UNIVERSITY OF GAZİANTEP
GRADUATE SCHOOL OF
NATURAL & APPLIED SCIENCES

VISUALIZATION AND DETERMINATION OF THE GEOMETRICAL PARAMETERS OF FRIEZE YARNS

M.Sc. THESIS

IN

MECHANICAL ENGINEERING

BY

BURCU KÜÇÜKOĞLU

JANUARY 2015

Visualization and Determination of the Geometrical Parameters of Frieze Yarns

M.Sc. Thesis

In

Mechanical Engineering

University of Gaziantep

Supervisor

Prof. Dr. Sadettin KAPUCU

By

Burcu KÜÇÜKOĞLU

January 2015

T.C
UNIVERSITY OF GAZİANTEP
GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES
MECHANICAL ENGINEERING

Name of the thesis: Visualization and Determination of the Geometrical Parameters of Frieze Yarns

Name of the student: Burcu KÜÇÜKOĞLU

Exam date: 09.01.2015

Approval of the Graduate School of Natural and Applied Sciences

Prof.Dr. Metin BEDİR
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. Mehmet Sait SÖYLEMEZ
Head of Department

This is to certify that we have read this thesis and that in our consensus/majority opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Prof. Dr. Sadettin KAPUCU
Supervisor

Examining Committee Members	Signature
Prof. Dr. Sadettin KAPUCU	....
Prof. Dr. L. Canan DÜLGER	....
Prof. Dr. Hakan YAVUZ	....

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Burcu KÜÇÜKOĞLU

ABSTRACT

Visualization and Determination of the Geometrical Parameters of Frieze Yarns

KÜÇÜKOĞLU Burcu
M.Sc. in Mechanical Eng.
Supervisor: Prof. Dr. Sadettin KAPUCU
January 2015, 57 pages

Carpet yarns have been commonly used in the carpet industry. Producers have been required to generate a new type of yarn by the competitive conditions in the carpet industry. To achieve this, carpet yarns have been passed by a particular process. With this process, a new type of yarn, called frieze/crimped carpet yarn, has been obtained. This crimp/frieze structure have different geometric shape and affect the opalescent effect on the carpet. The crimp count and geometric shape become important as it affects the carpet's appearance. In the carpet industry, crimp structure has been evaluated by human eye. This subjective evaluation causes confusion when determining the crimp count. These results cause the uncertainty about how much crimp count is available on the yarn. This main aim of this thesis is to develop an image processing algorithm to evaluate the frieze carpet yarn’s crimp count objectively. As a part of this thesis, the algorithms have been developed to evaluate the crimp count and similarity to each other. With the developed algorithm, a basic vision system that consists of a digital camera, a computer and a platform with white ground have been used. With the aid of the developed algorithm and with the image processing algorithm, crimp count and difference of crimp structure the yarns samples were easily determined and the results were presented.

Key Words: Frieze carpet yarn, Crimp count, Crimp geometry, Image processing, The developed algorithm

ÖZET

FRİZELİ HALI İPLİKLERİNİN GÖRÜNTÜLENMESİ VE GEOMETRİK PARAMETRELERİNİN BELİRLENMESİ

KÜÇÜKOĞLU Burcu
Yüksek Lisans Tezi, Mak. Müh. Bölümü
Tez Yöneticisi: Prof. Dr. Sadettin KAPUCU
Ocak 2015, 57 sayfa

Halı üretiminde yaygın olarak halı iplikleri kullanılmaktadır. Halı endüstrisindeki rekabet şartları üreticileri yeni iplik türü üretmeye yöneltmiştir. Bu amaçla, halı ipliklerinin belirli işlemlerden geçirilmesi ile frizeli/kıvrımlandırılmış halı ipliği adı verilen yeni bir iplik türü üretilmektedir. Bu kıvrımlı/frizeli yapı değişik geometrik yapılarda olup halıya yanar dönerli bir görünüm vermektedir. Kıvrım yapıları halı görünümünü etkilediğinden sayıları ve geometrik yapıları önem kazanmaktadır. Kıvrım yapılarının geometrik şekilleri farklı ve halı sanayisinde insan gözüyle, öznel olarak değerlendirildiğinden kıvrım sayılarının belirlenmesi esnasında karışıklıklar yaşanmaktadır. Karışıklıklar iplik üzerindeki kıvrım yapılarının gerçekte kaç tane olduğu konusunda belirsizliklere neden olmaktadır. Bu tezin temel amacı frizeli halı ipliklerinin kıvrım sayılarını görüntü işleme algoritmaları geliştirerek nesnel olarak belirlemeye çalışmaktır. Bu tez kapsamında kıvrım yapısının sayılarını belirlemek ve benzerliklerini değerlendirebilmek için algoritmalar geliştirilmiştir. Geliştirilen algoritmaların kullanılabilmesi için digital kamera, bilgisayar ve beyaz zeminli platformdan oluşan basit bir görüntüleme sistemi oluşturulmuştur. Geliştirilen algoritmalar ve görüntü işleme algoritması yardımıyla iplik örneklerinin farkları kolaylıkla tespit edilmiş ve sonuçlar sunulmuştur.

Anahtar Kelimeler: Frizeli iplik, Kıvrım sayısı, Kıvrım geometrisi, Görüntü işleme, Oluşturulmuş Algoritma

ACKNOWLEDGEMENTS

First of all I would like to thank to my supervisor Prof. Dr. Sadettin KAPUCU for his valuable suggestion and his efforts during the preparation of this study. I would like to thank to Prof. Dr. L. Canan DÜLGER for her positive criticism and suggestions. I would like to thank to my coworker Research Assistant Taha Tuna GÖKSU for his supports. And finally, I would like to thank to my family for their endless supports.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Heat-set bulked continuous filament (BCF) polypropylene yarns constitute one of the most important pile yarns used in the production of machine-woven carpets. As carpets made from non-heat-set BCF polypropylene yarns lack resiliency and loss of appearance, heat setting of BCF yarns has proved to be very useful in overcoming these deficiencies [1].

Polypropylene Bulk Continuous Filament (BCF) carpet yarn is compressed with two rollers to give crimp and steam onto the BCF carpet yarns before fixing process. After the yarns compress process, polypropylene BCF carpet yarns are designated Frieze carpet yarn. Frieze carpet yarns are commonly used for generating carpet yarn manufacturing, because frieze carpet yarns affect the carpet's appearance. Frieze carpet yarns are taken crimp when BCF carpet yarns compress, these crimps to give the opalescent effect on carpet and affected the customer. Because of opalescent effect crimp count and crimp structure becomes important, therefore the crimping effect on the yarn must be known for the best carpet with effectual appearance.

Frieze carpet yarns have been taken heat treatment after compress processing to fix crimp structure, due to BCF carpet yarns thermoplastic property. Heat treatment is applied in the heat chamber. Crimp/waviness structure onto the yarns are given by stuffer-box. Stuffer-box working principle depends on the compressed yarn between two rollers when the yarns pass the roller, simultaneously crimp appearance are given onto the yarns and to pile up in stuffer box. When the yarns passing between the rollers compress is applied via the roller fastness, end of the heat chamber BCF carpet yarns have been had the irregular crimp character.

The irregular crimp form makes it difficult to evaluate the crimp which is actually crimped or not. In carpet industry, crimps have not been defined objectively. Crimp character onto the yarn has been evaluated by human eye inspection as subjective measure. The different crimp count has been evaluated by some of carpet manufacturers. On the very same yarn, different crimp counts can be evaluated by two different manufacturers. This is mainly due to irregular crimp character.

Due to the lack of objective evaluation method of crimp structure, carpet manufacturers have been trying to find new methods and tools. With the human eye inspection determining the crimp structurebecomes a troublesome and time consuming process. In the modern times, computer vision system may helps us to evaluate the crimp structure conviniently.

The aim of this thesis is to evaluate crimp structure via a computer system with reliable results. For this reason, digital image processing tool, a part of MATLAB program, has been chosen. Image processing tool provides enhancement to the image as a result of which, the captured image from yarn specimen is evaluated conveniently.

1.2 Thesis Structure

The structure of the thesis has been given as follows:

Chapter 1 gives a brief introduction of crimp character on the carpet and as they are defined by the carpet manufacturers. Crimp's importance on carpet and effect on customer are explained.

Chapter 2 is about a brief literature survey about crimp structure and decribes a capturing of a crimp structure. A crimp structure is defined with the digital image processing method.

Chapter 3 is about a brief image analysis stage, image enhancement, image segmentation and morphological methods. When the raw image is captured from CCD camera, it is converted to digital image, it is stored in the memory and the image is improved to evaluate for human eye inspection. The reason for using the morphological operations is to utilize image enhancement and image segmentation methods to improve image's detail with available image processing techniques.

Chapter 4 gives the details about the count of the crimp on the frieze carpet yarn samples with image processing. Before defining the crimp count on the digital images, which are captured from the camera, there are some treatments with morphological operations and image enhancement methods used. All details of these treatments and resulting crimp count will be given in this chapter.

Chapter 5 introduces a brief literature about fractal geometry, box counting, equispaced dimension methods. Part of fractal geometry, which is box counting and equispaced dimension, will be used to evaluate differences of crimp structure each from other. Box counting and equispaced dimension methods will be given with the results and will be compared with each other.

In Chapter 6, methods for determining to determine crimp morphology and classification of crimp structure is classified with the leading results of crimp morphology. When evaluating crimp structure, 11 parameters describing the crimp structure has been taken into account. All crimp structure's 11 parameters will be evaluated and will be used to compare its structure.

In Chapter 7, conclusion and discussion of the study are given. Future works are discussed.

CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

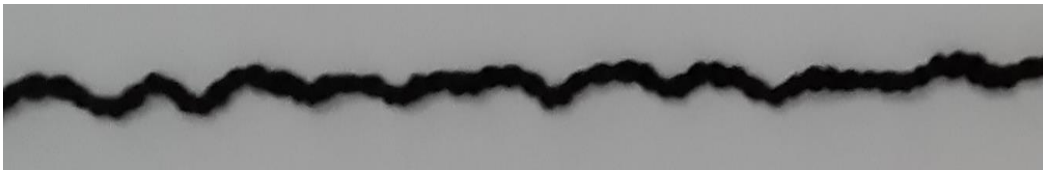
Crimp is the one of the most important special feature of the yarn for shaggy carpet. Crimp shows waviness of the yarn. Irregular waviness, different amplitude and frequency of waviness are usually desired to obtain better appearance of the carpet. This condition makes it difficult to measurement crimp structure, decide if crimp or not crimp and also count the crimps. Up to the present time, attempts have been made to describe frieze effect/crimp in terms of the geometry of the yarn path by human eye inspection. In fact, current methods of carpet yarn crimp evaluation are rudimentary and/or rely on the subjective judgment of the tester. The lack of objectivity of the test method and the inconsistency of the test results have led the industry to develop new methods and devices.

All natural fibers have crimp characters. These crimp structures give strength to fiber. Synthetic fiber aims to emulate to natural fiber. Synthetic fiber generated filament forms and a straight fiber. When generating filament form of yarns, the crimp structure is given on the synthetic fiber marginally. This crimp structure does not reach an adequate strength. Man made filament fiber requires another treatment about crimp characters. BCF yarns are synthetic fabric, therefore crimp character are achieved with a stuffer-box.

The use of stuffer box crimpers to crimp synthetic fibers is a well known process. A conventional stuffer box crimper generally comprises of a pair of cooperating cylindrical parallel nipping rollers forming a nip, a stuffer box, and a pair of cheek plates in contact with the lateral side surfaces of the nipping rollers to preventing the lateral egress of the fibers. In general, synthetic fibers are pulled through a pair of nip rollers and forced into a stuffer box including. The synthetic fibers are folded perpendicular to their direction of travel as they encounter the back pressure caused by the force stuffing the synthetic fibers being pressed against the flapper; thereby forming the crimped synthetic fibers [2].

Figure 2.1(a) shows the yarns before crimping treatment and Figure 2.1(b) shows the yarns after crimping treatment, respectively. After stuffer-box processing crimp frequency and amplitude are raised, raised crimp frequency and amplitude give strength to yarn.

(a)



(b)

Figure 2.1 BCF yarns; a) before crimping treatment b) after crimping treatment

Stuffer-box method is a texturing yarn method. Texturing method has been applied on synthetic continuous filament yarn to bulk the yarns. Stuffer-box texturing method has been used to give the crimp character on the yarn. Carpet yarns get the sunlight and than reflect it. Crimp character helps reflect the sunlight in opalescent form. This condition appeals the customer, therefore crimp structure has been applied with the stuffer-box method.

2.2 Determination of Textile parameters using image processing

The technology of processing digital image is useful for measuring the geometric attribute of yarn. Digital image processing is basically used for two purposes: improving the visual appearance of images to a human eye and preparing images for measurement of the features and structures. With digital image processing the images are processed using the stages as follows: taking the image and storing in a memory then converting it to numerical data. Image analysis methods have been developed since 1960s and commonly used in textile manufacturing [3].

Tae Jin Kang et al. [4] have developed an automatical method to analyze the structure of woven fabric and objectively evaluate the fabric using image processing and analysis. They have captured the image with CCD camera from the fabric and used transmissive light to lighten the warp and weft position. Gaussian filter is used to remove noise in the image. Histogram equalization is used to improve image contrast. By counting the warp and weft direction, the position of the yarn is determined with image processing for defect detection.

Wen-Hong Yu et al. [5] have worked on automatically reproduce harness drafts and chain drafts of woven fabrics and weave of woven fabrics with image processing. They have captured the image from the fabric with CCD camera, and used a 3×3 neighborhood filter mask. The noise on the image is removed. To determine the weave diagram for the weave pattern. The columns and rows have been observed, to find the repeated weave pattern and compare them to see if they are identical or distinct by using image processing.

Sun-Chong Liu et al. [6] have studied on to define twist character of a yarn automatically with the image processing techniques. The high-pass filter have been used for sharpening the image. The length of fiber has been represented by the 8 neighborhood chain code to determine the twist angle and twist direction.

Cooke W.D et al. [7] have presented a study about the image analysis for determining the twist level, woolen textiles from the first-century Romans Vindolanda. The captured image of woolen textile has been magnified and then thresholding and skeleton image processing techniques has been applied to determine the S and Z direction of the twist.

J. Sobus et al. [8] have studied on the image analysis for characterization fiber crimp. Fibers images have been captured, digitized and enhanced by the noise removal. Several morphological operations, such as skeleton, dilation, boundary description and thinning have been applied. Line boundary descriptions are obtained at the end. This representation has been used for storing data and defining the directions of data. They have presented 11 parameters to define crimp characteristics of the fiber.

Moo Sung Lee et al. [9] have developed software and hardware systems to measure the crimp as automatically under zero tension. The samples' image have been taken when specimen plate was moving. Some image prosessing techniques have been used to extract the crimp shape. Quantitative information of crimp has been determined with Fourier series and statistical analysis techniques.

2.3 Determination of Crimp Structure with Fractal Geometry

Fractal geometry has been found by Mandelbrot in 1975. Fractal geometry can be used to determine the non-integer object's shape like mountains, clouds. Crimp structure resembles the non-integer object's shape, therefore crimp structure can be evaluated with Fractal geometry technique.

Jae Yeol Lee et al. [10] have used the fractal geometry to define three dimensional structure of filament crimping. They have captured images with CCD camera from the fabric. A mirror is applied for viewing the XYZ coordinates of every point on the filament. After determining the real world 3D coordinate for every point in the filament crimp, the shape of the crimp wave has been reconstructed by computer and have been applied fractal geometry to evaluate crimps' complexity. In this study, the 3D cube method has been used to cover the crimp since crimp has 3 dimensions (XYZ), the conventional crimp ratio has also been determined. As a result of this study, the complexity of crimping can be evaluated quantitatively with fractal dimension.

Tae Jin Kang et al. [11] have used the fractal geometry to evaluate the wrinkles and the seam puckers from the fabric. In this study, the fractal geometry has been used to evaluate the wrinkles. The seam puckers with a branch of fractal geometry which are cubical box-counting method and cross sectional method. As a result of this study, different fractal dimension has been found. This situation has been related to the fabric wrinkles and the puckers surface. The fabric surface can be evaluated with the fractal geometry with a high degree of correlation coefficient.

Yoichiro Muraoka et al. [12] have analyzed the fiber crimp with a branch of fractal dimension called box-counting. In this study, the number of grid boxes which is filled by the image have been counted. The length side of the grid have been taken as 4 mm 40 mm. This method has been chosen because the fiber image clearly has been detailed. The number of grid boxes has been counted easily to determine with the fractal.

Xu-hon Yang [13] has analyzed the crimped morphology of fibers to use branch of fractal geometry called box-counting method using image processing. Fiber's fractal characteristic has been determined and used to simulate the crimped morphologies with random fractal curve.

2.4 Determination of Temperature effect on the Frieze Carpet Yarn's Crimp Structure

Recently, in the carpet industry frieze carpet yarns have been used to manufacture carpet. With increasing utilization of frieze carpet yarn investigators the crimp effect to the carpet has been started to research. When obtaining the frieze carpet yarn, fixing treatment with temperature has been applied to crimp structure.

Dadgar et al. [14] has investigated the crimp stability by weight hanging method. Stability of crimp has been compared in constant frieze condition but different time and temperature conditions heat treatment. Degree of stability has been determined by the help of Fuzzy Logic system.

CHAPTER 3

IMAGE PROCESSING METHODS

3.1 Stages of Image Analysis

The analogue representation of an image on the scene cannot be directly converted by a computer. The produce a digital image, an analog to digital converter must be used. When transforming the analogue image to digital form, there are some stages such as image-acquisition, image processing and image-display stages.These stages are explained in the following sections.

3.1.1 Image Acquisition

Image Acquisition stage is the first stage of image-processing. First of all, the image is to be captured by the camera to convert it to a digital image and then to be stored in a memory. For capturing images, some energy source would be needed for illustrating it on the scene. The energy source of capturing images is generally sun however, if the sunlight is not available then another light source must be used. Figure 3.1 shows the acquisition stage of the image, the sunlight is the energy source used. The object absorbs energy which comes from the sun and reflects the energy whereby object sensed by a camera. The image is then captured by the camera.

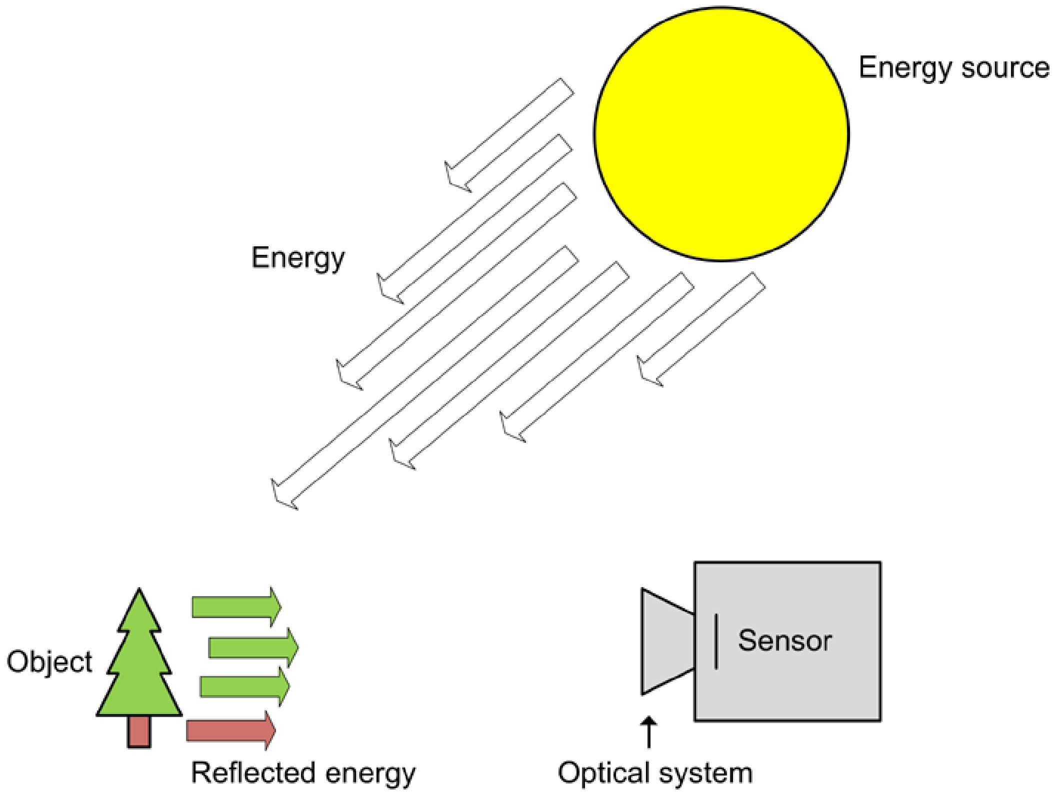


Figure 3.1 Overview of the typical image acquisition process; with the sun as light source, a tree as an object and a digital camera is used to capture the image [15].

The object reflects energy which comes from the energy source, therefore the image can be realized and can be captured by camera. Reflected light passes through the camera and then the coming signal is transferred to image processing stage.

3.1.2 Image Processing

The signal received from the camera is digitized and it is stored on the frame-grabber in the memory as a square two-dimensional array. Frame-grabber is an electronic device that captures individual frames from an analog video signal or a digital video stream. It usually takes place as a component of a computer vision system. Video frames are captured in digital form and then displayed, stored or transmitted in raw or compressed to digital form [16].

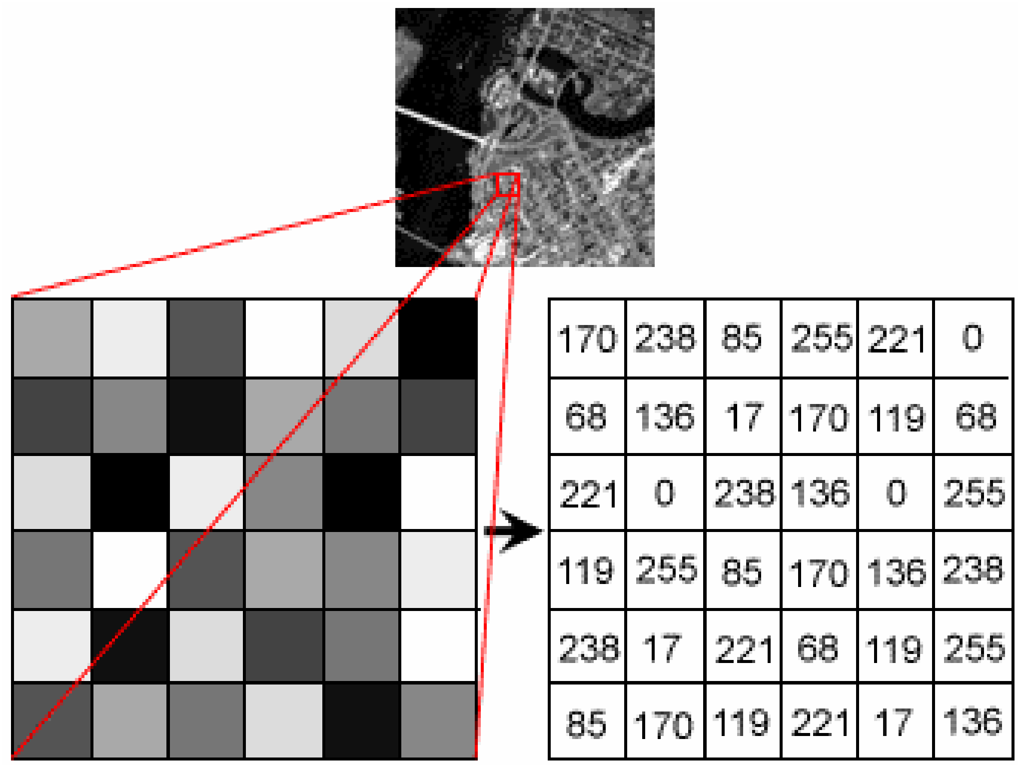


Figure 3.2 Digitized image forms [17].

The digital form of the image stored is a two dimensional array of numbers where these numbers represent the intensity of the light in a small area in which name is denoted pixels. Figure 3.2 shows how the digital image is denoted with pixel.

3.1.3 Image Display

Having performed digitizing and storing steps, digital image is represented on the scene which can be seen by human eye. Figure 3.3 shows the output digital image which taken from the yarn with a CCD camera.

Figure 3.3 Output image

3.2 Image Enhancement

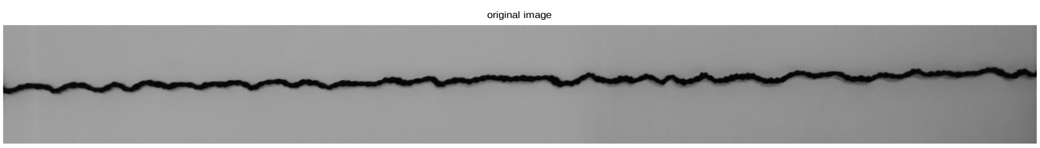
Image enhancement refers to accentuation, or sharpening, of image features such as edges, boundaries, or contrast to make a graphic display more useful for display and analysis. The enhancement process does not increase the inherent information content in the data. But it does increase the dynamic range of the chosen features so that they can be detected easily [18].

3.2.1 Spatial Domain Enhancement

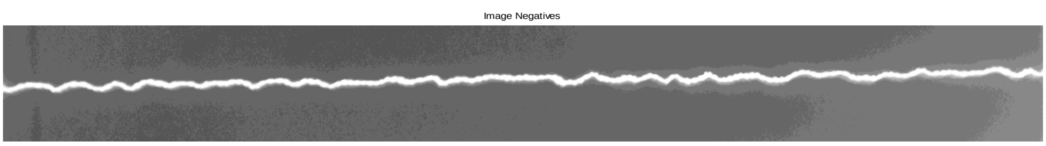
Spatial domain techniques directly deal with the image pixels. The pixel values are manipulated to achieve the desired enhancement. Spatial techniques are particularly useful for directly altering the gray level values of individual pixels and hence the overall contrast of the entire image. The pixel values of the processed image depend on pixel values of the original image. It can be given by the expression $g(x, y) = T[f(x, y)]$, where T is a gray level transformation in point processing. Some important spatial domain enhancement methods are thresholding transforming, image negative transformation, non-linear spatial filter (median filter).

3.2.1.1 Image Negative Transformation

The most basic and simple operation in digital image processing is to compute the negative of an image. The pixel gray values are inverted to compute the negative of an image. The negative image is useful for enhancing white or gray detail embedded in dark regions of an image [19]. Figure 3.4(a) shows the original image captured from the sample, Figure 3.4(b) shows the images that crimp detail in dark areas via convert to negative images, respectively.



(a) Original image

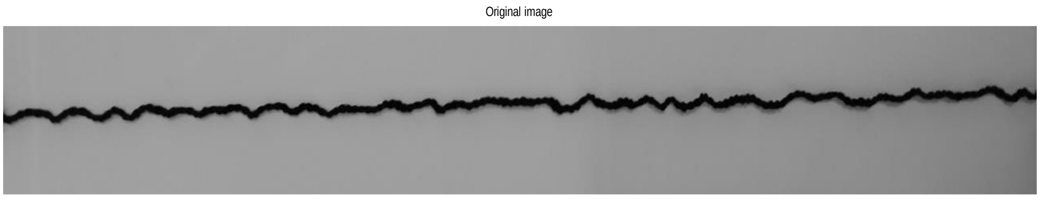


(b) Negative image

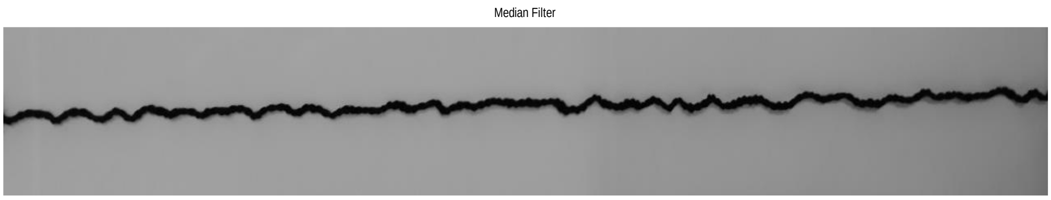
Figure 3.4 Representation of the crimped yarn

3.2.1.2 Nonlinear Spatial Filter

Median filtering is a nonlinear spatial filter often used in image processing to reduce "salt and pepper" noise. A median filter is more effective than convolution when the goal is to simultaneously reduce noise and preserve edges [20]. After capturing the image, median filter was applied for reduction of noise. Figure 3.5(a) shows the original image captured from the sample. Median filter is then applied. The resulted image is given Figure 3.5(b), respectively.



(a) Original image

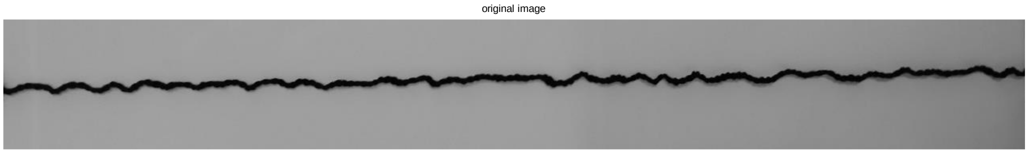


(b) Median filter image

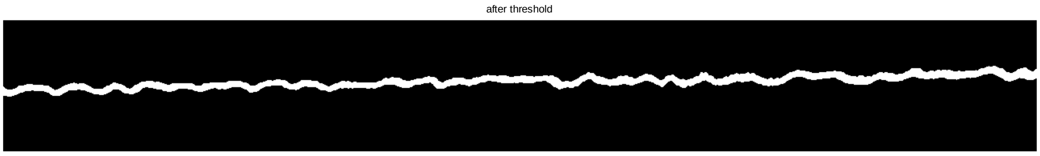
Figure 3.5 Nonlinear spatial filter images

3.2.2 Image Thresholding Transformation

Thresholding is a well-known technique for image segmentation. Thresholding method's working principle is to convert the grayscale image to a binary image (black and white). Threshold value is in 0-1 range. Image processing selects this range automatically. Figure 3.6(a) shows the original image captured from the sample, then thresholding method is applied. Figure 3.6(b) shows the result image of the thresholding method.



(a) Original image



(b) Thresholding

Figure 3.6 Thresholding

3.3 Image segmentation

Edge detection is the basic process of image segmentation.

3.3.1 Sobel Edge Detector

Edge detection functions determine brightness and discontinuous of the ever-changing sharply image. When an edge detection function is applied, function follows the brightness of the image and draws a line along the object edge. So that the image's edge is determined.

Sobel edge detection gives better performance than others. Sobel edge detection consists of a pair of 3×3 convolution masks. One mask is rotated by 90° and the other mask obtained.

-1	0	+1
-2	0	+2
-1	0	+1

Gx

+1	+2	+1
0	0	0
-1	-2	-1

Gy

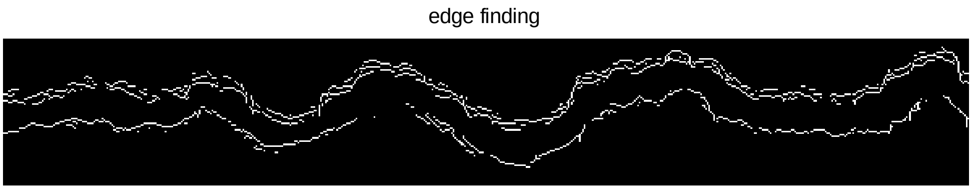
Figure 3.7 Sobel convolution masks [21].

$$|G| = \sqrt{G_x^2 + G_y^2} \tag{3.1}$$

$$\theta=\arctan(\frac{G_y}{G_x}) \tag{3.2}$$

Figure 3.7 shows two Sobel convolution masks in horizontal and vertical forms. Eq 3.1 is used to determine the absolute magnitude of the gradient at each point and the orientation of that gradient while Eq 3.2 determines the relative to the pixel grid. The partial derivatives of the formulas above need to be calculated for each pixel location. Figure 3.8(a) shows the original image captured from the sample and Figure 3.8(a) shows applied Sobel edge detection method image result.

(a) Original image



(b) Sobel edge detector

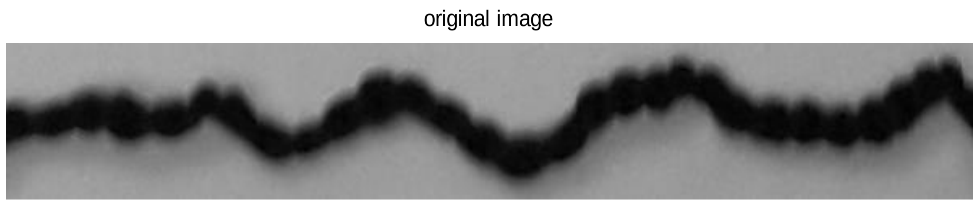
Figure 3.8 Sobel edge detector

3.4 Morphological Operations

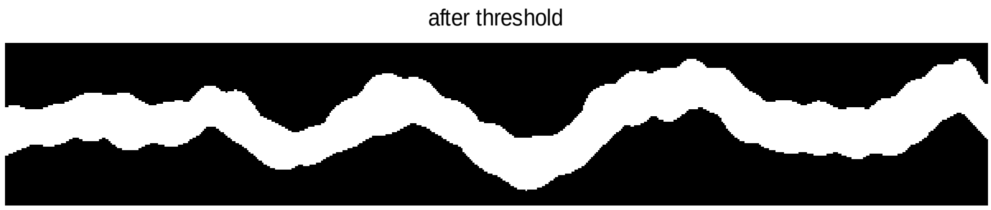
Morphological operations are useful representation and description of the image's shape. Morphological operations are not changing the image size, input image and output image. Morphological operations are applied to binary images. Some basic morphological operations are; erosion, skeletonization and spur.

3.4.1 Erosion

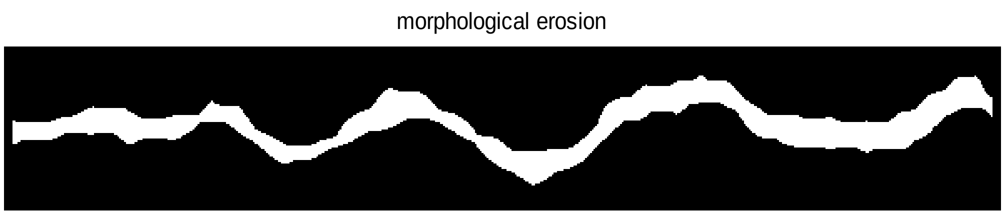
Erosion is another common morphological operator like dilation. Erosion operator is applied to binary images. The Erosion operator’s working principle is unlike the Dilation operator. Erosion is a thinned object with structuring element in the binary image. Erosion operator’s is used to gradually reduce the boundaries on the foreground pixels. When erosion operation is applied, the pixels shrink therefore hole areas are increased. Thus an output image is seemed to be thinner than input image. Figure 3.9 shows clearly how the erosion effects the frieze yarn. The first image is an original gray level image, the second image shows the raw image is converted the binary image, the third image shows the result of the erosion method applied on binary image.



(a) Original image



(b) Thresholding

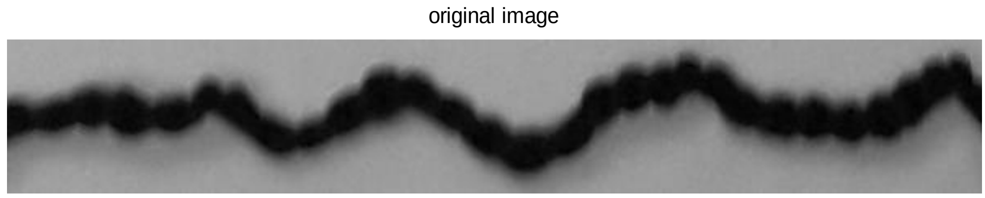


(c) Eroding

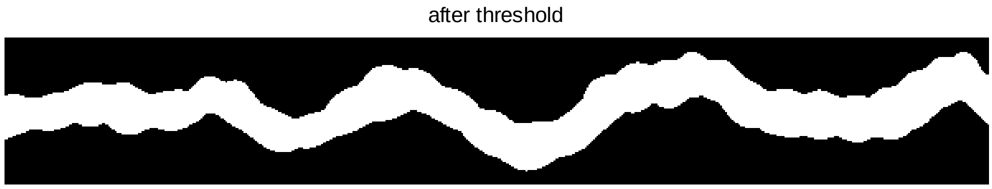
Figure 3.9 Erode method

3.4.2 Skeletonization

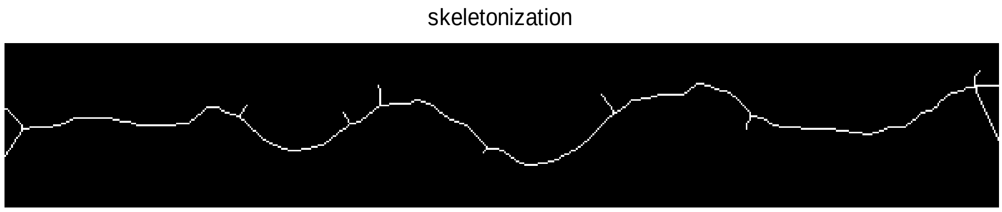
Skeletonization operation must be used with binary image. Skeletonization working principle is that of preserving the shape of the original object. But all needless pixels are removed from the image. The result of skeletonization does not permit break down of the object's shape. Figure 3.10 shows clearly skeletonization operation. The gray level image is converted to binary image. Skeletonization operation is then applied to binary image. Third image only consists of the original shape of the object like a line.



(a) Original image



(b) Thresholding

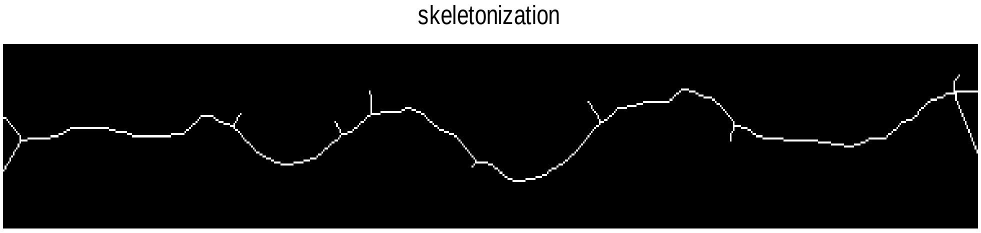


(c)Skeletonization

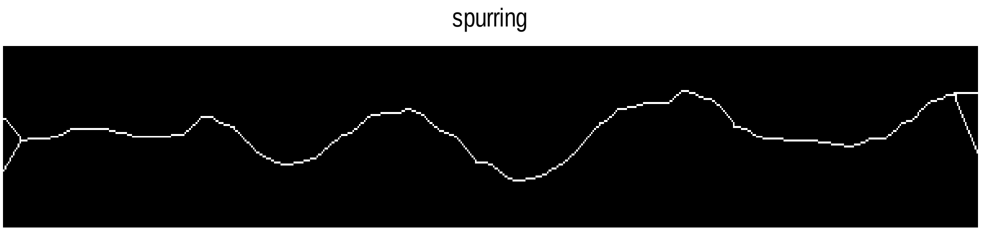
Figure 3.10 Skeletonization; a) original image, b) Thresholding, c) skeletonization

3.4.3 Spur

Spur function works with bwmorph function. After skeletonization, skeleton images have branches like a tree. Spur function removes the spur pixels on the image. Figure 3.11 shows the spur function effect clearly. The first image shows after skeletonization operation, as shown the image has branches. The second image shows after spur pixels are removed, as shown the branches disappears.



(a) Skeletonization



(b) Spurring

Figure 3.11 Spur function; a) After skeletonization image, b) Spurring.

CHAPTER 4

CRIMP COUNTING BY A COMPUTER VISION SYSTEM

4.1 Introduction

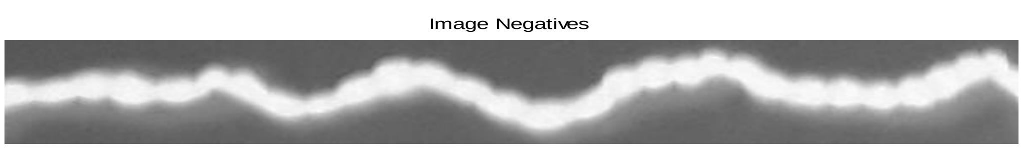
Crimp count is important for the opalescent effect. The carpet manufacturer want to know the number of crimps on a frieze yarn. In practice, crimp count treatment has been done subjectively with the human eye. These results are not reliable. To reliably achieve the crimp count on the yarn, a computer vision system has been constructed. Figure 4.1 shows the vision system which is prepared to define the crimp count. It consists of a computer, a digital camera, an adjustable camera holder and a plate.

Figure 4.1 A simple computer vision system to count the crimp on the yarn

4.2 Count the crimp structure

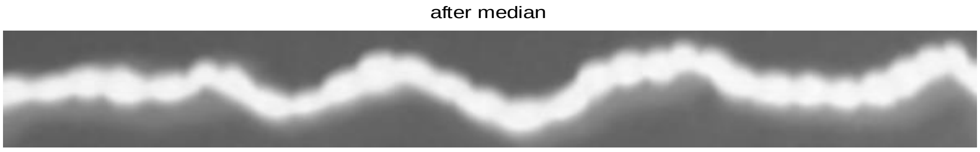
Crimp count can be defined by the help of image processing technique. The first step has been working with image processing to capture the image with a camera from samples of frieze carpet yarns. Images which are taken from the samples, have had some noise. Therefore, median filter has been applied to reduce the noise. After applying the median filter, the images are converted to the negative image. The reason for converting images to negative images is that, the crimp characters have 2 dimensions and with irregular distribution. Negative image has been ensured to improve the appearance of the dark area on the image. So crimp characters' and their structures can easily be evaluated on the negative image. Before applying morphological operation, Sobel edge detection has been applied to determine the edge of the crimp character. So the crimp character is recognized easily. Morphological operation is applied to binary image to apply the morphological operation. Digital image has been converted to binary image with thresholding. Erode method, which is part of morphological operations in image process, has been applied before skeletonization. The object which is in the image has been made thinner by the eroding, therefore this process is beneficial before applying the skeletonization. Skeletonization has been applied to determine the crimp's morphology. After skeletonization crimp's morphology can be viewed but the image has been had some branch. Therefore spur method has been applied after skeletonization to wipe out the branches. Figure 4.2 (a, b, c, d, e, f, g, h) show all of the processes which are applied the image, respectively.

(a) Original image



(b) Negative image

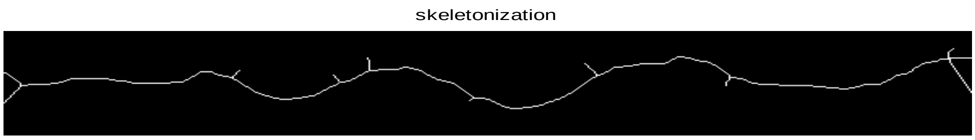
(c) Sobel edge detector



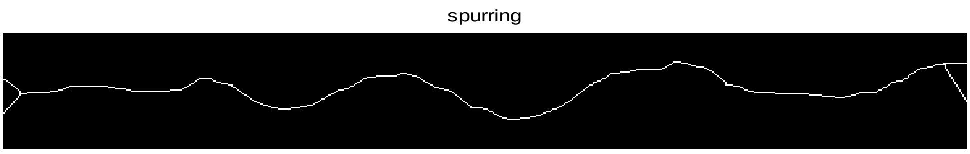
(d) Median filtering

(e) Thresholding

(f) Eroding



(g) Skeletonization



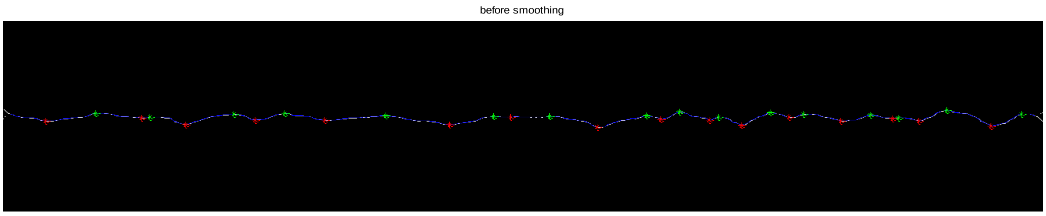
(h) Spurring

Figure 4.2 Image processing operations;

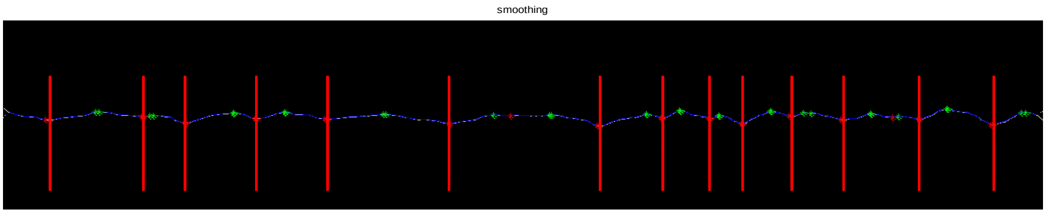
a) Original image, b) negative image, c) Sobel edge detector, d) median filtering, e) thresholding, f) eroding, g) skeletonization, h) spurring, respectively.

When these treatments are completed, the smoothing function has been applied, because some structure to resemble crimp on the image. Smoothing function has been applied to eliminate these crimps like a noisy source, after this process count the crimp result is more reliable than before applying the smooth function.

To determine the crimp's maximum and minimum point peakdet function has been applied to the smoothed image. Figure 4.3 shows the crimps' maximum and minimum point before smoothing and after smoothing treatment. Green stars represent the maximum points, red stars represent the minimum points.



(a) Before smoothing function image

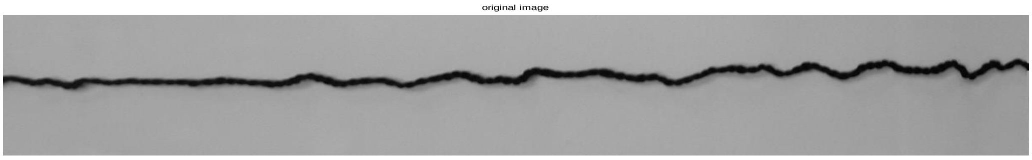


(b) After smoothing function image

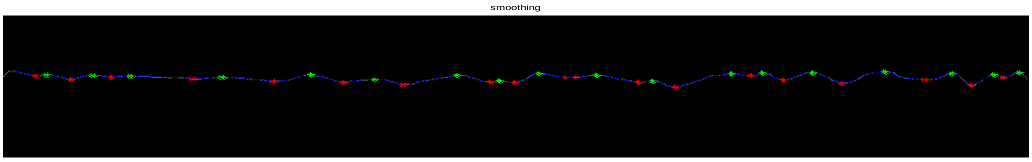
Figure 4.3 a) Before smoothing treatment result of maximum and minimum points (16 local maximum), b) after smoothing treatment result of maximum and minimum points (4 local minimum)

The crimp structure has been accepted as a crimp if maximum points and minimum points are seperated by at least 3 pixels. If this distance is less than 3, then the resulting crimp counts is not reliable. Figure 4.4 shows the 10 samples, the original image, maximum and minimum points and last samples' crimp count. The mark **a** is denoted in the first sample image, while **b** is denoted in the second sample image. It has been given sequentially with an alphabet character, the last **j** has been denoted with the last samples' image.

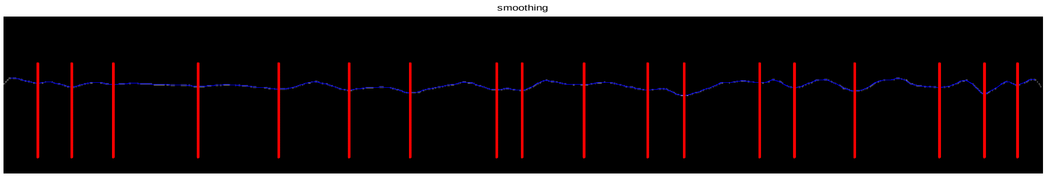
(Sample No 1) (a)



(a) Original image

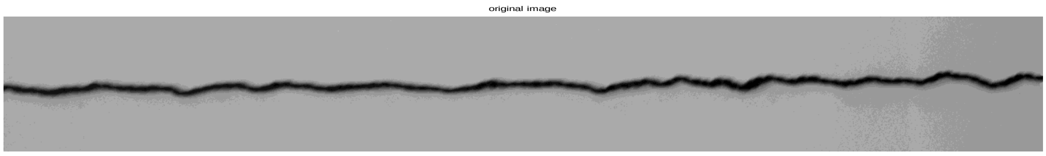


(b) Before smoothing function image

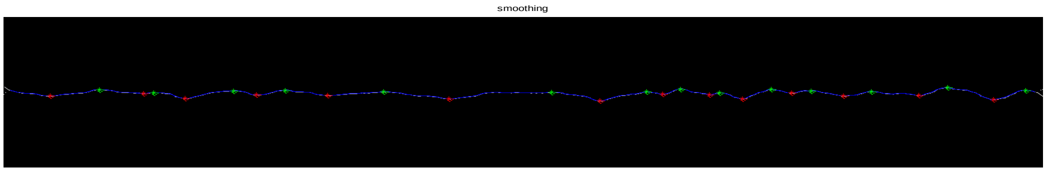


(c) After smoothing function image

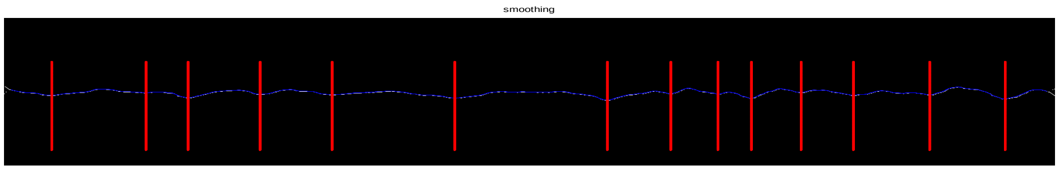
(Sample No 2) (b)



(a) Original image

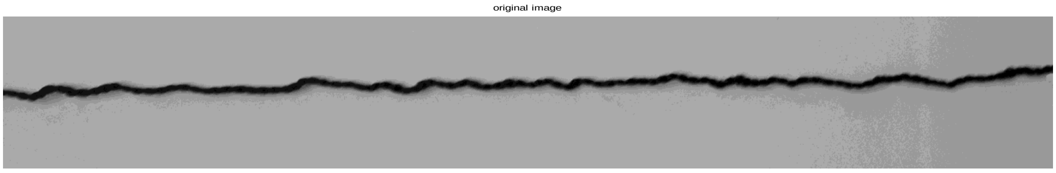


(b) Before smoothing function image

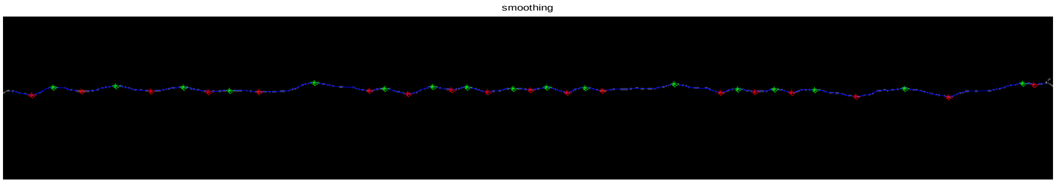


(c) After smoothing function image

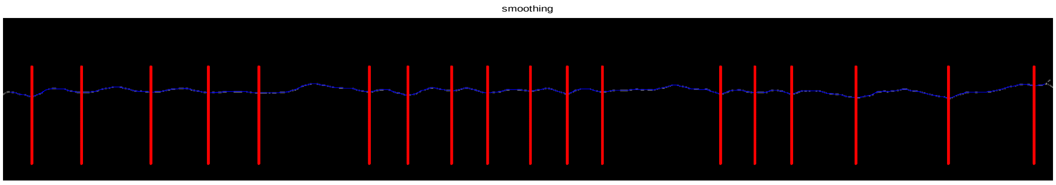
(Sample No 3) (c)



(a) Original image

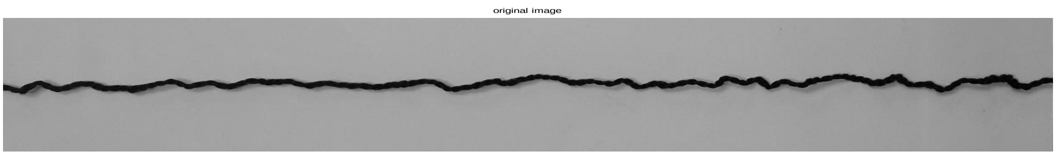


(b) Before smoothing function image

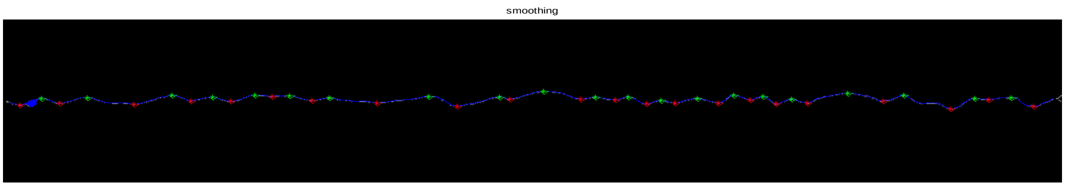


(c) After smoothing function image

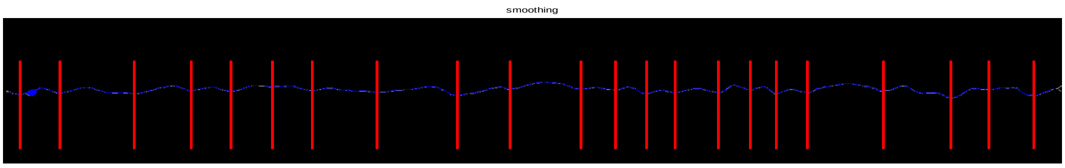
(Sample No 4) (d)



(a) Original image

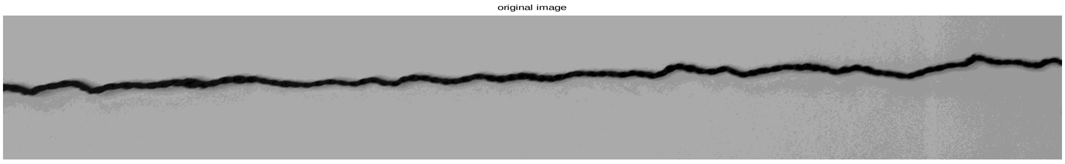


(b) Before smoothing function image

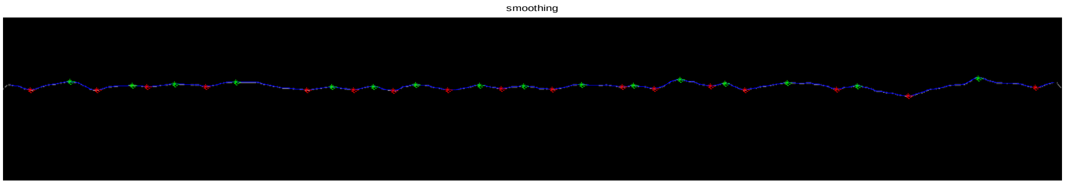


(c) After smoothing function image

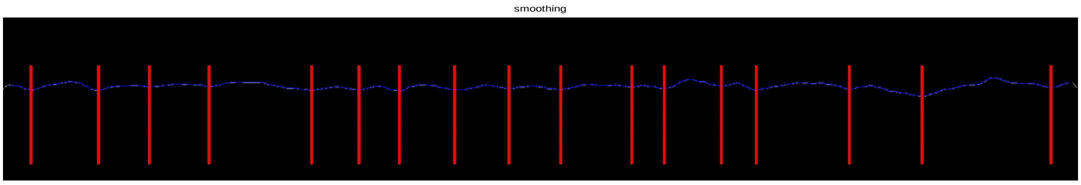
(Sample No 5) (e)



(a) Original image

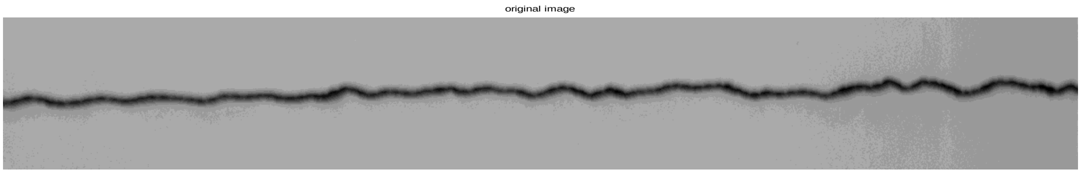


(b) Before smoothing function image

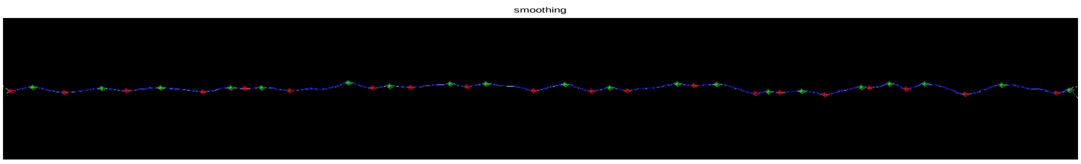


(c) After smoothing function image

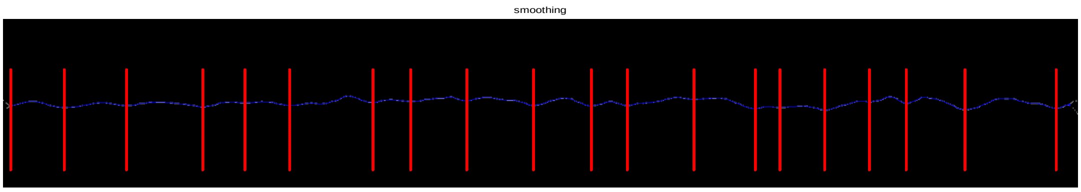
(Sample No 6) (f)



(a) Original image

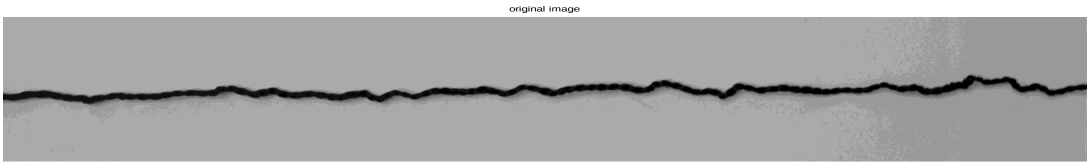


(b) Before smoothing function image

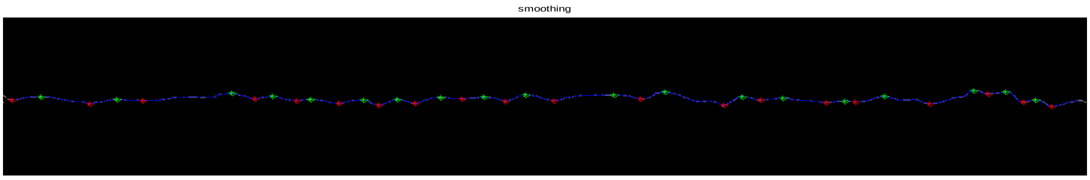


(c) After smoothing function image

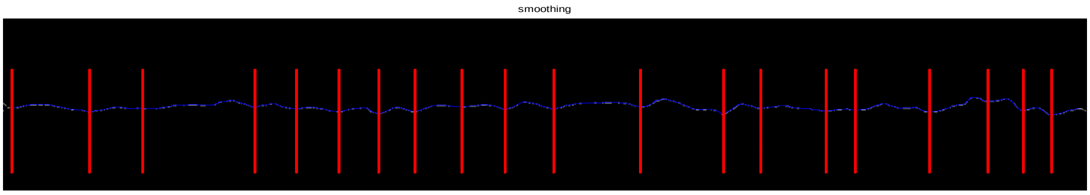
(Sample No 7) (g)



(a) Original image

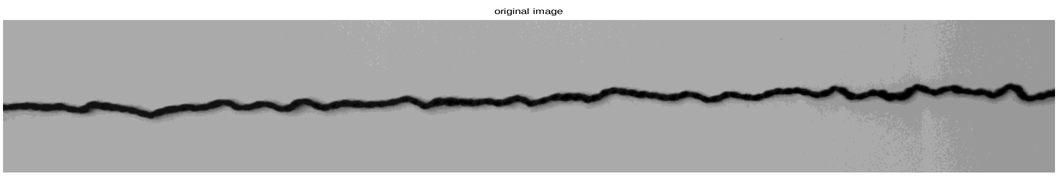


(b) Before smoothing function image

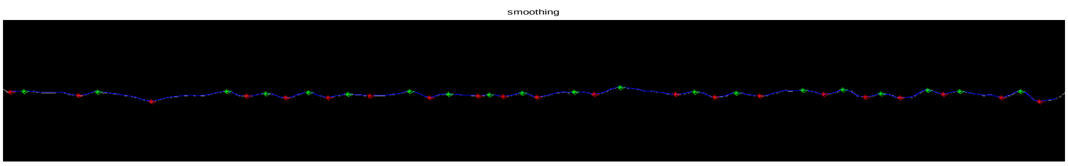


(c) After smoothing function image

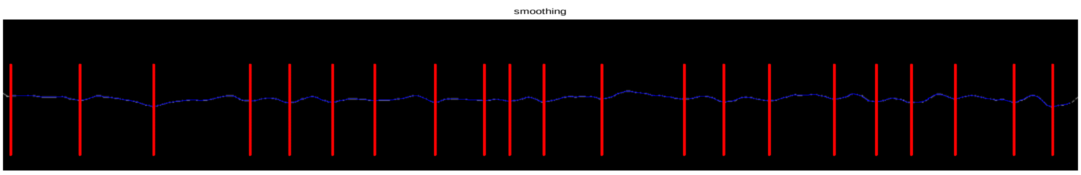
(Sample No 8) (h)



(a) Original image

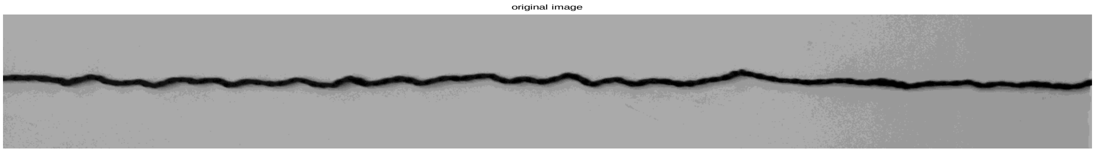


(b) Before smoothing function image

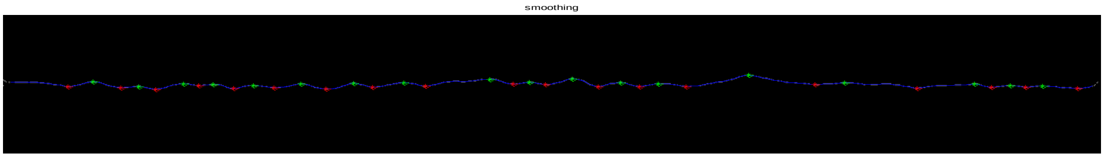


(c) After smoothing function image

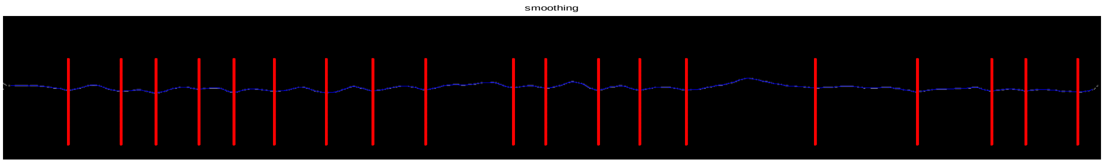
(Sample No 9) (i)



(a) Original image

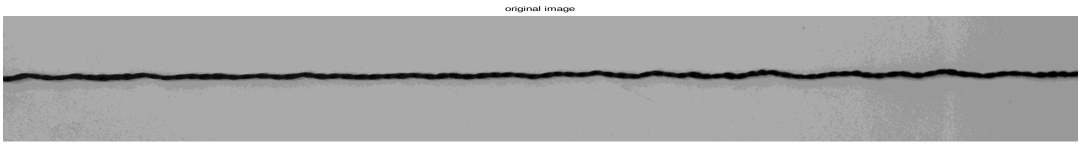


(b) Before smoothing function image

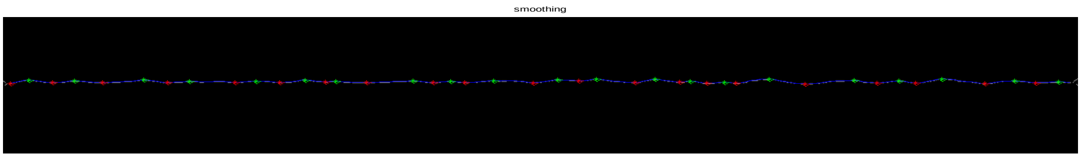


(c) After smoothing function image

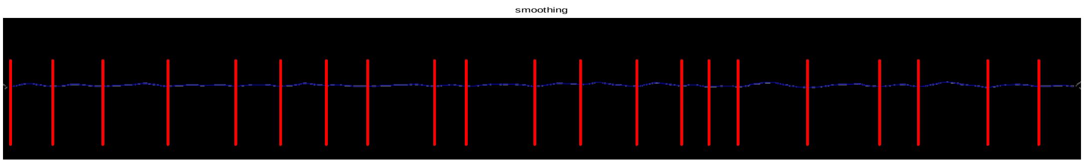
(Sample No 10) (j)



(a) Original image



(b) Before smoothing function image



(c) After smoothing function image

Figure 4.4 All samples original images, defined maximum and minimum points on the crimp structure, samples' crimp counts, respectively.

All of the samples crimp count has been determined by image processing. The results are given in Table 4.1. As it is seen, the proposed program is a very helpful to determine the crimp count on the frieze carpet yarns.

Table 4.1 Crimp counts obtained by vision system

Specimen	Figure	Crimp Count
No 1	Figure 4.4 a	18
No 2	Figure 4.4 b	14
No 3	Figure 4.4 c	18
No 4	Figure 4.4 d	22
No 5	Figure 4.4 e	17
No 6	Figure 4.4 f	20
No 7	Figure 4.4 g	20
No 8	Figure 4.4 h	21
No 9	Figure 4.4 i	19
No 10	Figure 4.4 j	21

CHAPTER 5

FRACTAL GEOMETRY

5.1 Introduction

In mathematics, fractal term is generally used to denote the collective name of complicated geometrical shape which resembles each other. Fractal geometry has been found by Mandelbrot in 1975. The fractal geometry term has been used to denote the irregular shape of the object. Fractal shape has not been described with Euclidian geometry like square, rectangular or circular. Fractal geometry conversely of Euclidian geometry has a fractal number. Fractal dimension can be determined with fractal curve. Some natural fractals and some mathematical fractals resemble each other and spread randomly, therefore these kinds of fractals can be scaled statistically. Fractal dimension has been used in particularly cases where the geometry consists of a superficially random structures of the physical systems observed as gradually widespreading.

The fractal dimension has been used in image classification to measure surface roughness where different natural scenes such as mountains, clouds, trees, and deserts generate different fractal dimensions [22]. The branch of fractal geometry box counting method and equispaced dimension are used widespread.

5.2 Branches of Fractal Dimension

The fractal geometries branches box counting dimension and equispaced dimension methods are used widespread. These methods working principle are explained below.

5.2.1 Box-Counting Method

The box counting is a method to store the data for analyzing the object which is a complex and non integer. The box counting method working principle has been depended on dividing the image smaller piece with determined size of the box, the results of dividing with boxes has been related to the scale factor. First step in this method is to analyze each small piece which is divided. In the second step, changed details are given with a scale factor.

The scale factor has been related with ratio of how many boxes are needed to encase the object and box's one side size in double logarithmic plot form. In the procedure of box counting for fractal dimension estimation, the image must be surrounded by a four-square frame with the least possible area and the condition of linear relationship must be satisfied in a log-log plot. Boxes count has been inverse proportion with boxes one side size, if the side size has a large scale box count is less or reverses that condition. Log N (r) is dividing always - log (r), because it is used the log-log plot's slope.

$$D = \lim_{r \to 0} \frac{\log N(r)}{-\log(r)} \tag{5.1}$$

Equation 5.1 result gives to us the fractal dimension. "r" is denoted as the box side size, "N" is denoted as the counted boxes, and "D" is denoted as the fractal dimension.

5.2.2 Equispaced Dimension Method

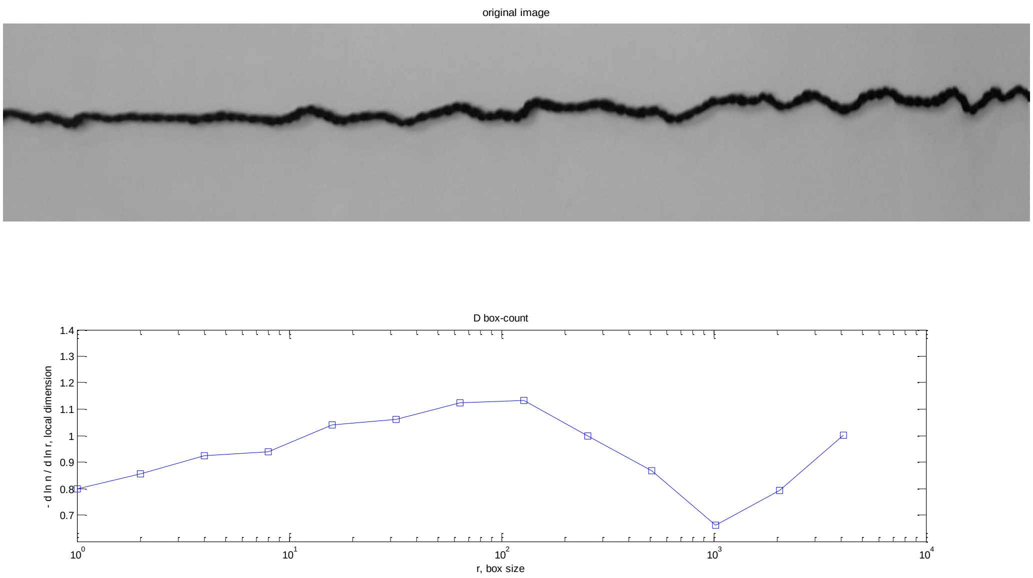
Equispaced dimension is an alternative method for determining the fractal dimension. In Equispaced dimension technique, the boundary to be characterized is first digitized. The polygon which is the estimation of the boundary perimeter at a given inspection resolution (the number of steps times the space in between the dots). It is created by stepping along the digitized point for a specified number of steps and then drawing a line between the first and the last step. When these perimeter estimates are plotted against the step size [23].

5.3 Yarn Crimp Analysis with Box Counting Method

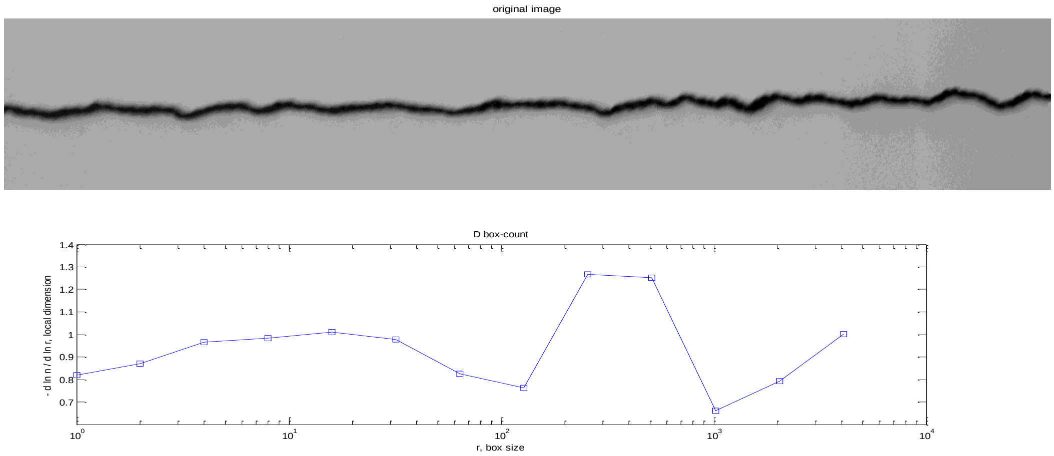
Fractal geometry is used to evaluate the irregularities of crimped filament yarns. The box counting dimension is widely used as a practical method of arbitrary geometry, because it is easy to set the mesh size and count the number of occupied boxes in the repeated experiments [24].

Box counting and equispaced dimension methods have been used to classify the crimp structure. Here 10 specimens have been prepared from polypropylene Bulk Continuous Filament (BCF) carpet yarn the same color and different shape of crimp structure. Similarly 9 sample crimps' structure resembles to each other, but one of 10 samples has been especially taken the special to observe the differences.

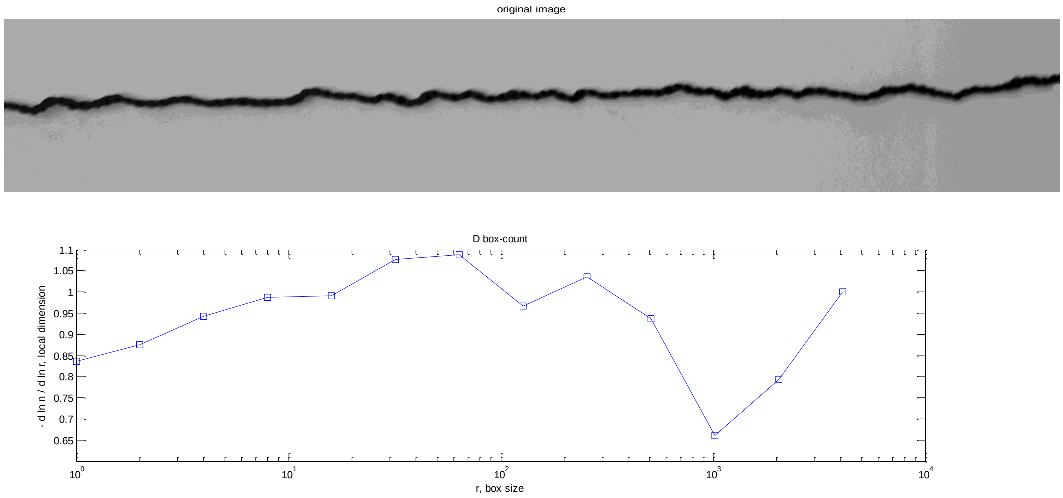
Before applying box counting method, some treatments have been applied to samples. The digital image has been captured with a camera from the samples. Some morphological operations have been applied. All operations are given and all operations results images have been represented in Chapter 4, Figure 4.2. Having performed the morphological operations, the box counting method is applied to the samples. Figure 5.1(a, b, c, d, e, f, g, h, i, j) shows the all samples' original image and graph of box counting method results.



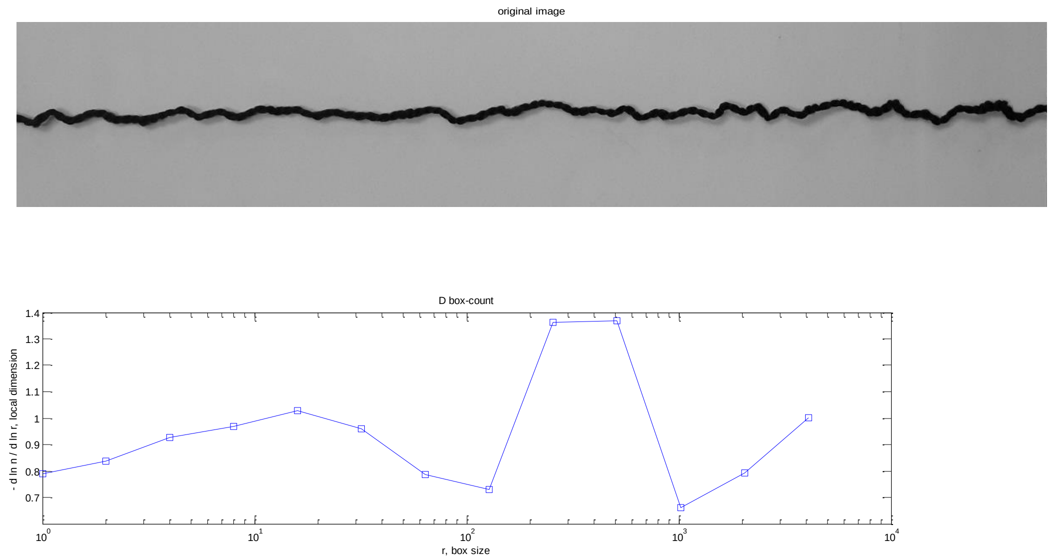
(a) Sample No 1; original image and its box counting graph



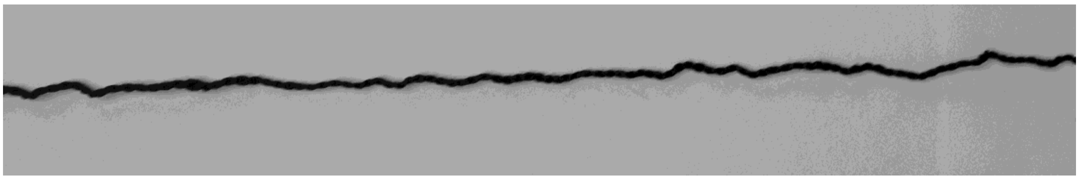
(b) Sample No 2; original image and its box counting graph

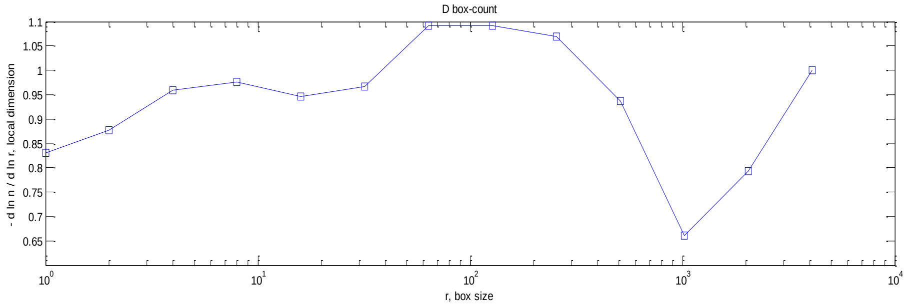


(c) Sample No 3; original image and its box counting graph



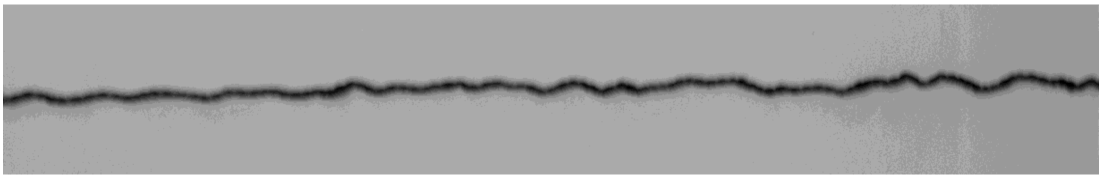
(d) Sample No 4; original image and its box counting graph original image

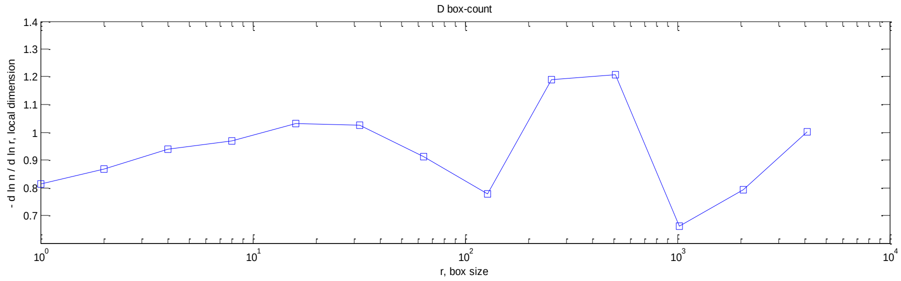




(e) Sample No 5; original image and its box counting graph

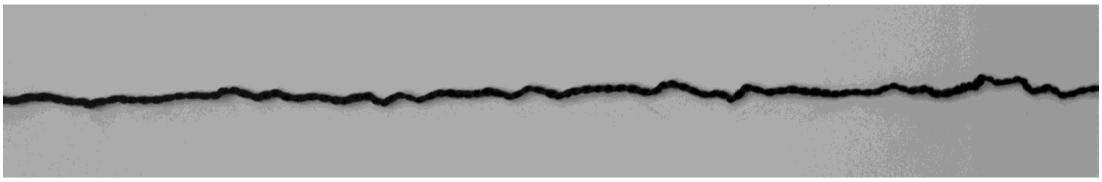
original image

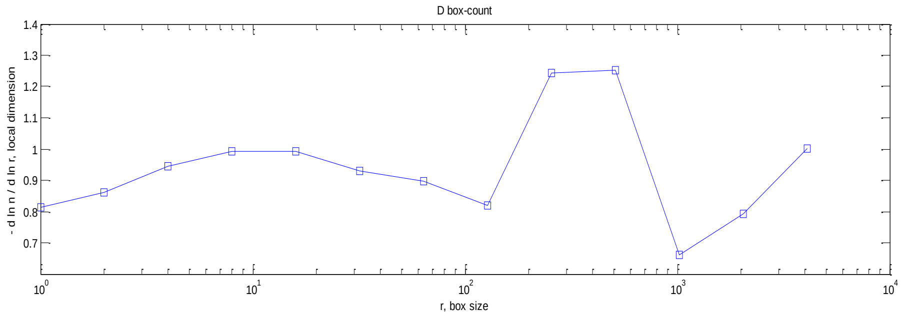




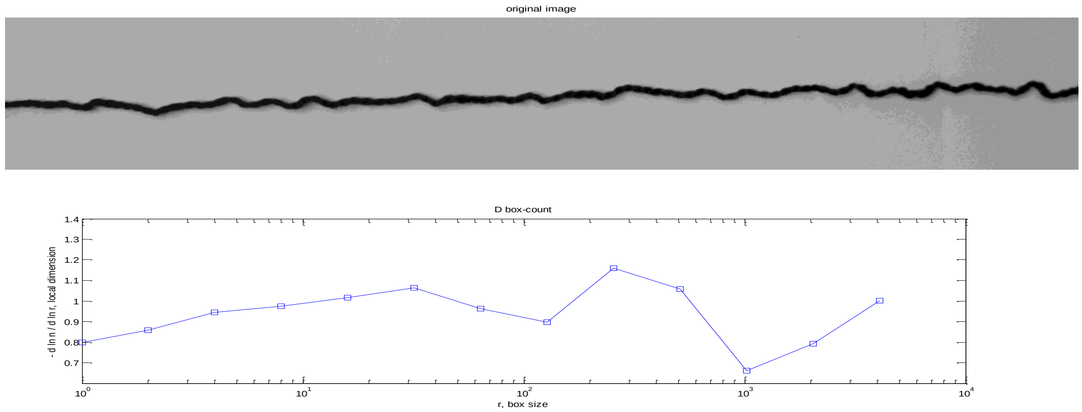
(f) Sample No 6; original image and its box counting graph

original image

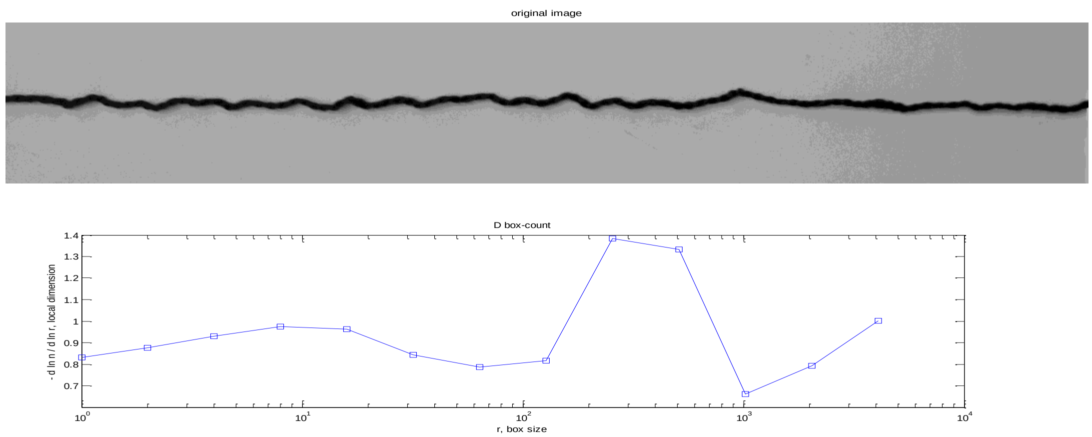




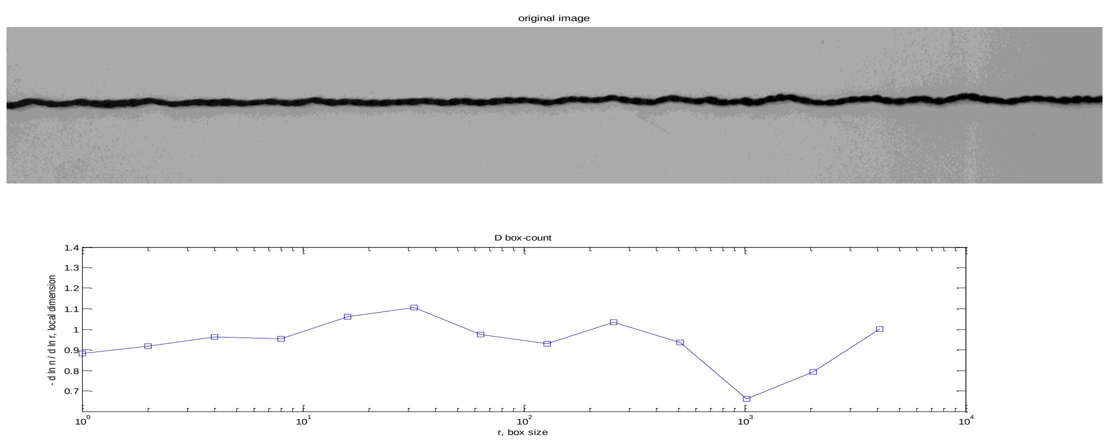
(g) Sample No 7; original image and its box counting graph



(h) Sample No 8; original image and its box counting graph



(i) Sample No 8; original image and its box counting graph



(j) Sample No 2; original image and its box counting graph

Figure 5.1 All specimens' with original images and graphs' taken by image box counting method

All samples' box counting dimensions have been determined via image processing. In Figure 5.1, a is denoted as the first sample image, b is denoted as the second sample image and it has been going sequentially with alphabet character, the last j has been denoted with the last samples' image. In the results graph of box counting, x axis refers the box size (R), y axis refers the box count dimension results (D). Box counting dimension results (D) relate with box size (R) and box count (N). Box counting results which are taken results of the graph have been given to detail in Table 5.1 and Table 5.2. Table 5.1 shows alteration of box count (N) with box size (R), Table 5.2 shows alteration of box size (R) with the box counting result (D).

Table 5.1 Alteration of box count (N) with box size (R)

R	1	2	4	8	16	32	64	128	256	512	1024	2048	4096
N1	2517	1446	768	402	209	95	48	20	10	5	3	2	1
N2	2481	1405	742	369	190	91	49	29	17	5	3	2	1
N3	2474	1386	735	375	187	95	42	21	11	5	3	2	1
N4	2542	1472	797	407	208	98	55	33	20	5	3	2	1
N5	2490	1401	739	371	191	100	50	22	11	5	3	2	1
N6	2483	1414	746	385	195	92	47	26	16	5	3	2	1
N7	2501	1424	759	384	192	97	53	28	17	5	3	2	1
N8	2505	1439	761	389	197	95	45	25	13	5	3	2	1
N9	2470	1388	734	383	190	101	59	34	19	5	3	2	1
N10	2474	1341	694	353	185	81	40	21	11	5	3	2	1

Table 5.2 Alteration of box counting dimension (D) with box size (R)

R	1	2	4	8	16	32	64	128	256	512	1024	2048	4096
D_1	0,80	0,86	0,92	0,94	1,04	1,06	1,12	1,13	1,00	0,87	0,66	0,79	1,0
D_2	0,82	0,87	0,96	0,98	1,00	0,98	0,82	0,76	1,27	1,25	0,66	0,79	1,0
D_3	0,84	0,88	0,94	0,99	0,99	1,08	1,09	0,97	1,04	0,94	0,66	0,79	1,0
D_4	0,79	0,84	0,93	0,97	1,03	0,96	0,79	0,73	1,36	1,37	0,66	0,79	1,0
D_5	0,83	0,88	0,96	0,98	0,95	0,97	1,10	1,10	1,07	0,94	0,66	0,79	1,0
D_6	0,81	0,87	0,94	0,97	1,03	1,03	0,91	0,78	1,19	1,21	0,66	0,79	1,0
D_7	0,81	0,86	0,95	0,99	0,99	0,93	0,90	0,82	1,24	1,25	0,66	0,79	1,0
D_8	0,80	0,86	0,94	0,97	1,02	1,07	0,96	0,90	1,16	1,06	0,66	0,79	1,0
D_9	0,83	0,88	0,93	0,98	0,96	0,84	0,79	0,82	1,38	1,33	0,66	0,79	1,0
D_10	0,88	0,92	0,96	0,95	1,06	1,10	0,97	0,93	1,04	0,94	0,66	0,79	1,0

In Table 5.1 and Table 5.2, "R" denotes the box size as pixel. As seen Table 1, all sample box counts has been stayed constant when the box size reached 512. This situation is normal, because all samples' lengths have been taken the same. To relate with this situation when the box size increased, the box counts have been decreased. Results of box count with the same dividend box size are nearly the same for all samples. The number of 1 in Table 5.1, has been denoted the image pixel size, in other word yarns' lengths in terms of pixel. In these samples 2450 pixels equal to 40 cm. With this scale first yarns' (N1) length 2517 pixels, in real this pixel correspond to 41.09 cm or 410.9 mm.

Table 5.2 has been denoted the box count dimension. The reason why the box count dimension method has been applied to classify the crimp characters. But all samples' box count dimension results nearly the same. N10 and D_10 have been denoted as the last sample which has had different shape of crimp character. When applying the box count method, it is expected to define different shapes of crimp character, but results of method have been demonstrated this method is not find the different shape of crimp character. So, this method was not beneficial to classify the crimp character.

5.4 Yarn Crimp Analysis with Equispaced Dimension Method

Equispaced dimension has been used to classify the crimp character as the box counting method. Ten specimens have been taken from BCF yarn the same color and the last sample's shape of crimp character has been taken different to observe the differences of crimp character. Before equispaced dimension technique, morphological operations have been applied as a box counting method. The digital image has been captured by the camera. Original image's noise has been removed with median filter. After filtering operation image has been converted to negative images. Before erode morphological operation threshold treatment has been applied to the image. After threshold and erode morphological operation, the image skeleton method is applied to the image instantly skeleton method. Spur method is then applied to the image. After spur method equispaced dimension method has been applied. The equispaced dimension method is divided the sample in equal lengths of points, then estimation length is given of two points and dividend as the step count. Figure 5.2 shows the one sample's which is chosen randomly the original image, dividend with 2 pixels equal point results image, dividend with 4 pixels equal point results image and dividend with 10 pixels equal point results image, respectively.

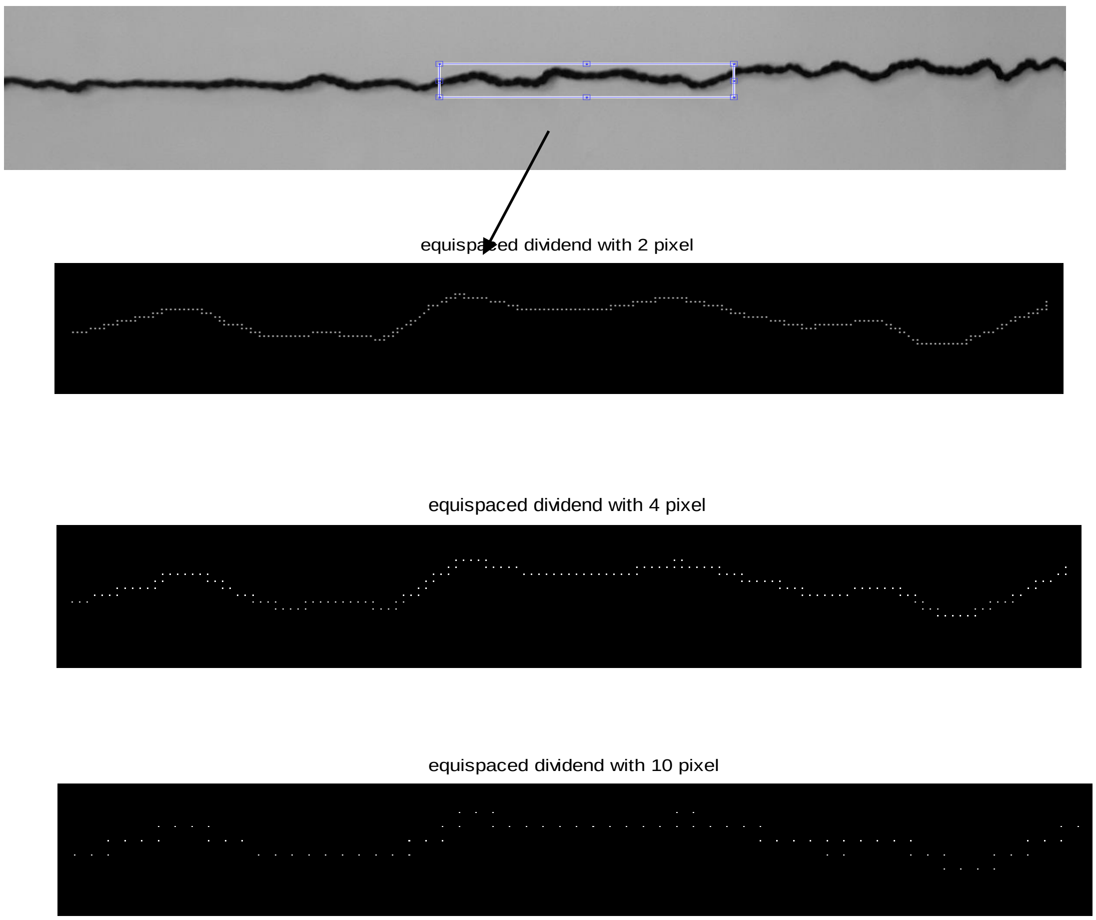


Figure 5.2 One sample's original image, dividend with 2 pixels equal point results' image, dividend with 4 pixels equal point results' image, dividend with 10 pixels equal point results' image, respectively.

All samples have been divided by equal point with the aid of image process. As seen Figure 5.2, when dividend pixel has been increased count of step number decreased, these two parameters' have been changed with inverse proportion. As a result of equispaced method, the samples' estimated lengths has been found. The samples' lengths have been altered with step number and dividend pixel size. The samples' dividend step numbers have been decreased; measured samples' lengths have been decreased to depend on step number. Equispaced method results have been given to detail in Table 5.3 and Table 5.4. Table 5.3 shows the estimated length of samples' to alter with dividend pixel size, Table 5.4 shows the step counts to alter with dividend pixel size.

Table 5.3 Alteration step count (S) with dividend pixel size (r)

R	**2**	**4**	**8**	**16**	**32**	**64**	**128**	**256**	**512**	**1024**	**2048**
S1	978	603	340	182	93	47	26	10	6	3	2
S2	939	570	326	176	87	42	20	10	10	3	2
S3	941	579	329	171	93	49	21	10	7	3	2
S4	1015	635	358	186	97	45	20	10	12	3	2
S5	935	586	324	165	90	47	26	10	7	3	2
S6	956	585	333	177	96	48	20	10	10	3	2
S7	972	599	336	177	96	41	20	10	11	3	2
S8	996	602	338	179	98	47	20	10	9	3	2
S9	949	580	334	175	96	41	20	10	11	3	2
S10	892	548	304	161	77	42	20	10	6	3	2

Table 5.4 Alteration samples' length (L) with dividend pixel size (r)

R	**2**	**4**	**8**	**16**	**32**	**64**	**128**	**256**	**512**	**1024**	**2048**
L1	3007455	1503115	749120	372725	183338	88694	42616	19669	7408	2046	1023
L2	2953119	1474744	735558	365966	181186	88820	42684	19706	7421	2048	1024
L3	2961119	1477521	735741	364857	180666	88572	42676	19704	7423	2047	1023
L4	3013639	1504938	750593	373753	183822	90927	44692	19552	7353	2022	1004
L5	2953784	1476252	736322	365149	180798	88653	42570	19705	7420	2048	1022
L6	2973227	1483643	740647	368485	181212	88822	42698	19708	7423	2047	1022
L7	2992981	1493437	744891	369400	182869	88454	42495	19624	7392	2041	1019
L8	3001144	1498729	747511	371918	182935	84491	42514	19620	7386	2038	1018
L9	2952871	1474633	735510	365943	181167	88807	42672	19701	7422	2047	1023
L10	2941826	1467887	730911	363641	178821	86466	40385	17536	7424	2048	1024

In Table 5.3, "L" is denoted as the results length of equispaced method; "r" is denoted dividend pixel size. In Table 5.4, "S" is denoted step count; "r" is denoted dividend pixel size. As seen Table 5.3, results lengths of equispaced dimension have been altered with dividend pixel size. L10 and S10 are denoted as last sample which crimps character different from the others. When the results length of equispaced method has been divided to step counts, the samples' length can be found in pixels. As a result of equispaced method have been found length to first 9 samples nearly the same. This situation is different to the last sample.

To L10 sample 2, 4, 8, 16 dividend pixels results of equispaced have been found similar other 9 samples' results. But the same sample's result length to 32, 64, 128, 256 dividend pixel have been found different from the other 9 samples' results. When the sample has been divided by equispaced pixel size, crimp's part pixels which come across the dividend pixel can be changed in column and row position of the pixel. When dividend pixel size has been enlarged, the pixel number which has been used to count the length decreased. In parallel with this situation the length which has been found result of the equispaced method decreased.

In S10 sample, results of step count with 2, 4, 8, 16 dividend pixel size the same other 9 sample the reason why this situation dividend pixel size small and pixel distance which have been used to count length very close. The results of step count with 32, 64, 128, 256 dividend pixel size has been found different other 9 samples, the reason why this situation the dividend pixel size was a big and pixel number which has been used to count the length was less. The result length has been counted longer when crimp character divided with equal pixel size. If pixels come across the straight part of yarn result length has been counted less. Hence, the crimp's character can be determined straighter than other 9 samples' crimp character with the result of this length.

Step counts have been found the same all samples when dividend pixel size between 128 to 2048. The sample which is denoted with S10 crimp's character has been defined straighter than the other 9 samples. Samples real length can be calculated with pixel count. For these samples 2450 pixels equal to 40 cm or 400 mm.

S1 step counts and L1 length are denoted first samples' step count and result lenght of equispaced dimension method. If results length of equispaced dimension has been divided with step counts sample's real length can be found as a pixel. This calculation result for the first sample have been found as 3075 pixels, in other word 50,2 cm.

The equispaced dimension method has been applied to samples to determine the differential of crimp character. Before applying equispaced method last sample's crimp structures have been evaluated and the differential has been determined. When the results of equispaced dimension methods have been evaluated differential can be found. The equispaced dimension method has been beneficial to classify the crimp structure.

CHAPTER 6

EVALUATION OF CRIMP MORPHOLOGY BY BONDARY DESCRIPTIONS

6.1 Introduction

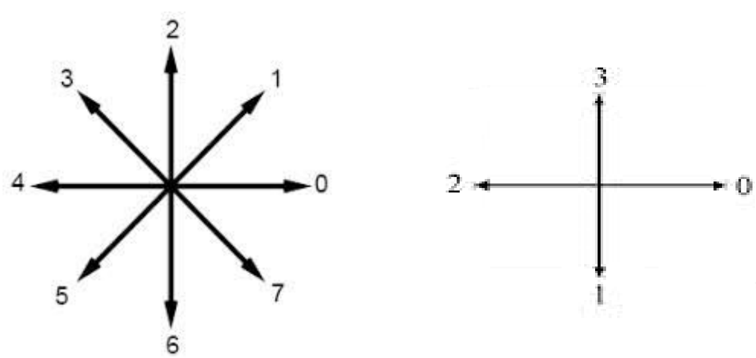
The crimp structure has not got a regular shape because of the manufactured process. This condition causes differentiate to assessment, to count and to make difficult classification of crimp structure. In order to assess the crimp structure accurately, some kind of crimp's morphological feature must be known. Therefore, Sobus et al [7] has been found 11 parameters related with the crimp morphology. These parameters can help accurately classification of the crimp. The crimp's digital image must be treated some process, before to determine the crimp morphology with 11 parameters. Crimps' boundary has been defined with boundary descriptors. Chain code is commonly used for boundary description. So, crimps' boundary has been defined with the aid of chain code. But, chain code is very sensible treatment. When the image's boundary has been defined by chain code two things become important: Chain code's starting point and clearness of the image. If the digital image is not smooth, chain code consequent can be changed. Thus, before applying chain code image's noise must be removed. The second important thing is starting point, because chain code consequent has been related with a starting point. If starting point has been changed, chain code results can be changed. Therefore, when chain code is to be applied carefully to define the starting point.

6.2 Boundary Descriptors

The first step in image analysis system is segmentation. This step is followed by representation and description schemes. The output of the segmentation process is the boundary pixels of objects. The representation of the object boundaries is important for the boundary of an object [25].

6.2.1 Chain Code

The chain code is commonly used to define the boundary which belongs to the image. The image's boundary can be coded and stored in the memory with the help of chain code's directions. The directions of chain code have different aspects changing with the directions. The object's boundary is stored with these directions which is coming up the object's boundary pixel the same. The stored data in the memory gives us the boundary of the image. Two kinds of chain code can be used to define the image boundary. The first one is four directions the second one is eight directions. Figure 6.1 shows the eight directions chain code and four directions chain code respectively. Table 6.1 shows the chain code directions, the angles and the lengths which are determined via directions.



(a) (b)

Figure 6.1 (a) eight directions chain code, (b) four directions chain code

Chain Code Directions								
Parameters	0	1	2	3	4	5	6	7
Chain angle	0	45	90	135	180	225	270	315
Chain length	1	$\sqrt{2}$	1	$\sqrt{2}$	1	$\sqrt{2}$	1	$\sqrt{2}$
X coordinate	1	1	0	-1	-1	-1	0	1
Y coordinate	0	-1	-1	-1	0	1	1	1

Table 6.1 Chain code directions, lengths and angles

When defining boundary of image with chain code starting point has become important. Compute the chain code by scanning the image to find the starting pixel of the object. From that pixel, we traverse the boundary and decide directions and save them as an array or list. This step is repeated until the end pixel is reached. If end pixel not an equal start pixel, then the shape is not closed. The image's boundary can be calculated the perimeter which is defined by chain code's directions and aspects by summing up the elements of the chain code sequence. If end pixel equal start pixel, then a closed shape is obtained [26]. Figure 6.2 shows the image which is represented opened shape in chain code. Figure 6.3 shows the image which is represented closed shape in chain code.

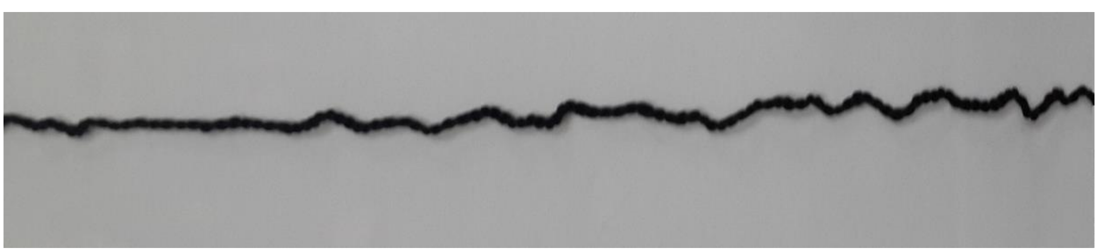


Figure 6.2 Opened shape image

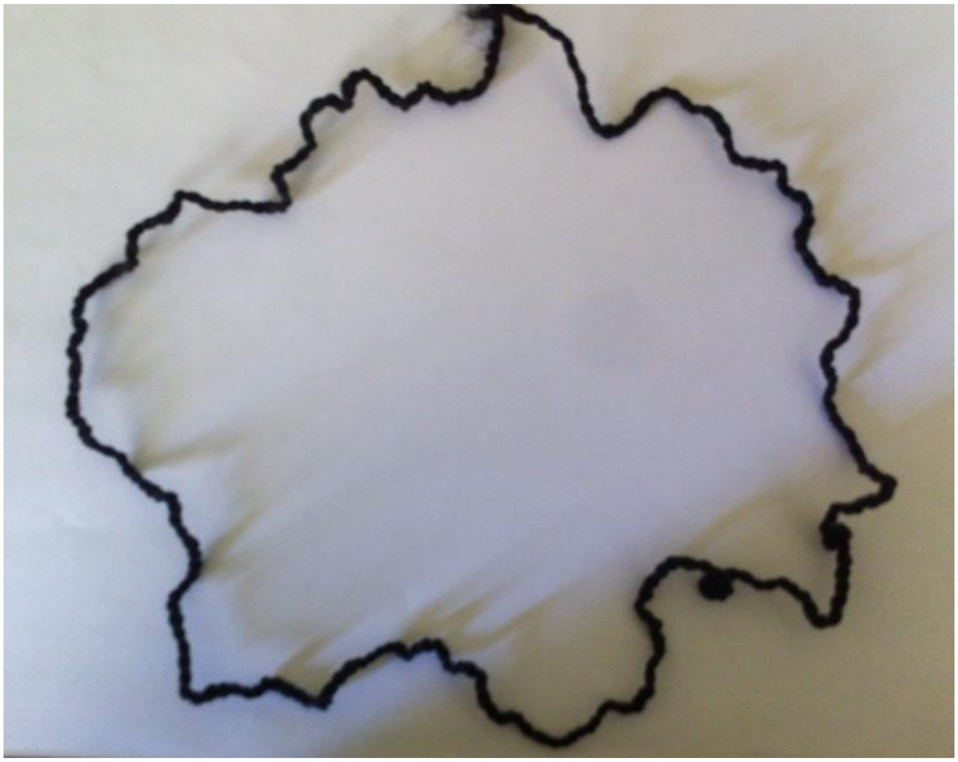


Figure 6.3 Closed shape image

As seen Figure 6.2 yarn's starting point and end point which is used to define the chain code sequence is not the same. Figure 6.2 is denoted the opened shape. As seen Figure 6.3 yarn's starting point and end point which is used to define the chain code sequence is the same. Figure 6.3 is called the closed shape.

6.2.2 Define Sample's Chain Code

Chain code has been applied to binary (black-white) image. Original image which has been captured with a camera from samples is not binary image. So, some treatments have been applied samples to obtain the binary image. Binary image has been obtained after the threshold process. Normal threshold is converted to the same value of threshold image's every point, but sometimes this value has not been enough to obtain clearance for the digital image. In many images has been decided very difficult which pixel belongs to foreground which pixel belongs to the background. In this case, adaptive threshold is a very useful digital image to convert the binary image. Figure 6.4 shows the differentiate of global threshold and adaptive threshold.

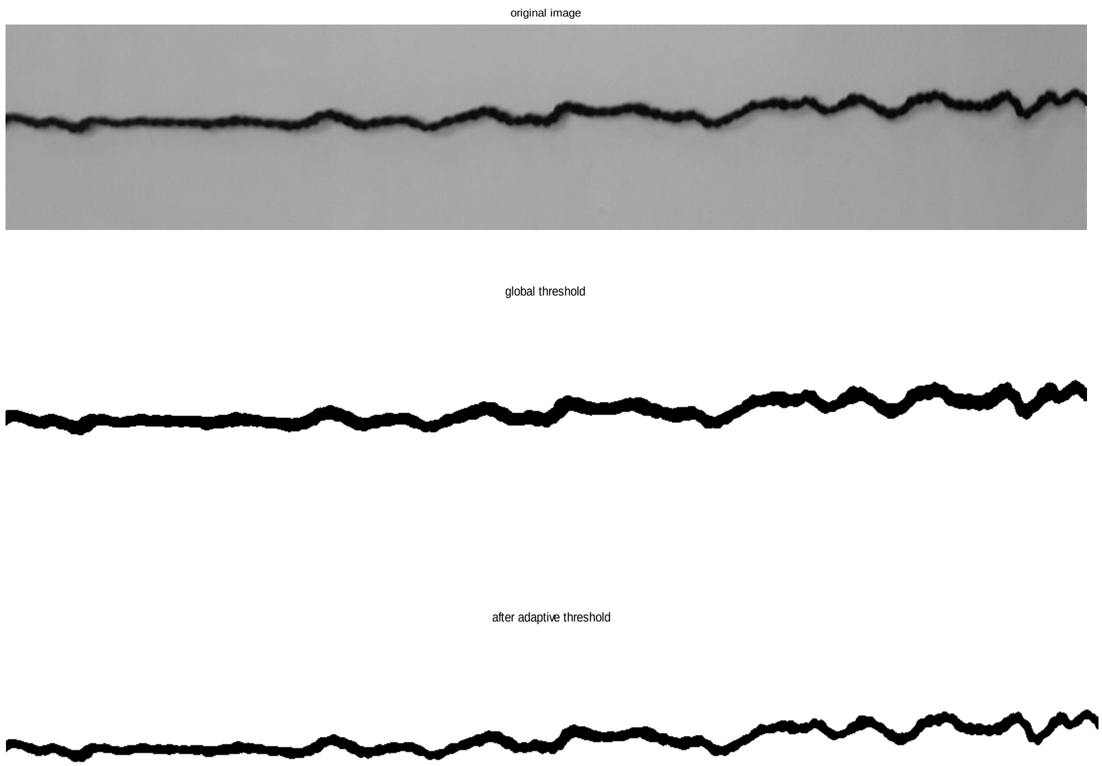
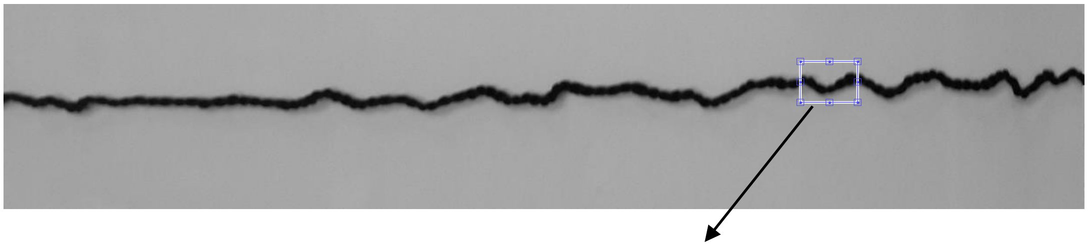


Figure 6.4 Original image of sample, results image of global threshold, results image of adaptivethreshold, respectively.

As seen in Figure 6.4, the adaptive threshold gives more detail than the global threshold. Thus, adaptive threshold was beneficial before applying the chain code. After threshold treatment, some more morphological operations have been applied to sample. All operations have been mentioned and all operations results images are represented in Chapter 4, Figure 4.2. After morphological operations chain code has been applied to samples. Figure 6.5 shows the results of chain code sequence for randomly chosen sample's part.



07007076670770777707707707707070700070007000000010000010010010101010101
0101010010100101010100101000106

Figure 6.5 One sample's partial representation with chain code

Samples' chain codes have been determined with the help of image process. In Figure 6.5, represented sample’s which is chosen randomly chain code. As seen in igure 6.5, sample's chain code results consists of generally 0, 1, 6, 7 directions. Chain code's treatment way is right to left in these samples. Thus, the result of chain code consists of only 0, 1, 6, 7 directions. 0 directions denote the sample's pixel position to come across straight with right, 1 directions denote the sample's pixel position to come across up to right with 45°, 6 directions denote the sample's pixel position to come across down position, 7 directions denote the sample's pixel position to come across down to the right with 45°.

The reason why the chain code has been defined these opened shape to find the yarn's length. Yarn's length must be known because of 11 parameters which are related to crimp structure.

6.3 Crimp Parameters

There are 11 parameters which are used to define crimp structure are explained below. They are given as natural length, crimp counts, elongated length, crimp percent, spatial frequency, noncrimp, height, width, crimp angle, crimp intensity, crimp sharpness. Detailed discussion about the 11 parameters can be found in [7].

(1.) *Natural length C_{nl} (pixel):* The measured image's length which is taken from the sample is not exposed with any tension. All samples' image has been taken the same length and the same position. Hence, this parameter cannot be used to determine crimp structure in this work.

(2.) *Crimp counts C_p:* Crimp count on the natural length of yarn.

(3.) *Elongated length C_{el} (pixel):* The measured image's length with tension which does not destroy the crimp structure.

(4.) *Crimp percent $C_{\%}$:* The percentage value of difference from elongation length and natural length.

(5.) *Spatial frequency C_{sf} (1/pixel):* The dominant crimp wave which is on the natural length can be determined by Fast Fourier Transform (FFT) [26]. After an FFT treatment wave length of crimp has been defined roughly.

(6.) *Noncrimp C_{nc} (pixel):* Total length which remain unchanged of slope on the yarn.

(7.) *Height C_h (pixel):* Vertical length between the peak point of the crimp structure to end point of crimp. (Figure 6.6)

(8.) *Widht C_w (pixel):* Horizontal length between the starting point of crimp structure to end point of crimp. (Figure 6.6)

(9.) *Crimp Angle C_a (˚):* The angle between two lines which are drawn tangent from crimp's shoulders where the slope is maximum. (Figure 6.6)

C_a is related to crimp sharpness, it cannot be used to define the crimp sharpness alone.

(10.) *Crimp intensity C_i:*

$$0 \leq C_{am} \leq (h_0 + C_{am}) \quad (6.1)$$

crimp intensity can be defined with 6.2 when C_{am} is in 6.1 .

$$0 \leq C_i = \frac{C_{am}}{h_0 + C_{am}} \leq 1 \quad (6.2)$$

C_{am}; is the amplitude of crimp, in case h_0 reverse of C_{am} ($-C_{am}$). C_i is related to the crimp sharpness, it cannot be used to define the sharpness of crimp alone.

(11.) *Crimp sharpness C_S*: Sharpness of crimp has been defined with C_a and C_i as seen in 6.3.

$$0 \leq C_s = \left(1 - \frac{C_a}{180}\right) C_i \leq 1 \quad (6.3)$$

Figure 6.6 shows some crimp parameters which are mentioned above C_h, C_w, C_a, C_{am}, h_0 on the crimp structure.

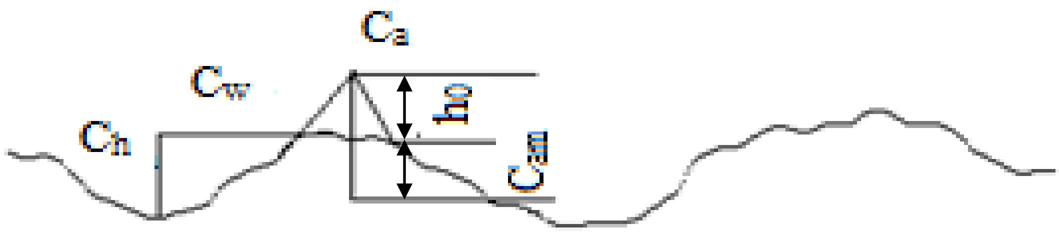


Figure 6.6 Representation of some crimp parameters on the crimp

6.4 Evaluation of the parameters on the crimp structure

The digital image is captured with a camera from the samples and some morphological operations are applied by using of image processing. All operations armentioned and all operations results images have been represented in Chapter 4, figure 4.2. After morphological operations all 11 parameters have been determined on the crimp structure. Table 6.2 shows the results of parameters.

Table 6.2 Representation results of 11 parameters [a]

Sample Num.	C_{nl}	C_{el}	$C_{\%}$	C_{nc}	C_p	C_a	C_i	C_s	C_h	C_w	C_{sf}
No 1	2417	2710	12,1	631	18	158,02	0,360	0,055	9,64	57,79	0,0029
No 2	2417	2642	9,3	647	14	153,35	0,479	0,071	18,32	136,79	0,0029
No 3	2417	2637	9,1	608	18	117,17	0,478	0,172	22,69	82,00	0,0037
No 4	2417	2790	15,4	472	22	123,52	0,326	0,101	21,00	107,38	0,0028
No 5	2417	2650	9,7	537	17	119,78	0,468	0,192	21,88	86,59	0,0029
No 6	2417	2664	10,2	564	20	132,17	0,447	0,121	11,69	47,62	0,0004
No 7	2417	2688	11,2	624	20	148,31	0,419	0,076	10,27	57,20	0,0012
No 8	2417	2712	12,2	527	21	151,01	0,407	0,069	10,24	64,23	0,0025
No 9	2417	2642	9,3	608	19	134,40	0,465	0,121	17,00	62,38	0,0004
No 10	2417	2549	5,5	1001	21	140,66	0,454	0,106	11,91	43,09	0,0050

[a] *C_{nl}=natural length, C_{el}=elongated length, C_p=crimp counts, $C_{\%}$= crimp percent, C_{nc}= noncrimp C_a= crimp angle, C_s= crimp sharpness, C_i=crimp intensity, C_h=crimp height, C_w= crimp width, C_{sf}= spatial frequency*

In Table 6.2, the N10 is denoted as the last sample that is crimp morphology different from the others. C_{nl} is denoted as the natural length of yarn in term of pixel and have been found the same value for all samples. Therefore, this parameter cannot be used to define the difference of crimp structure. C_{el} is denoted as the elongated length of yarn in terms of pixel. This parameter result has been shown on the alteration in the last sample. The last sample's crimp structure is straighter than the other samples. Elongated length is longer than the natural length and the crimp structure effects length directly proportional. If the crimp structure is the sharp elongated length longer than straight crimp structure's elongated length. Thus, the last sample's elongated length has been found as less than the others. C_{el} parameter can be used to define the difference of the crimp structure. $C_{\%}$ is denoted as the percent of crimp and it is related with C_{el} and C_{nl}. Although C_{nl} values have been determined the same for the all samples, the last sample's $C_{\%}$ has been determined differently from the others. For this reason, the crimp percent *($C_{\%}$)* can be used to determine the difference of crimp structure. The other parameter is C_{nc}, it is denoted total of noncrimp points on the yarn. As seen Table 6.2, the last sample's noncrimp value is higher than the others. If crimp structure has straight character noncrimp value is determined high. The last sample's crimp has straight structure.

Depending upon the crimp's straight structure noncrimp value is counted high. So, C_{nc} parameter can be used to determine the difference of crimp structure. C_p is the other parameter to determine crimp morphology. C_p denotes the crimp count on the yarn. This parameter is not effective to determine difference of crimp structure. It gives information only about the crimp count on the yarn. So, crimp count cannot be used to determine the difference of crimp structure. C_a denotes as the crimp angle and C_i denotes as the crimp intensity, they are all related to the crimp sharpness.

As seen in Table 6.2, C_a and C_i values have been found similar to the all samples. Therefore, C_a and C_i parameters cannot be used to determine the difference of crimp structure. The other parameter C_s is related to crimp sharpness like C_a and C_i. C_s values for all samples resemble each other. So, C_s parameter cannot be used to define the difference of crimp structure. C_h is denoted crimp height and C_w is denoted crimp width.

The last sample's crimp structure is different from the others. Therefore these two parameters results have been expected different. But, as seen in Table 6.2 these parameters results intermediate of other nine sample results. Hence, C_h and C_w parameters cannot use to determine the difference of crimp structure. The last parameter C_{sf} is denoted spatial frequency of crimp structure. As seen in Table 6.2, C_{sf} result is different from the others. But, it defines only the dominant crimp character on the yarn. Therefore, this parameter is not adequate to determine the difference of crimp structure.

The result of this work, in all parameters only C_{el}, C_{nc} and $C_{\%}$ can be used to determine the difference of crimp structure. The others are not sufficient to determine the crimp structure.

CHAPTER 7

CONCLUSION AND DISCUSSION

7.1 Conclusions and Discussion on the Present Work

The aim of this study is to solve the confusion about crimp structure for the carpet industry. For this purpose, some useful algorithms have been developed by the help of image processing techniques. The study is focused on the determining crimp count and classify the crimp which are on the frieze carpet yarn. Developed algorithms are used to evaluate the crimp structure, to count how much crimp is available on the frieze carpet yarn. The crimp structure is evaluated objectively. In carpet industry, the crimp structure has been evaluated by the human eye as subjectively. The developed algorithm makes it easy to evaluate it objectively. The result of this study is that the crimp structure can be evaluated as objectively.

In this study, for determining the crimp structure with image processing three main stages have been studied. These stages are given as; the considerations on image processing, considerations on the crimp structure, considerations on the crimp's morphology.

i) Considerations on Image Processing

The evaluation of part of image processing has included the stages of image analysis for capturing images from the camera how can be stored as a digital image, image enhancement, image segmentation and morphological operations. The reason why these methods were applied to digital images to obtain the clearest image for the image processing.

ii) Considerations on Crimp Structure

In order to count the crimp, ten frieze carpet yarn samples image were captured by the camera. They were then converted to the digital form. Crimp counts were determined with the developed algorithm by the help of image processing on the digital images. When counting the crimp has been required, the attention difference pixel between the crimp's peak to crimp's right and left legs. Crimp's difference pixel between peak to two legs has been taken least 3 pixel. Sample's crimp counts have been changed 14 to 22. The result of this study frieze carpet yarn crimp count has been determined objectively. In carpet industry, the developed algorithm which belongs to this part of this study will be used safely to determine the frieze carpet yarn's crimp count objectively.

In order to determine the difference between the crimp structure fractal geometry's two branches which are box counting dimension method and equispaced dimension method were applied to the digital image with the help of image processing. To accomplish this task one sample's crimp structure has been taken differently from others. Box counting dimension method and equispaced dimension method were applied to 10 samples. The fractal geometry's branch was chosen due to crimp's irregular shape. The box counting method results, which are box count and fractal dimension, have been given in detail Table 5.1 and Table 5.2.

Box counting results were found nearly the same for all samples. The box counting method cannot be used to determine the difference of crimp structure. Equispaced dimension was applied the same task as box counting dimension. Equispaced dimenison results which are lenghts of between pixels and step count have been given with detail in Table 5.3 and Table 5.4. The last sample is denoted as the different sample in the tables. The last sample's step counts were found different from the others when dividend pixel size was 2, 4, 8, 16, 32. Dividend pixel size bigger than 32 pixel equispaced dimension method is not found by the difference of crimp structure. For this reason, the equispaced dimension method cannot be used to determine the difference of crimp structure unless dividend pixel size is bigger than 32 pixels.

iii) Consideration on the Crimp's Morphology

In order to determine the crimp's morphology and classify the crimped yarn, 11 parameters which have been found by Sobus et al. has been used to evaluate the crimp structure on the frieze carpet yarn. 11 parameters were determined on the digital forms of frieze carpet yarn's image with the help of image processing. These parameters are as follows; C_{nl} *(natural length),* C_{el} *(elongated length),* C_p *(crimp counts),* $C_{\%}$ *(crimp percent),* C_{nc} *(noncrimp),* C_a *(crimp angle),* C_s *(crimp sharpness),* C_i *(crimp intensity),* C_h *(crimp height),* C_w *(crimp width),* C_{sf} *(spatial frequency).* All these parameters were found separately all crimp structures which are on the yarn. In this study, all samples natural length was taken the same length, then this parameter was not used to classify the crimp structure. Crimp structure is affected to elongated length. Elongated length has been measured longer if crimp has willingly structure. The result of this study, the last sample's elongated length as seen in Table 6.2 was measured shorter than the others. The reason is that last sample's crimp structure was straighter than the other 9 samples. Depending on the result of this parameter, it can be used to evaluate the difference of crimp structure.

Crimp counting is one of the main aim of this study. Crimp count parameter was determined for all samples, but crimp count cannot be used to determine the difference of crimp structure. The other parameters related to crimp structure are crimp sharpness, crimp intensity and crimp angle. These parameters results were found closed for the all samples. For this reason these parameters cannot use to determine the difference of crimp structure. Crimp percent is the other parameter for determining the crimp structure. Crimp percent is related with natural length and elongated length of yarn. Although the natural length is the same for all samples, the crimp percent was found different value. Therefore, this parameter can be used to determine the difference of crimp structure. The other parameter noncrimp, it is related to the non change of slope on the yarn, in other words, it is related to the shape of crimp structure. If crimp has straight structure noncrimp value finds high. In this study, noncrimp value was found different from the last sample. For depending on this reason, the noncrimp parameter can be able to use the other parameter to determine the difference of crimp structure. Spatial frequency parameter only defines the dominant crimp wave on the yarn. Therefore, this parameter cannot be used to determine the difference of crimp structure. The last parameters are crimp height and crimp width. In this study, crimp height and crimp width parameters results were found resemble for all samples. Therefore, these parameters cannot be used to define the difference of crimp structure.

To accomplish the developed algorithm, crimp count was determined separately for all samples. The aim of determining the difference of crimp structure one method and three parameters.

7.2 Future Work

After the fixing treatment frieze carpet yarns are passed onto the moving plate. Through this study the stable camera was used to take images of the samples. As a further study, a mechanism can be developed with attached camera positioned above the plate. It can be easily used to capture the images on a moving plate.

Crimps structure has two dimensions which are back and front. Captured images of the samples were inverted to the negative image to easily observable of crimp structure which is on the ground of the image. To determine the crimp count on the yarn to obtain more reliable results about the crimp count, two cameras can be used to count crimp structure in two different ways.

To determine the difference of crimp structure on the yarn fractal geometries' branches which are *box counting dimension method* and *equispaced dimension method*. Eleven parameters related to crimp structure were used. Equispaced dimension method was useful to define the difference of crimp structure. If the crimp has frizzly structure equispaced dimension method result about number of equispaced point increase. C_{nc} is part of 11 parameters and it is represented total of the noncrimp length of yarn. The Equispaced dimension method and C_{nc} parameter can be used together to determine the reliability degree of these treatments with each other.

The man-made filament yarns is required to resemble natural yarn in terms of crimp. Crimp structure gives strength to yarn. As a further study, crimp count's effect can be determined on the strength of carpet.

REFERENCES

[1] Sarkeshick, S., Tavanai, H., Zarrebini, M., and Morshed, M. (2009). "An investigation on the effects of heat-setting process on the properties of polypropylene bulked continuous filament yarns", *The Journal of The Textile Institute*. **100**(2), 128-134.

[2] http://www.google.com/patents/US7152288.

[3] Behera, B.K. (2004). Image Processing in Textiles. *Textile Progress*. **35:2**, 1-193.

[4] Kang, J.K., Choi, S.H., Kim, S.M., and Oh, K.W. (2001). "Automatic Structure Analysis and Objective Evalution of Woven Fabric Using Image Analysis", *Textile Research Journal*. **71**(3), 261-270.

[5] Huang, C.C., Liu, S.C. and Yu, W.H. (2000). Woven Fabric Analysis by Image Processing. Part l: Identification of Weave Patterns. *Textile Research Journal*. **70**(6), 481-485.

[6] Huang, C.C., Liu, S.C. (2001). "Woven Fabric Analysis by Image Processing. Part ll: Computing the Twist Angle", *Textile Research Journal*. **71**(4), 362-366.

[7] Cooke, W.D., Cork, C.R. and Wild, J.P. (1996). "The Use of Image Analysis to Determine Yarn Twist Level in Archaeological Textiles", *Archaeometry*. **38**, 337-345.

[8] Sobus, J., Xu, B., and Pourdeyhimi, B. (1992). "Characterizing Fiber Crimp by Image Analysis: Definition, Algorithms, and Techniques", *Textile Research Journal*. **62**(2), 73-80.

[9] Oh, S., Lee, M. S., and Kim, S. (2014). "Automatic Measurement of Yarn Crimp Using Image Analysis", *Journal of Testing and Evaluation*. *42*(2).

[10] Lee, J.Y., Kang, T.J. (2001). "Filament Crimp in Three Dimensions Measured by Image Analysis and Fractal Geometry", *Textile Research Journal*. **71**(2) ,112-116.

[11] Lee, Y.L., Kang, T.J. (2000). "Objective Evalution of Fabric Wrinkles and Seam Puckers Using Fractal Geometry", *Textile Research Journal*. **70**(6), 469-475.

[12] Muraoka , Y., Inoue, K., Tagaya, H., Nishizawa, K. (1995). "Fiber Crimp Analysis by Fractal Dimension", *Textile Research Journal*. **65**(8), 454-460.

[13] Yang, X. (2010). "Fractal Approach to Fiber's Crimped Morphology", *International Journal of Nonlinear Sciences and Numerical Simulation*. **11**, 287-290.

[14] Dadgar, M., Varkiani, H. M. S., Merati, A. A., and Sarkheyli, A. (2013). "Comparison of Mamdani and Sugeno fuzzy inference system in prediction of residual frieze effect of frieze carpet yarns", *Tekstilna Industrija*. **61**(2), 16-25.

[15] http://www.springer.com/978-1-4471-2502-0

[16] http://en.wikipedia.org/wiki/Frame_grabber

[17] http://www.drkmm.com/resources/INTRODUCTIONTO_IMAGE_PROCESSING_29aug06.pdf

[18] Anıl K. Jain, (1989). "Fundamentals of Digital Image Processing", California: Prentice Hall.

[19] Raman Maini, Himanshu Aggarwal (2010). "A Comprehensive Review of Image Enhancement Techniques", *Journal of Computing*. **2**, 8-13.

[20] Matlab Image Processing Toolbox Release Notes Version 8 (2013a)

[21] http://cse.secs.oakland.edu/hanna/cse571W2005/ImageProcessing/sobel.pdf

[22] Yu, L., Zhang, D., Wang, K., Yang, W. (2005). "Coarse iris classification using box-counting to estimate fractal dimensions", *Pattern Recognition*. **38**, 1791-1798.

[23] Kaye, B. H. (1997). *Powder mixing* (Vol. 10). Springer.

[24] Kang, T. J., Lee, J. Y.,Kwansoo, C.and Lee, S. (1999). "Evaluating Yarn Crimp with Fractal Geometry", *Textile Research Journal*. **69**(7), 527-534.

[25] ANNADURAI, S., SHANMUGALAKSHMI, R. (2007). "Fundamentals of Digital Image Processing", India: Dorling Kindersley.

[26] Sleit, A. T., and Jabay, R. O. (2006). "A Chain Code Approach for Recognizing Basic Shapes".

[27] Brigham, E. 0. (1988). "The fast Fourier transform and its applications", *Printice-Hall*, *Englewood Cliffs*.