram the L,a,b values of the trash particles only can be seen .In the below given histograms the sample selected is of quite low level of trash particles and the three histograms shows how we can differentiate the cotton and trash particles.

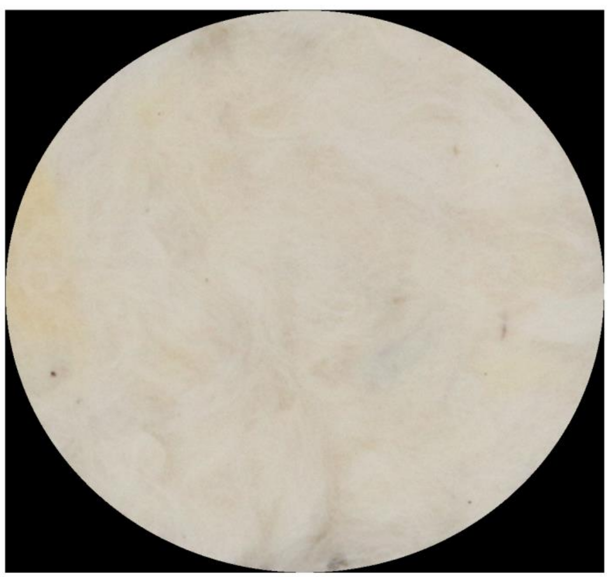


Figure 85. Cotton Sample Image with very low amount of trash particles.

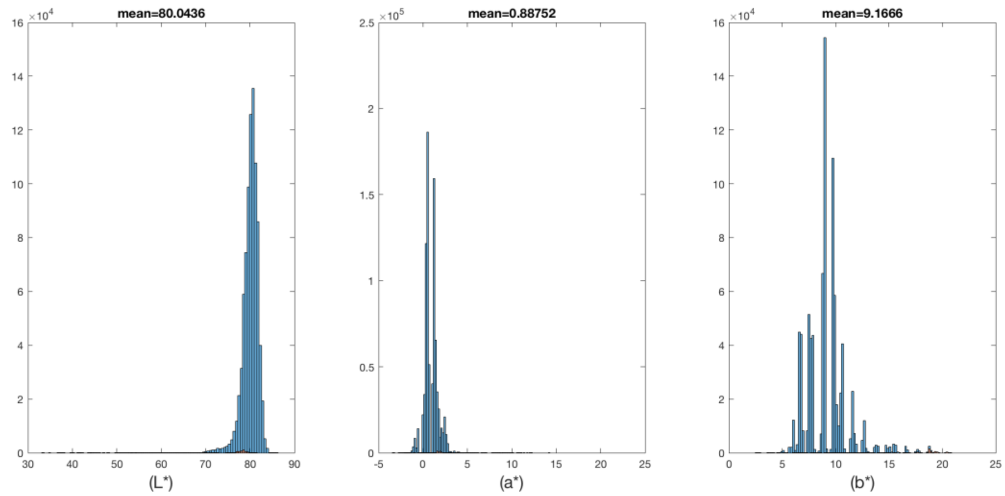


Figure 86. Histogram showing the L,a,b values of the cotton and trash particles both.

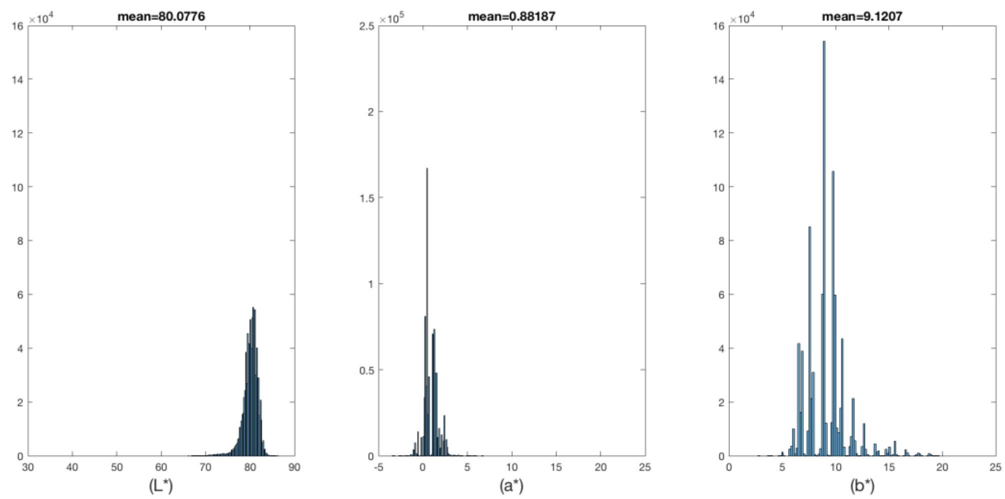


Figure 87. Histogram showing the L,a,b values of the cotton.

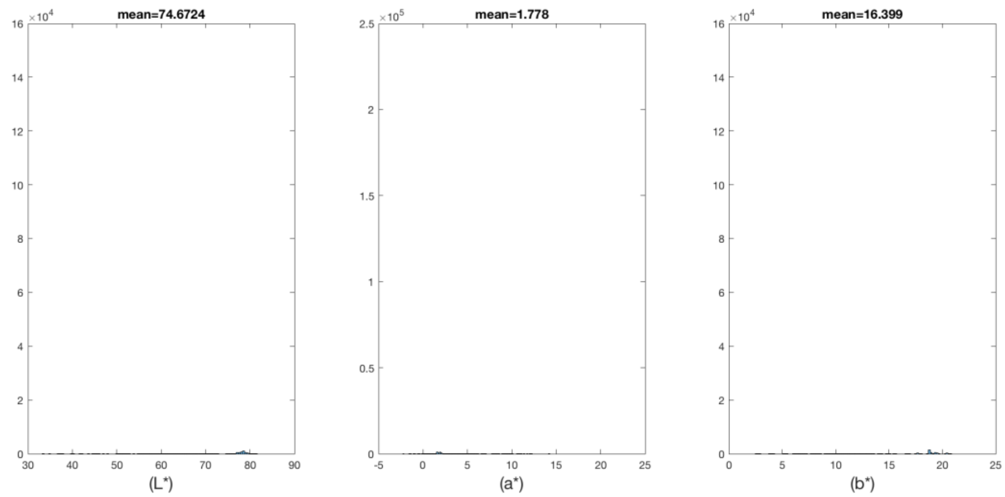


Figure 88. Histogram showing the L,a,b values of the trash particles.

The second sample which is selected is having relatively few amount of trash particles present on the surface of the sample. In the previous histograms it can be seen that the trash particles are almost invisible in the fig (88). The sample is almost having less amount of trash particles present on the surface of the samples. The fig (87) shows that the cotton histograms which is quite visible that the cotton sample having good amount of pixels. In the Fig (86) the whole image is shown in the cotton and also trash particles. So, the scaling of the y-axis in all the three histograms is kept constant just to show the comparison that how the full image histogram and the cotton histogram and the trash histograms can be differentiate from each other. This also helps us to measure the color property of the sample in very good manners without any kind of disturbance created by the trash particles. And the results now can be reliable and are in good compatibility with the visual inspection also because the visual inspection process is actually based on color measurement by removing the trash particles from the surface of the cotton. This system is quite useful in the color measurement of cotton and will upgrade the color grading phenomenon of the cotton.

The below given image shows us the small amount of trash particles on the surface of cotton. The sample contain trash particles more as compared to the previous sample.

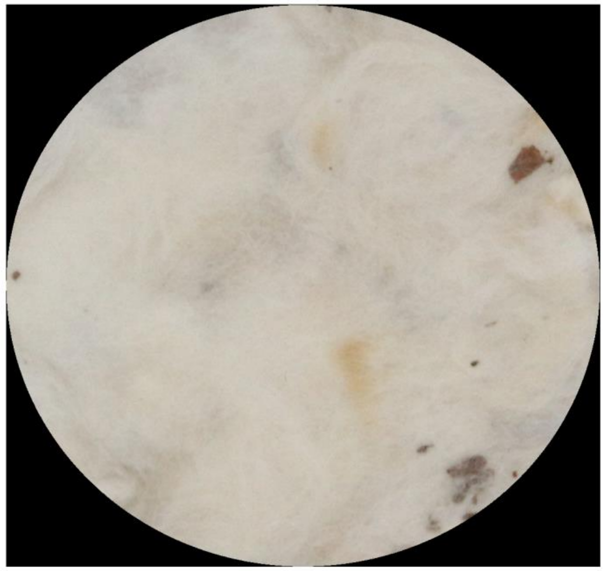


Figure 89. Cotton image with small amount of trash particles.

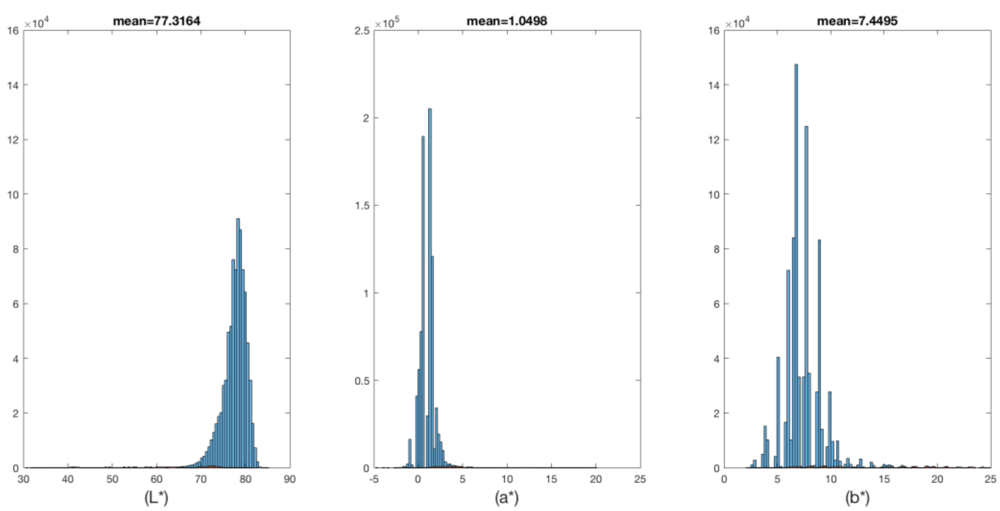


Figure 90. Histogram showing the L,a,b values of the cotton and trash particles.

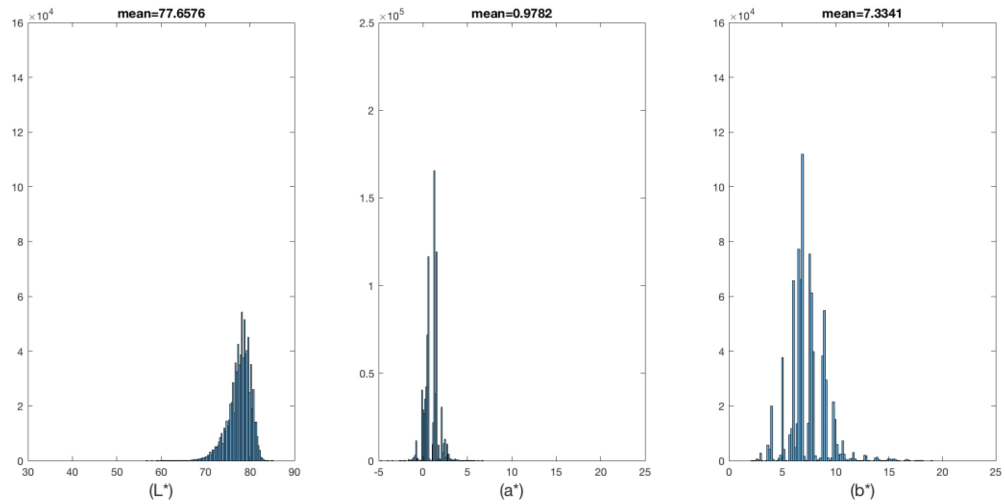


Figure 91. Histogram showing the L,a,b values of the cotton.

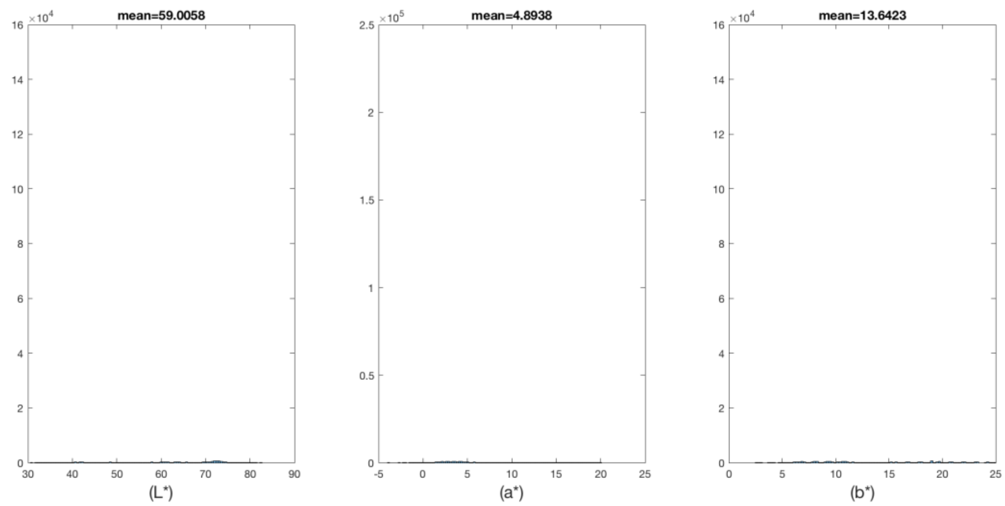


Figure 92. . Histogram showing the L,a,b values of the trash particles.

In the fig (92) it can be clearly seen that the small amount of trash particles can be detect in the L* a* b*. But due to the large y-axis it can be seen comparatively better detection of trash particles as compared to the previous sample.

The third and the last sample which is selected is basically is the sample which is full of the trash particles on the surface of the cotton sample. The nature of the trash particles can be different.

Figure 93. Cotton Image with large amount of trash particles.

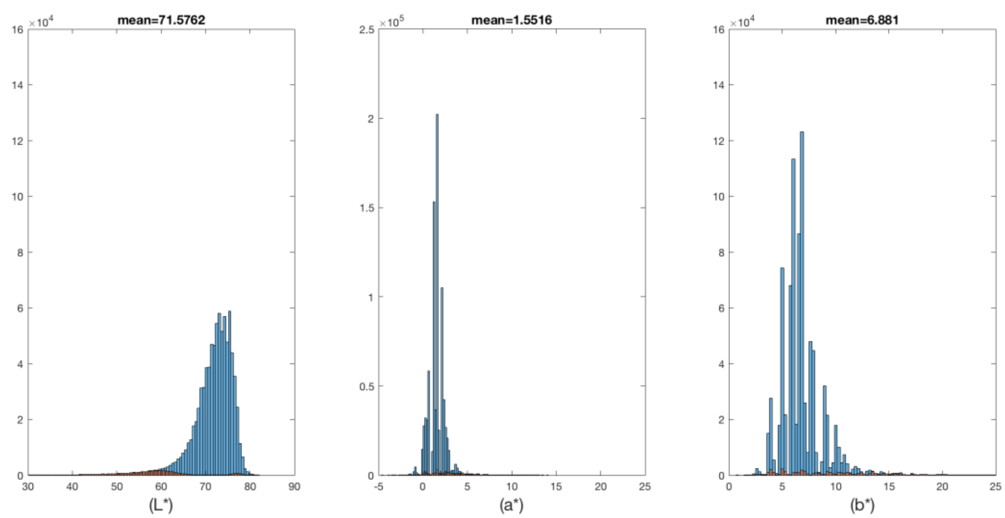


Figure 94. Histogram showing the L,a,b values of the cotton and trash particles.

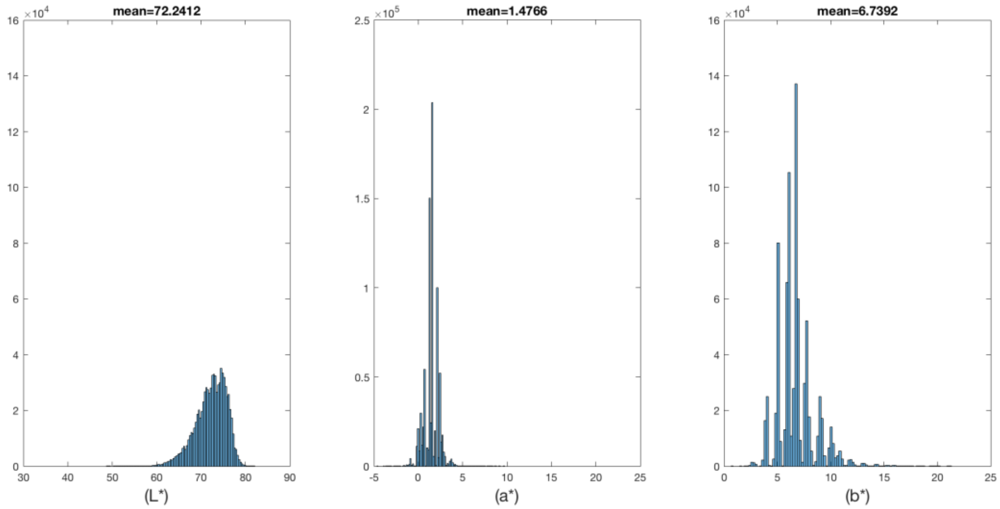


Figure 95. Histogram showing the L,a,b values of the cotton.

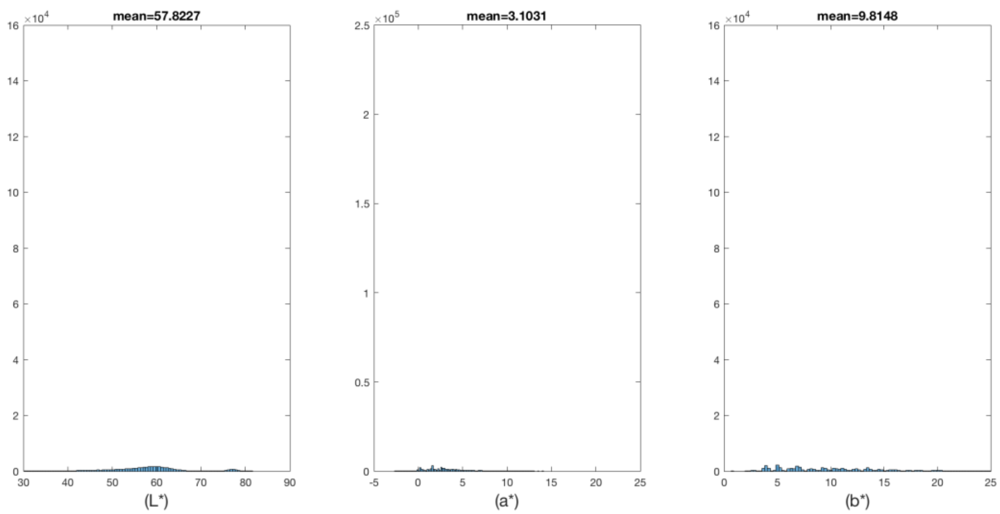


Figure 96. Histogram showing the L,a,b values of the trash particles.

So, the histograms shown here shows that how the system actually can differentiate and measure the cotton color separately. With the help of three different kind of histograms which really shows that how it can be seen the cotton color separately and also the trash particles. The trash particles present on the surface of the sample can be different in nature also as described earlier. They can be of brown color, green color and also of different color like piece of polypropylene which is quite common as cotton is transported in these kinds of bags to the factories.

5.7 Conclusion

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.

The software which is developed here for the cotton precise color measurement and also for the foreign matter detection is a very good enhancement in the cotton color grading industry.

Previously a value was taken into consideration while grading the cotton color. But now as described in the results the a value will help us to detect the green color trash particles like leaves with the help of a region in the histograms.

This is a good addition in the cotton color industry. This will enhance the precise color measurement of the cotton and also in some other color industry where the foreign matters can be disturbance. This software will be easily transportable in the fields to measure the color of raw cotton as well. So, even the color grading for the ginning factories can also be improved as the seed color of the cotton can also e recognized.

6 New Findings of the Research

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.

Improved HVI color diagram is used in the research and the limit points of the white, light spotted, spotted, tinged and yellow stained region are shown not only shown in one color space but they are also shown in different color spaces. The most important part of the research is that this improved diagram is actually consisting of three parameters. The color of cotton with the help of this diagram can be graded and assessed in the 3d graph. The old HVI color diagram is actually consist of two parameters by neglecting (a) which represents redness/greenness. Now, this new HVI diagram development method can be used to represent the cotton color in globally recognized color spaces. This shows that the cotton color assessment will be more accurate and precise as compared to the previous method which was actually ignoring the third factor.

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.

7 Appendix

Table 34. The limits points of the white dotted line are represented in these three different color regions based on the statistical analysis.

	Rd	a	b	X	Y	Z	x	y	Y
1	50.00	1.27	6.4	50.04	50.00	43.52	0.35	0.35	50.00
2	55.15	1.07	6.6	54.88	55.15	50.00	0.34	0.34	55.15
3	59.28	0.91	6.8	58.78	59.28	55.04	0.34	0.34	59.28
4	62.56	0.80	7	61.91	62.56	58.93	0.34	0.34	62.56
5	65.18	0.72	7.2	64.40	65.18	61.94	0.34	0.34	65.18
6	67.27	0.67	7.4	66.41	67.27	64.25	0.34	0.34	67.27
7	68.98	0.64	7.6	68.05	68.98	66.06	0.34	0.34	68.98
8	70.40	0.62	7.8	69.43	70.40	67.51	0.33	0.34	70.40
9	71.64	0.61	8	70.63	71.64	68.72	0.33	0.34	71.64
10	72.76	0.60	8.2	71.73	72.76	69.78	0.33	0.34	72.76
11	73.84	0.60	8.4	72.78	73.84	70.79	0.33	0.34	73.84
12	74.90	0.60	8.6	73.82	74.90	71.78	0.33	0.34	74.90
13	75.98	0.60	8.8	74.87	75.98	72.78	0.33	0.34	75.98
14	77.06	0.60	9	75.93	77.06	73.80	0.33	0.34	77.06
15	78.14	0.60	9.2	76.98	78.14	74.82	0.33	0.34	78.14
16	79.18	0.59	9.4	78.00	79.18	75.79	0.33	0.34	79.18
17	80.13	0.60	9.6	78.93	80.13	76.65	0.33	0.34	80.13
18	80.92	0.61	9.8	79.72	80.93	77.30	0.34	0.34	80.93
19	81.47	0.64	10	80.26	81.47	77.64	0.34	0.34	81.47

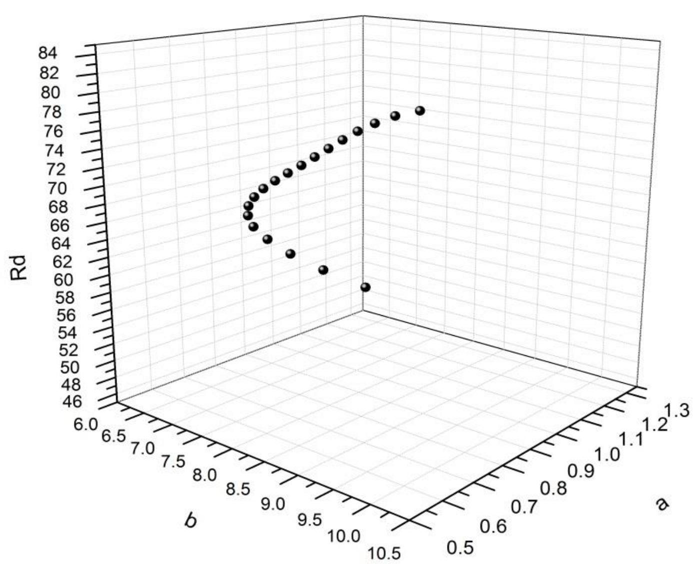


Figure 97. White dotted line represented in Rd a b diagram.

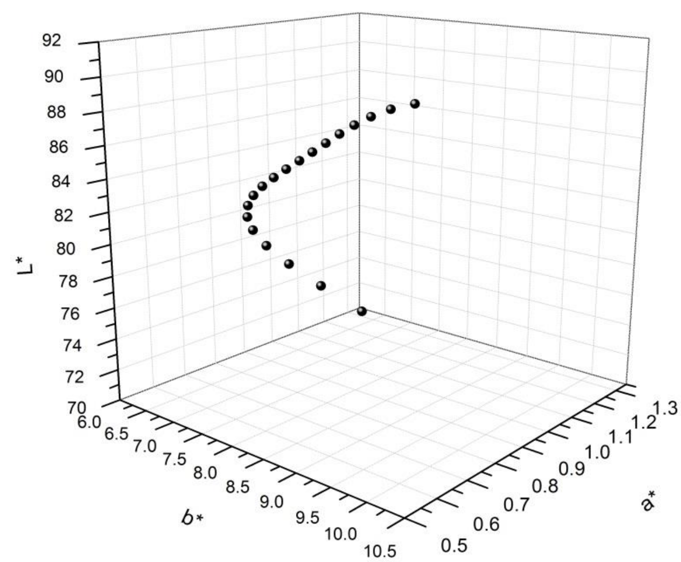


Figure 98. White dotted line represented in L a b diagram.

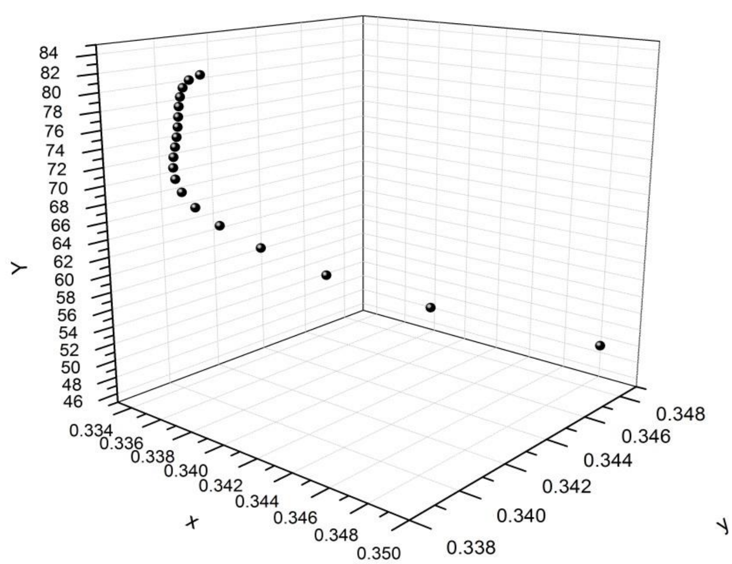


Figure 99. White dotted line represented in x y Y diagram.

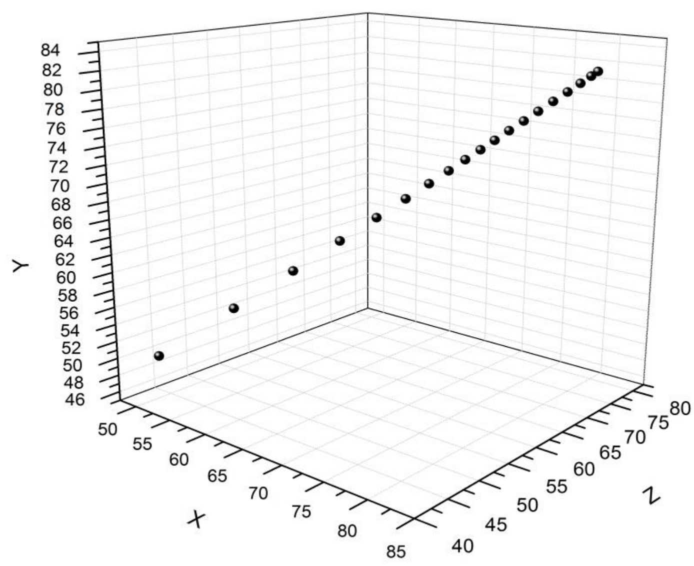


Figure 100. White dotted line represented in CIE XYZ diagram.

Table 35. The limits points of the light spotted line are represented in these three different color regions based on the statistical analysis.

	Rd	a	b	X	Y	Z	x	y	Y
1	42.66	2.16	8.4	43.74	42.66	27.98	0.38	0.37	42.66
2	49.24	1.88	8.6	49.80	49.24	37.10	0.37	0.36	49.24
3	54.37	1.68	8.8	54.59	54.37	43.87	0.36	0.36	54.37
4	58.32	1.53	9	58.31	58.32	48.89	0.35	0.35	58.32
5	61.35	1.43	9.2	61.17	61.35	52.59	0.35	0.35	61.35
6	63.67	1.37	9.4	63.38	63.67	55.31	0.35	0.35	63.67
7	65.48	1.33	9.6	65.11	65.48	57.33	0.35	0.35	65.48
8	66.94	1.31	9.8	66.52	66.94	58.88	0.35	0.35	66.94
9	68.18	1.30	10	67.72	68.18	60.14	0.35	0.35	68.18
10	69.32	1.30	10.2	68.82	69.32	61.26	0.35	0.35	69.32
11	70.42	1.29	10.4	69.90	70.42	62.34	0.34	0.35	70.42
12	71.55	1.29	10.6	71.00	71.55	63.45	0.34	0.35	71.55
13	72.72	1.28	10.8	72.13	72.72	64.62	0.34	0.35	72.72
14	73.93	1.27	11	73.31	73.93	65.84	0.34	0.35	73.93
15	75.15	1.26	11.2	74.49	75.15	67.07	0.34	0.35	75.15
16	76.30	1.26	11.4	75.61	76.30	68.22	0.34	0.35	76.30
17	77.31	1.26	11.6	76.59	77.31	69.17	0.34	0.35	77.31
18	78.05	1.28	11.8	77.32	78.05	69.77	0.34	0.35	78.05
19	78.37	1.31	12	77.65	78.37	69.82	0.34	0.35	78.37

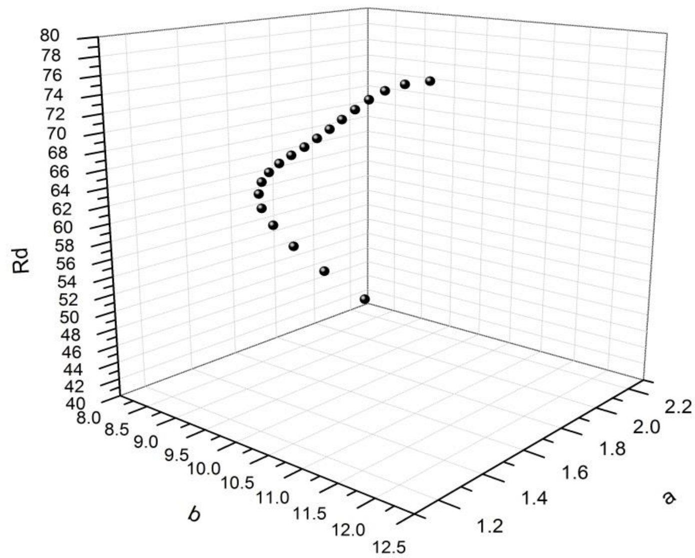


Figure 101. Light Spotted line represented in Rd a b diagram.

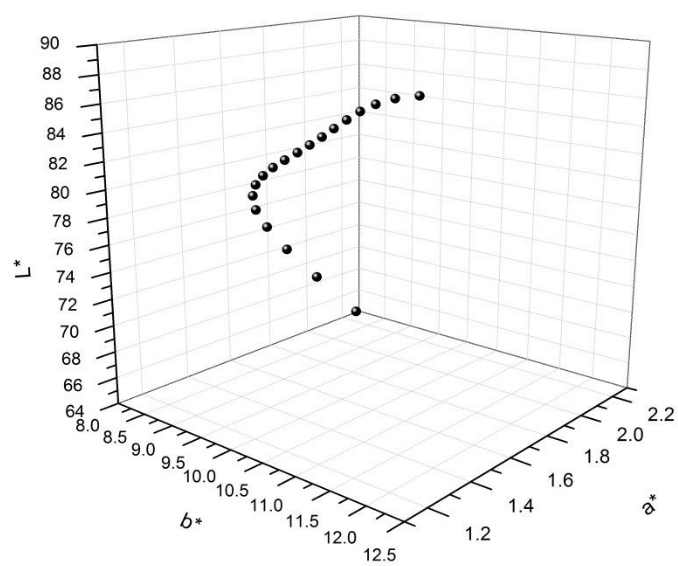


Figure 102. Light Spotted line represented in L a b diagram.

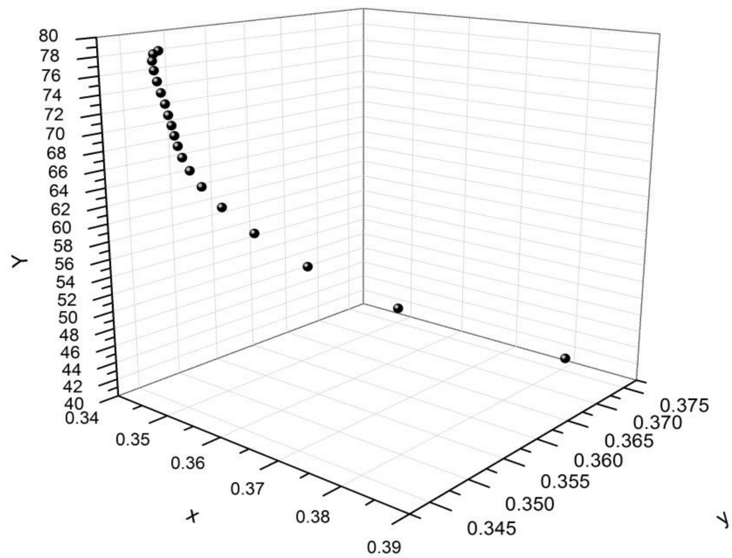


Figure 103. Light Spotted line represented in x y Y diagram.

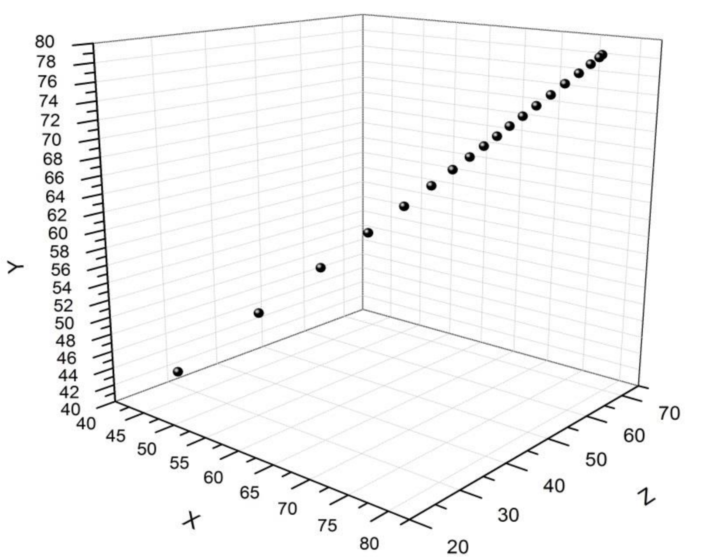


Figure 104. Light Spotted line represented in CIE XYZ diagram.

Table 36. The limits points of the spotted line are represented in these three different color regions based on the statistical analysis.

	Rd	a	b	X	Y	Z	x	y	Y
1	41.28	2.80	10.6	43.00	41.28	19.92	0.41	0.40	41.28
2	46.97	2.57	10.8	48.19	46.97	28.28	0.39	0.38	46.97
3	51.55	2.39	11	52.43	51.55	34.67	0.38	0.37	51.55
4	55.24	2.26	11.2	55.87	55.24	39.59	0.37	0.37	55.24
5	58.20	2.16	11.4	58.65	58.20	43.39	0.37	0.36	58.20
6	60.59	2.10	11.6	60.91	60.59	46.34	0.36	0.36	60.59
7	62.54	2.05	11.8	62.77	62.54	48.66	0.36	0.36	62.54
8	64.18	2.02	12	64.34	64.18	50.53	0.36	0.36	64.18
9	65.60	2.00	12.2	65.70	65.60	52.09	0.36	0.36	65.60
10	66.88	1.99	12.4	66.92	66.88	53.45	0.36	0.36	66.88
11	68.07	1.98	12.6	68.07	68.07	54.69	0.36	0.36	68.07
12	69.21	1.98	12.8	69.18	69.21	55.86	0.36	0.36	69.21
13	70.32	1.97	13	70.25	70.32	56.99	0.36	0.36	70.32
14	71.40	1.97	13.2	71.30	71.40	58.08	0.36	0.36	71.40
15	72.42	1.97	13.4	72.30	72.42	59.09	0.35	0.36	72.42
16	73.36	1.98	13.6	73.20	73.36	59.98	0.35	0.36	73.36
17	74.13	1.99	13.8	73.97	74.13	60.65	0.35	0.36	74.13
18	78.05	1.28	11.8	77.32	78.05	69.77	0.34	0.35	78.05
19	78.37	1.31	12	77.65	78.37	69.82	0.34	0.35	78.37

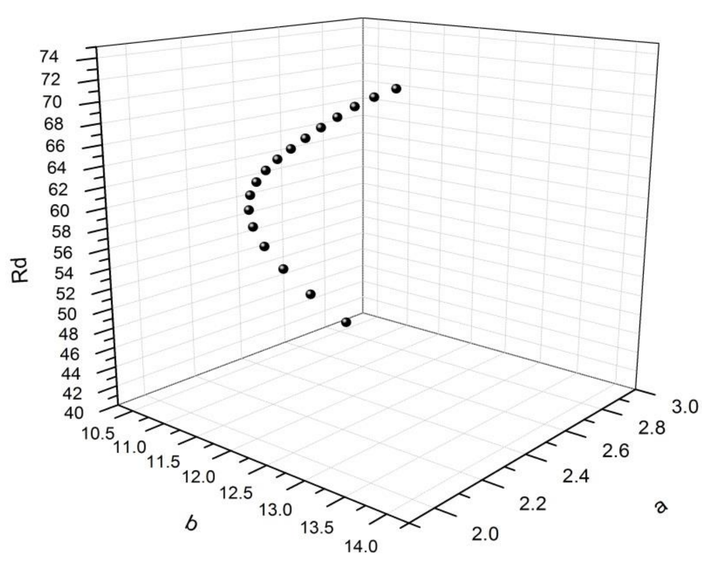


Figure 105.Spotted line represented in Rd a b diagram.

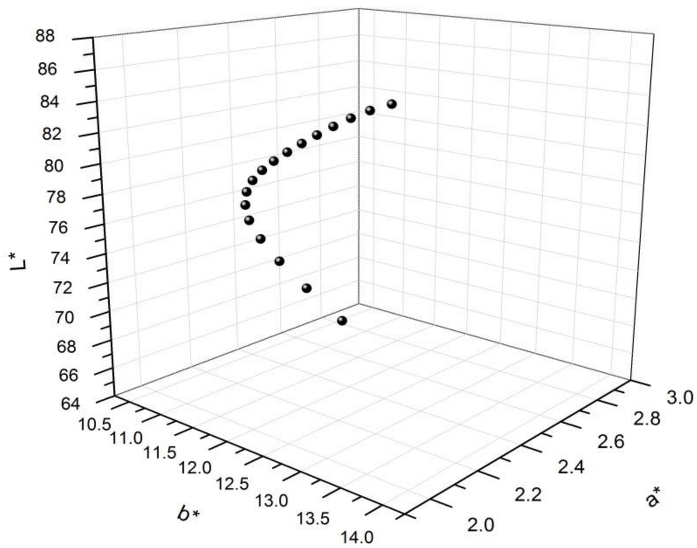


Figure 106. Spotted line represented in L a b diagram.

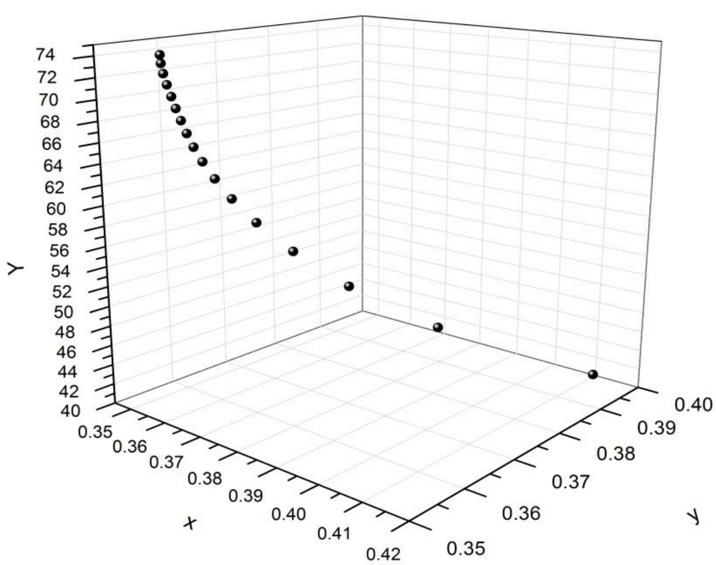


Figure 107. Spotted line represented in x y Y diagram.

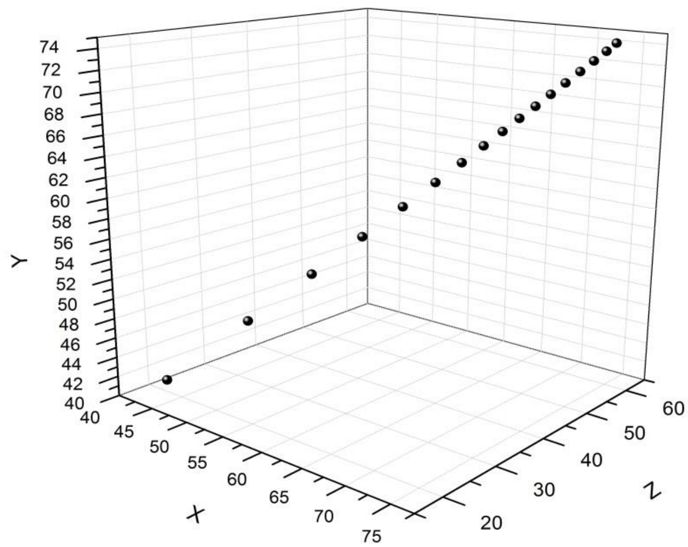


Figure 108. Spotted line represented in CIE XYZ diagram.

Table 37. The limits points of the spotted dotted line are represented in these three different color regions based on the statistical analysis.

	Rd	a	b	X	Y	Z	x	y	Y
1	51.18	2.10	9.8	51.85	51.18	36.99	0.37	0.37	51.18
2	55.39	1.94	10	55.77	55.39	42.54	0.36	0.36	55.39
3	58.72	1.83	10.2	58.91	58.72	46.78	0.36	0.36	58.72
4	61.36	1.75	10.4	61.40	61.36	50.01	0.36	0.36	61.36
5	63.46	1.69	10.6	63.41	63.46	52.49	0.35	0.35	63.46
6	65.17	1.66	10.8	65.04	65.17	54.42	0.35	0.35	65.17
7	66.60	1.64	11	66.42	66.60	55.96	0.35	0.35	66.60
8	67.85	1.63	11.2	67.62	67.85	57.25	0.35	0.35	67.85
9	68.99	1.62	11.4	68.73	68.99	58.39	0.35	0.35	68.99
10	70.07	1.62	11.6	69.78	70.07	59.46	0.35	0.35	70.07
11	71.13	1.62	11.8	70.81	71.13	60.50	0.35	0.35	71.13
12	72.18	1.62	12	71.83	72.18	61.53	0.35	0.35	72.18
13	73.22	1.62	12.2	72.84	73.22	62.54	0.35	0.35	73.22
14	74.22	1.62	12.4	73.81	74.22	63.49	0.35	0.35	74.22
15	75.12	1.63	12.6	74.69	75.12	64.32	0.35	0.35	75.12
16	75.85	1.65	12.8	75.41	75.85	64.92	0.35	0.35	75.85
17	76.33	1.67	13	75.90	76.33	65.19	0.35	0.35	76.33
18	78.05	1.28	11.8	77.32	78.05	69.77	0.34	0.35	78.05
19	78.37	1.31	12	77.65	78.37	69.82	0.34	0.35	78.37

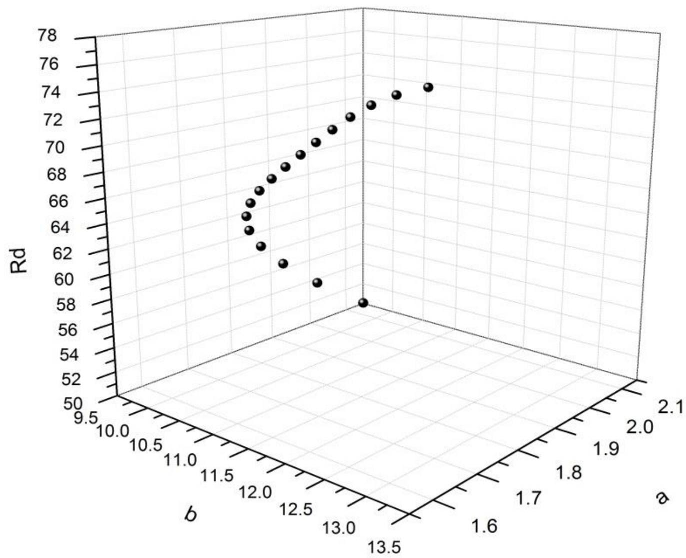


Figure 109. Spotted dotted line represented in Rd a b diagram.

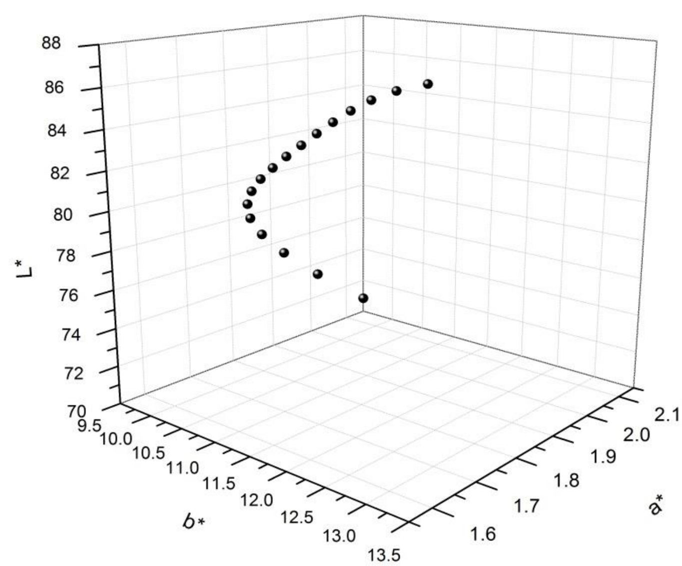


Figure 110. Spotted dotted line represented in L a b diagram.

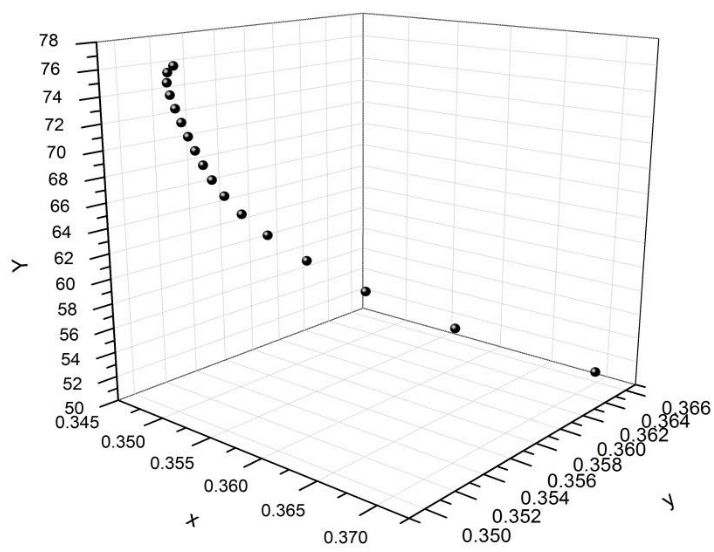


Figure 111. Spotted dotted line represented in x y Y diagram.

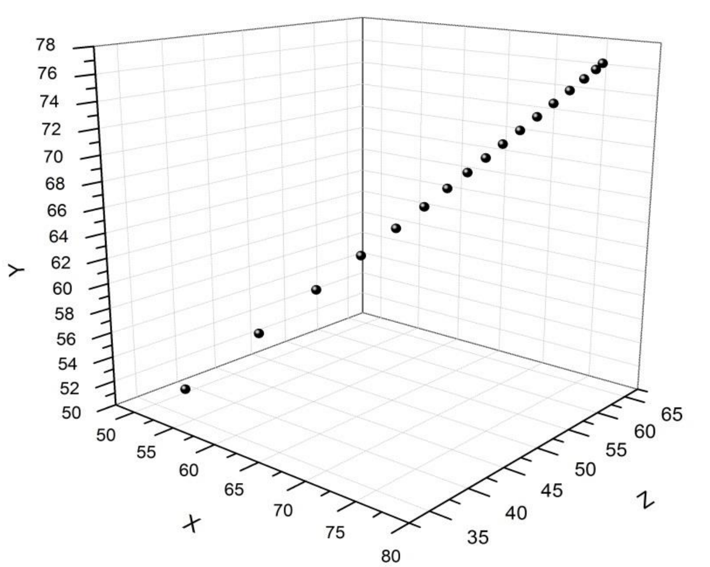


Figure 112. Spotted dotted line represented in CIE XYZ diagram.

Table 38. The limits points of the tinged line are represented in these three different color regions based on the statistical analysis.

	Rd	a	b	X	Y	Z	x	y	Y
1	42.82	3.40	13.2	44.98	42.82	15.45	0.44	0.41	42.82
2	47.00	3.24	13.4	48.79	47.00	21.80	0.41	0.40	47.00
3	50.40	3.13	13.6	51.92	50.40	26.69	0.40	0.39	50.40
4	53.17	3.04	13.8	54.49	53.17	30.50	0.39	0.38	53.17
5	55.46	2.98	14	56.63	55.46	33.52	0.39	0.38	55.46
6	57.40	2.93	14.2	58.45	57.40	35.98	0.38	0.38	57.40
7	59.08	2.90	14.4	60.05	59.08	38.04	0.38	0.38	59.08
8	60.60	2.88	14.6	61.49	60.60	39.84	0.38	0.37	60.60
9	62.00	2.86	14.8	62.82	62.00	41.47	0.38	0.37	62.00
10	63.34	2.84	15	64.10	63.34	43.00	0.38	0.37	63.34
11	64.62	2.83	15.2	65.32	64.62	44.43	0.37	0.37	64.62
12	65.84	2.82	15.4	66.49	65.84	45.78	0.37	0.37	65.84
13	66.97	2.82	15.6	67.58	66.97	47.01	0.37	0.37	66.97
14	67.98	2.82	15.8	68.55	67.98	48.04	0.37	0.37	67.98
15	68.78	2.83	16	69.34	68.78	48.79	0.37	0.37	68.78

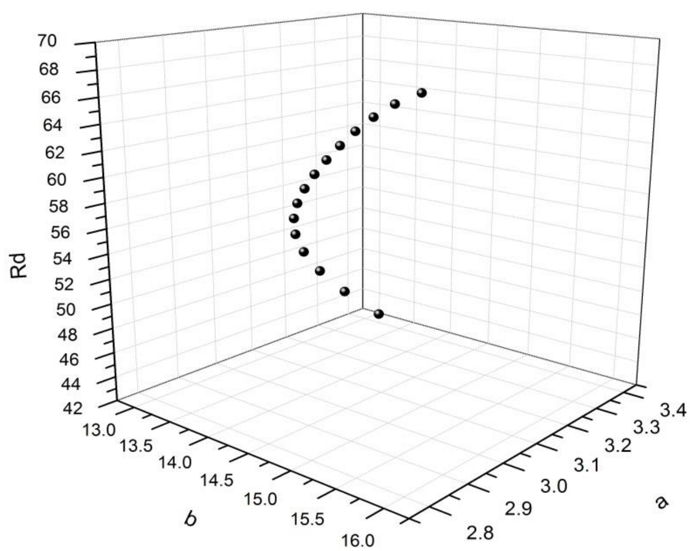


Figure 113. Tinged line represented in Rd a b diagram.

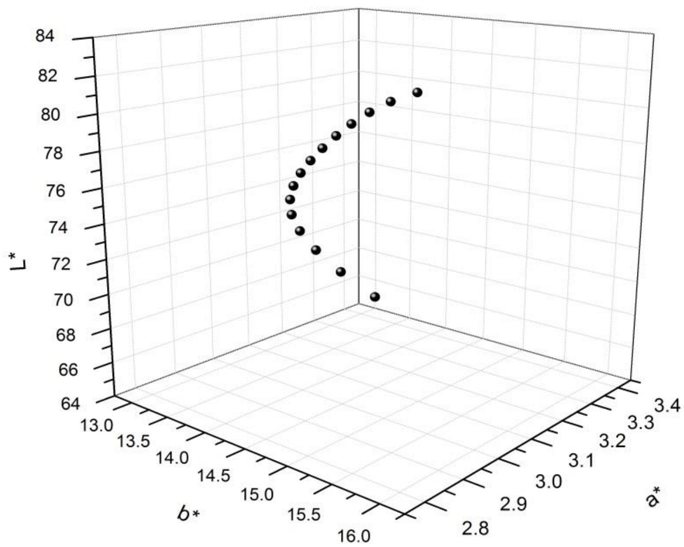


Figure 114. Tinged line represented in L a b diagram.

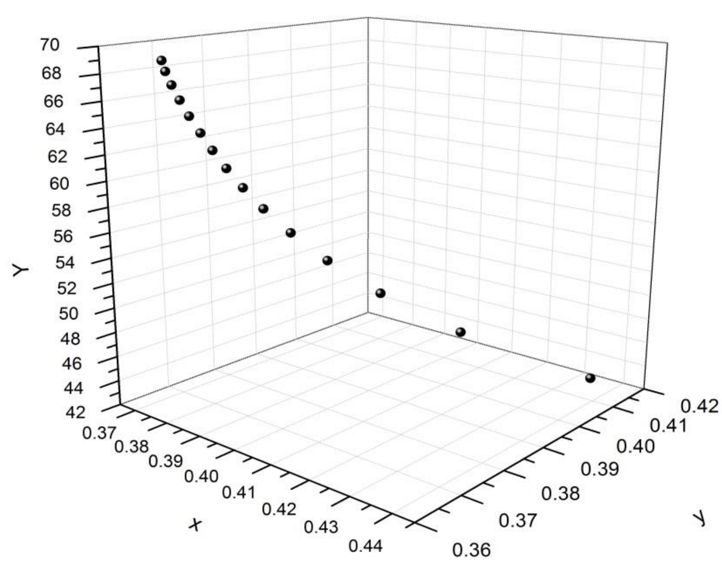


Figure 115. Tinged line represented in x y Y diagram.

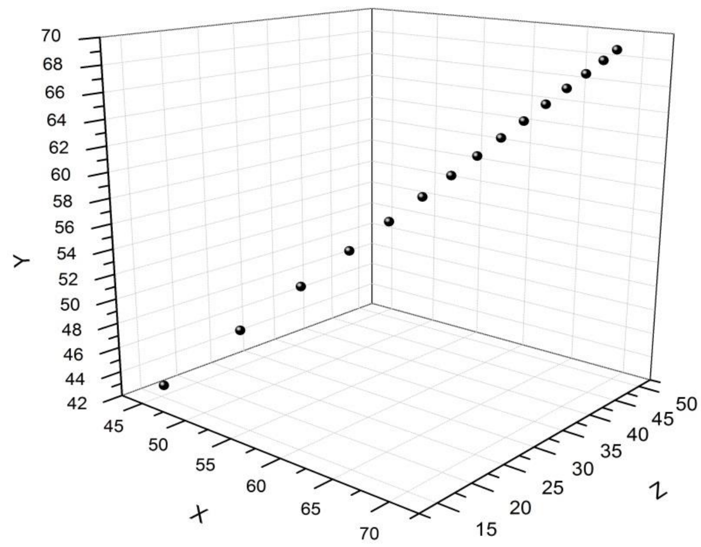


Figure 116. Tinged line represented in CIE XYZ diagram.

Table 39. The limits points of the tinged dotted line are represented in these three different color regions based on the statistical analysis.

	Rd	a	b	X	Y	Z	x	y	Y
1	53.69	2.65	12.4	54.68	53.69	34.55	0.38	0.38	53.69
2	56.12	2.58	12.6	56.96	56.12	37.69	0.38	0.37	56.12
3	58.29	2.52	12.8	59.01	58.29	40.42	0.37	0.37	58.29
4	60.23	2.48	13	60.84	60.23	42.79	0.37	0.37	60.23
5	61.97	2.44	13.2	62.49	61.97	44.85	0.37	0.37	61.97
6	63.52	2.42	13.4	63.98	63.52	46.65	0.37	0.36	63.52
7	64.93	2.40	13.6	65.32	64.93	48.23	0.37	0.36	64.93
8	66.20	2.39	13.8	66.54	66.20	49.62	0.36	0.36	66.20
9	67.37	2.38	14	67.67	67.37	50.86	0.36	0.36	67.37
10	68.46	2.38	14.2	68.72	68.46	51.98	0.36	0.36	68.46
11	69.48	2.38	14.4	69.71	69.48	53.01	0.36	0.36	69.48
12	70.46	2.38	14.6	70.66	70.46	53.99	0.36	0.36	70.46
13	71.43	2.39	14.8	71.60	71.43	54.94	0.36	0.36	71.43

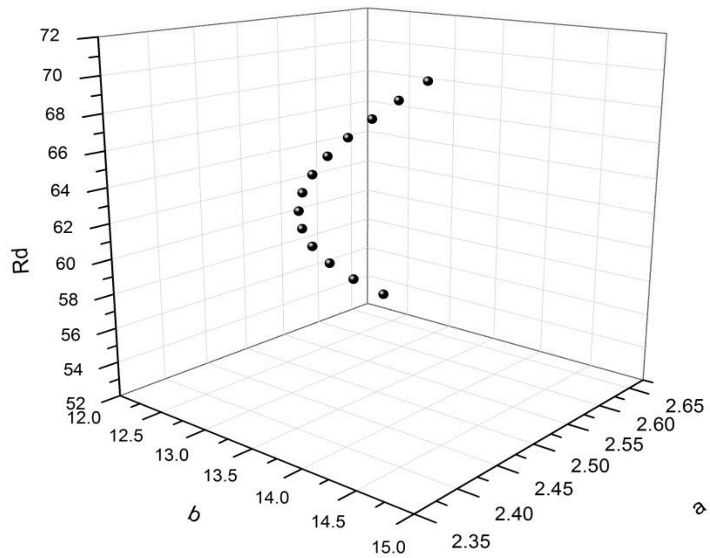


Figure 117. Tinged dotted line represented in Rd a b diagram.

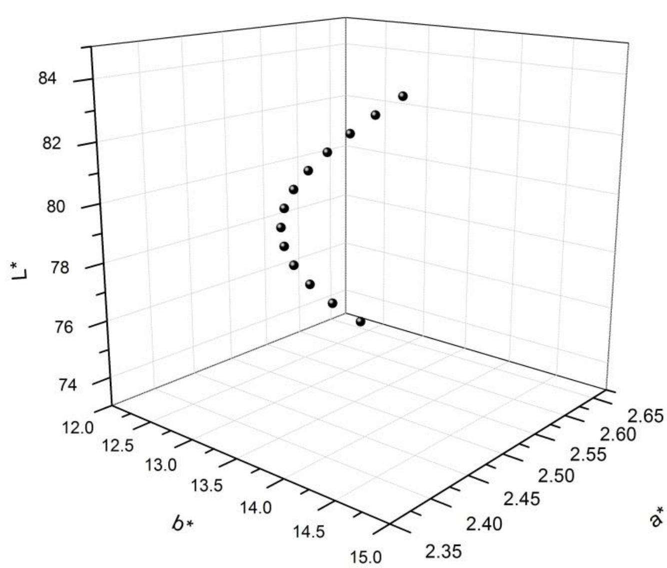


Figure 118. . Tinged dotted line represented in L a b diagram.

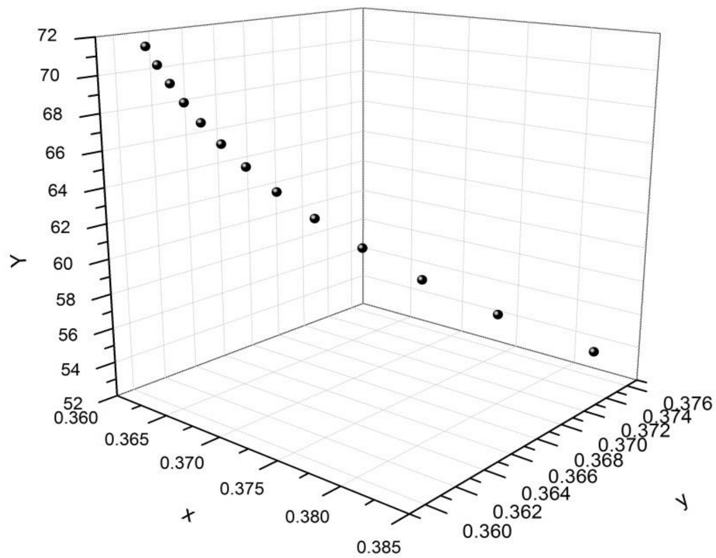


Figure 119. Tinged dotted line represented in x y Y diagram.

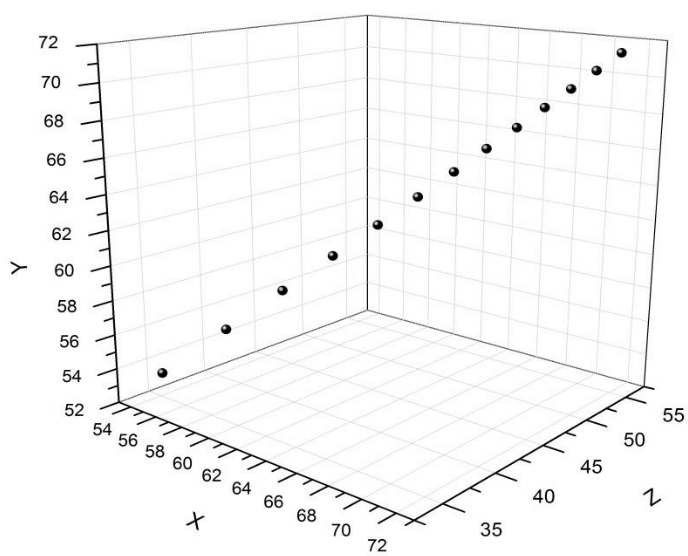


Figure 120. . Tinged dotted line represented in CIE XYZ diagram.

7.1 Matlab software codes

```
close all;clear
Files = dir('*.CR2');
numFiles = length(Files);
mydata = cell(1,numFiles);
for k = 1:numFiles
 mydata{k} = imread(Files(k).name);
end
I1=mydata{1};
I=im2double(I1);
ff1=((I(:,:,1)-0.82).^2+(I(:,:,2)-0.14).^2+(I(:,:,3)-0.25).^2).^(0.5);
ff2=((I(:,:,1)-0.10).^2+(I(:,:,2)-0.52).^2+(I(:,:,3)-0.47).^2).^(0.5);
ff1=ff1<0.1;ff1=medfilt2(ff1,[11 11]);
s1 = regionprops(ff1,'centroid');x1=s1.Centroid(1);y1=s1.Centroid(2);
ff2=ff2<0.1;ff2=medfilt2(ff2,[11 11]);
s2 = regionprops(ff2,'centroid');x2=s2.Centroid(1);y2=s2.Centroid(2);
%plot(x2,y2, 'r*')
if x1<x2
    x=x1+(abs(x2-x1))/2;
else
    x=x2+(abs(x2-x1))/2;
end
if y1<y2
    y=y1+(abs(y2-y1))/2;
else
```

```
    y=y2+(abs(y2-y1))/2;
end
coord(k,1)=y;coord(k,2)=x;imageSize = size(I);
Rad=520;ci = [y,x, Rad];%center and radius of circle([row,col,radius])
[xx,yy] = ndgrid((1:imageSize(1))-ci(1),(1:imageSize(2))-ci(2));
mask01 = double((xx.^2 + yy.^2)<ci(3)^2);
RR = I(:,:,1);GG = I(:,:,2);BB = I(:,:,3);
RR(mask01==0) = NaN;GG(mask01==0) = NaN;BB(mask01==0) = NaN;
RGB_NAN(:,:,1)=(RR);RGB_NAN(:,:,2)=(GG);RGB_NAN(:,:,3)=(BB);
```

Cropping of the Image

```
CroppedRGB_NAN = imcrop(RGB_NAN,[coord(k,2)-Rad coord(k,1)-Rad 2*Rad 2*Rad]);
figure,imshow(CroppedRGB_NAN)
for k = 1:numFiles
I1=mydata{k};
I=im2double(I1);
%figure,imshow(I)
ff1=((I(:,:,1)-0.82).^2+(I(:,:,2)-0.14).^2+(I(:,:,3)-0.25).^2).^(0.5);
ff2=((I(:,:,1)-0.10).^2+(I(:,:,2)-0.52).^2+(I(:,:,3)-0.47).^2).^(0.5);
ff1=ff1<0.1;
ff1=medfilt2(ff1,[11 11]);
s1 = regionprops(ff1,'centroid');x1=s1.Centroid(1);y1=s1.Centroid(2);
%figure;imshow(I1);hold on
%plot(x1,y1, 'b*')
ff2=ff2<0.1;
ff2=medfilt2(ff2,[11 11]);
```

```
s2 = regionprops(ff2,'centroid');x2=s2.Centroid(1);y2=s2.Centroid(2);
%plot(x2,y2, 'r*')
if x1<x2
   x=x1+(abs(x2-x1))/2;
else
   x=x2+(abs(x2-x1))/2;
end
if y1<y2
   y=y1+(abs(y2-y1))/2;
else
   y=y2+(abs(y2-y1))/2;
end
coord(k,1)=y;coord(k,2)=x;
imageSize = size(I);
Rad=520;
ci = [y,x, Rad];%center and radius of circle([row,col,radius])
[xx,yy] = ndgrid((1:imageSize(1))-ci(1),(1:imageSize(2))-ci(2));
mask01 = double((xx.^2 + yy.^2)<ci(3)^2);
cform1 = makecform('srgb2lab');
IMLAB= applycform(I,cform1);
```

L,a,b Values of the image segmented parts

```
LL = IMLAB(:,:,1);
aa = IMLAB(:,:,2);
bb = IMLAB(:,:,3);
LL(mask01==0) = NaN;
```

```
aa(mask01==0) = NaN;

bb(mask01==0) = NaN;
```

L a b values of the image non-segmented parts

```
LAB_NAN(:,:,1)=(LL);

LAB_NAN(:,:,2)=(aa);

LAB_NAN(:,:,3)=(bb);

CroppedLAB_NAN = imcrop(LAB_NAN,[coord(k,2)-Rad coord(k,1)-Rad 2*Rad 2*Rad]);

cropLAB_NANstore(k)={CroppedLAB_NAN};

figure,imshow(CroppedLAB_NAN(:,:,1),[])

end.

   Lcom = cat(3,
cropLAB_NANstore{1}(:,:,1),cropLAB_NANstore{2}(:,:,1),cropLAB_NANstore{3}(:,:,1),crop
LAB_NANstore{4}(:,:,1)) ;

Lmed=nanmedian(Lcom,3);

Lmean=nanmean(Lcom,3);

   acom = cat(3,
cropLAB_NANstore{1}(:,:,2),cropLAB_NANstore{2}(:,:,2),cropLAB_NANstore{3}(:,:,2),crop
LAB_NANstore{4}(:,:,2)) ;

amed=nanmedian(acom,3);

amean=nanmean(acom,3);

   bcom = cat(3,
cropLAB_NANstore{1}(:,:,3),cropLAB_NANstore{2}(:,:,3),cropLAB_NANstore{3}(:,:,3),crop
LAB_NANstore{4}(:,:,3)) ;

bmed=nanmedian(bcom,3);

bmean=nanmean(bcom,3);

   Lb=cropLAB_NANstore{1};

L=Lb(:,:,1);
```

```
a=Lb(:,:,2);
b=Lb(:,:,3);

   dis=sqrt((Lmed-L).^2+(amed-a).^2+(bmed-b).^2);
Lorg=CroppedRGB_NAN;
Lorg(dis>10)=0;
```

Show figure

```
figure,imshow(Lorg,[])
figure,imshow(dis,[])
figure,imshow(CroppedRGB_NAN)
if 4==2%for graphical representation
  Lb2=cropLAB_NANstore{1};
L2=Lb2(:,:,1);
a2=Lb2(:,:,2);
b2=Lb2(:,:,3);
L2(~(dis>10))=NaN;
b2(~(dis>10))=NaN;
a2(~(dis>10))=NaN;
[rr, cc]=size(L2);
Lshp = reshape(L2,rr,cc);
aLshp = reshape(a2,rr,cc);
bshp = reshape(b2,rr,cc);
figure,imshow(Lshp,[])
figure,imshow(aLshp,[])
figure,imshow(bshp,[])
```

```
figure,plot3(amed(:),bmed(:),Lmed(:),'or');xlabel('a*');ylabel('b*');zlabel('L')
hold on.
```

Plot of the Lab Values

```
plot3(aLshp(:),bshp(:),Lshp(:),'*b');grid on
figure,plot3(a(:),b(:),L(:),'or');xlabel('a*');ylabel('b*');zlabel('L')
hold on
plot3(aLshp(:),bshp(:),Lshp(:),'*b');grid on
figure,plot(Lshp(:),bshp(:),'or');xlabel('L*');ylabel('b*');
hold on
plot(L(:),b(:),'*b')
figure,plot(Lshp(:),bshp(:),'or');xlabel('L*');ylabel('b*');
hold on
plot(Lmed(:),bmed(:),'*b')
figure,plot(Lshp(:),aLshp(:),'or');xlabel('L*');ylabel('a*');
hold on
plot(L(:),a(:),'*b')
figure,plot(Lshp(:),aLshp(:),'or');xlabel('L*');ylabel('a*');
hold on
plot(Lmed(:),amed(:),'*b')
end
%figure,plot(Lmed(:),L(:),'ob')
Lstdorg=cropLAB_NANstore{1}(:,:,1);
Lstd=(Lstdorg-min(Lstdorg(:)))/(max(Lstdorg(:))-min(Lstdorg(:)));
Lmedstd=(Lmed-min(Lmed(:)))/(max(Lmed(:))-min(Lmed(:)));
LLab_Seg=cropLAB_NANstore{1}(:,:,1);
```

```
aLab_Seg=cropLAB_NANstore{1}(:,:,2);
bLab_Seg=cropLAB_NANstore{1}(:,:,3);
thr=10;
LLab_Seg(dis>thr)=NaN;
aLab_Seg(dis>thr)=NaN;
bLab_Seg(dis>thr)=NaN;
%figure,imshow(LLab_Seg,[])
j=1;
```

Sondata of the non-segmented part of the image

```
SONDATA(1,j)=nanmean(LLab_Seg(:));
SONDATA(2,j)=nanmedian(LLab_Seg(:));
SONDATA(3,j)=nanstd(LLab_Seg(:));
SONDATA(4,j)=nanmean(aLab_Seg(:));
SONDATA(5,j)=nanmedian(aLab_Seg(:));
SONDATA(6,j)=nanstd(aLab_Seg(:));
SONDATA(7,j)=nanmean(bLab_Seg(:));
SONDATA(8,j)=nanmedian(bLab_Seg(:));
SONDATA(9,j)=nanstd(bLab_Seg(:));
Ls=cropLAB_NANstore{1}(:,:,1);
as=cropLAB_NANstore{1}(:,:,2);
bs=cropLAB_NANstore{1}(:,:,3);.
```

Sondata of the segmented part

```
SONDATA(10,j)=nanmean(Ls(:));
SONDATA(11,j)=nanmedian(Ls(:));
SONDATA(12,j)=nanstd(Ls(:));
```

```
SONDATA(13,j)=nanmean(as(:));
SONDATA(14,j)=nanmedian(as(:));
SONDATA(15,j)=nanstd(as(:));
SONDATA(16,j)=nanmean(bs(:));
SONDATA(17,j)=nanmedian(bs(:));
SONDATA(18,j)=nanstd(bs(:));
```

Thrash content Thrash Lab values and mean median std are stored .

```
LLab_SegThrash=cropLAB_NANstore{1}(:,:,1);
aLab_SegThrash=cropLAB_NANstore{1}(:,:,2);
bLab_SegThrash=cropLAB_NANstore{1}(:,:,3);
thr=10;
LLab_SegThrash(dis<=thr)=NaN;
aLab_SegThrash(dis<=thr)=NaN;
bLab_SegThrash(dis<=thr)=NaN;
figure,imshow(LLab_SegThrash,[])
j=1;
SONDATA(19,j)=nanmean(LLab_SegThrash(:));
SONDATA(20,j)=nanmedian(LLab_SegThrash(:));
SONDATA(21,j)=nanstd(LLab_SegThrash(:));
SONDATA(22,j)=nanmean(aLab_SegThrash(:));
SONDATA(23,j)=nanmedian(aLab_SegThrash(:));
SONDATA(24,j)=nanstd(aLab_SegThrash(:));
SONDATA(25,j)=nanmean(bLab_SegThrash(:));
SONDATA(26,j)=nanmedian(bLab_SegThrash(:));
SONDATA(27,j)=nanstd(bLab_SegThrash(:));
```

% Histogram Figure

figure%Original Cotton Sample Histograms (Ls,as,bs) AND thrash histograms together

subplot(1,3,1),histogram(Ls(:),100),title(['mean=' num2str(SONDATA(10,j))],'FontSize',12),xlabel('(L*)','FontSize',16)

hold on.

Threshold histogram

subplot(1,3,2),histogram(as(:),100),title(['mean=' num2str(SONDATA(13,j))],'FontSize',12),xlabel('(a*)','FontSize',16)

hold on

histogram(aLab_SegThrash(:),100)

subplot(1,3,3),histogram(bs(:),100),title(['mean=' num2str(SONDATA(16,j))],'FontSize',12),xlabel('(b*)','FontSize',16)

hold on

histogram(bLab_SegThrash(:),100)

figure%Segmented Cotton Sample Histograms (LLab_Seg,a_Seg,b_Seg)

subplot(1,3,1),histogram(LLab_Seg(:),100),title(['mean=' num2str(SONDATA(1,j))],'FontSize',12),xlabel('(L*)','FontSize',16)

subplot(1,3,2),histogram(aLab_Seg(:),100),title(['mean=' num2str(SONDATA(4,j))],'FontSize',12),xlabel('(a*)','FontSize',16)

subplot(1,3,3),histogram(bLab_Seg(:),100),title(['mean=' num2str(SONDATA(7,j))],'FontSize',12),xlabel('(b*)','FontSize',16)

figure%Segmented Thrash region Histograms

subplot(1,3,1),histogram(LLab_SegThrash(:),100),title(['mean=' num2str(SONDATA(19,j))],'FontSize',12),xlabel('(L*)','FontSize',16)

subplot(1,3,2),histogram(aLab_SegThrash(:),100),title(['mean=' num2str(SONDATA(22,j))],'FontSize',12),xlabel('(a*)','FontSize',16)

subplot(1,3,3),histogram(bLab_SegThrash(:),100),title(['mean=' num2str(SONDATA(25,j))],'FontSize',12),xlabel('(b*)','FontSize',16).

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8.1 Articles in journal

[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)**

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[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.

[5a] Vik, M., Vikova, M. , and **Khan, N**. Trash segmentation and visual Assessment. *Autex Research journal*. (submitted).

8.2 International Conferences:

[6a] **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.

[7a] **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.

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[12a] **Khan N**, Vik M, Vikova M, Dichroism Measurement of dyed Polyester fiber. Svetlanka workshop: 16-19th Sep, 2014: p70-175.

9 Curriculum Vitae

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Research field/ Thesis topic	*Influence of UV radiations on bleached cotton knitted fabrics treated with different optical brighteners.*
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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.
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