영상처리 기법을 이용한 실시간 섬유 성량 검사 시스템 개발

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요 약

섬유 성량 검사는 섬유 염색 및 가공 공정에 있어서 중요한 사항들 중의 하나이며 이는 최종 섬유 제품의 질을 결정하는 중요한 역할을 수행한다. 본 논문에서는 섬유 제직 공정에 있어서 다양한 섬유 결함 검출과 섬유 결함의 위치 검출 뿐만 아니라 섬유의 밀도를 측정할 수 있는 실시간 섬유 성량 검사 시스템을 구현하였다. 제안한 방법은 실린더 렌즈를 사용하여 영역교차법을 적용한 섬유 밀도 측정 알고리즘과 섬유 결함을 검출하기 위하여 서브밴드 영상의 명암도 상관 행렬을 이용한 섬유 결함 검사 알고리즘으로 구성된다. 제안한 알고리즘의 성능 평가를 10종류의 실 섬유 결함 표본과 3가지 섬유의 원조직을 사용하였다. 제안한 알고리즘을 적용한 결과 섬유 가공 공정에 있어서 150m/min 속도까지 오차율 ±1% 범위내에서 섬유의 밀도 계산과 섬유 결함 검출이 가능하였다. 또한 제안한 알고리즘은 섬유 제직시 성량 검사가 필요한 공정에 있어서 섬유의 제직 상태를 모니터링 함으로써 생산성을 개선할 수 있다.

A Study for the Real-Time Textile Dimension Inspection System Using Image Processing Technique

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ABSTRACT

Textile dimension inspection is one of the basic issues in the textile dyeing and finishing industry. And also, it plays an important role in the quality control of total fabric products. In this paper, we implement a real-time textile dimension inspection system which detects various real defects, defect positions of textile and the density of textiles. The proposed method consists of textile density measurement algorithm with zone-crossing method which uses cylindrical lens and textile defect inspection algorithm using gray level co-occurrence features from subband image which detect various types of real defects. The performance of the proposed method is tested with a number of real textile samples with 10 types of defects and three basic structures of textile. By the dimension inspection of textile at continuous stages in the fabrication process, it is possible to measure the density of textile up to 150m/min and to detect the defect of textile at real time within ±1% error percentages. And also it can be monitored the condition of textile throughout at all the significant working process and can be improved textile quality.

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1. Introduction

Quality inspection of textile is an essential and important problem for textile industry. Currently, in the textile manufactures, dimension inspection of a fabric which moves at a speed of 20-150m/min is mostly done by human operators. Dimension inspection such as density, defect, width, length, etc., plays an important role in the automatic visual inspection of textile as well as in the control of textile quality control. Improved product quality contributes to increased profitability and consumer satisfaction.

Therefore to be ahead of the rest, quality has to be the priority in performance criteria of every textile manufacturer. These requirements create a significant demand for objective, more reliable, time and cost effective. Real-time textile dimension inspection system for the detection of textile defects and density can meet this requirement.

Many studies have been developed for the improvement of textile quality[1-4]. However, there have many problems to solve inspect automation and real-time problems. These problems can meets textile dimension inspection system which measures and displays various dimensions of textile such as width, length, and density of textiles, but also stores and records such data and automatically detects irregularities[5, 6].

The dimension of textile is a very important parameter in the development of textile quality and textile fabrication system. After finishing treatment in particular, it is absolutely necessary to know the exact textile dimension over the current textile. In order to inspect textile dimension automatically as regards quality of the finished textiles, it is necessary to be able to reliably measure the entire process of textile fabrication.

To improve these problems, we propose a textile density measurement method to calculate the density of textile automatically. And also, we propose a textile defect inspection method which continuously detect real defects of textile such as weft float, hole float, shuttle warp mark defect, shuttle mark weft defect, warp flat, paste fleck, warp edge defect, weft edge defect, warp thread defect and weft thread defect.

By inspection density and defects at continuous points of the fabrication process it is possible to monitor the textile dimensions throughout and control the states of fabrication, at all the significant stages.

In this paper, the problem of textile dimension inspection and the basic of textile analysis are stated in section 2. The proposed textile density measurement and defect inspection algorithms are mentioned in section 3. Experimental results with the real defected textile are shown in section 4. Finally we conclude with a summary of our proposed algorithm and outline our future work.

2. Problems of Textile Dimension Inspection and the Basic of Textile Analysis

Generally, textile quality grading which depends on the number of weft threads of textile, frequency of defects in a roll of the textile. Thus, the effectively performed textile dimension inspection not only maintains control over the quality of the total products, it also provides a continuous process control.

To ensure high quality of the final textile products, the textile is usually inspected visually. There have been many attempts to provide a method to visual textile inspection. However, it is still generally performed manually. The assessment of fabric quality relies on the inspector's attention and experience and also, this task very labor intensive, monotonous and tiring. To overcome these problems, automatic textile dimension inspection system is necessary. To implement of this system, the structure and the basic properties of textiles must be considered. The implementation of the real-time textile dimension inspection system is a solution, which provides reliable, objective and stable performance.

In the textile products, woven fabrics consist of warp and weft yarns which are interlaced with one another according to the class of structure and the form of design desired. And also, the structure of textile is somewhat different from the crossing state as well as the types of threads. Thus, the form of interlacing of warp and weft yarns can be divided basically into three categories such as plain weave, twill weave, and satin weave. The textile dimension inspection system should be able to rely on the visual attributes of the defects in order to identify them as well as the exact measurement of textile density to fabricate desired textile product.

Mostly, textile analysis techniques can be classified into statistical and structural approaches. The statistical approach involves a global analysis and characteristic of pattern. Meanwhile, the structural point of view, textile is formed by sub-patterns that occur repeatedly according to a certain placement rule. The main difference between these two approaches is the level of description of textile.

There seems to be no unique way to analyze every textile. The same textile may need to be analyzed differently depending on the application purpose. In this paper, we will provide the hybrid analysis approach based on textile density measurement algorithm to structural and textile defect inspection algorithm to statistical approach, respectively. Because density measurement will be processed from the structural states of weft thread image and defect inspection will be processed from the statistical features of gray level co-occurrence matrix.

3. Proposed Textile Dimension Inspection System

3.1 Textile Density Measurement Algorithm Using Zone-Crossing Method

The objective of our paper is to implement a textile dimension inspection system pertaining to the automated textile density measurement and defect detection of textile material.

In the textile fabrication manufactures, fabrics are proceeded over the weft straightener at a speed of minimum 20m/min up to maximum 150m/min. Thus, it is very difficult to measure the density of textile at real-time in the high speed moving textile object.

For the measuring of textile density at real-time, we suggest the new density measurement method using optical lens instead of frequency spectrum analysis. Because it is powerful to noise and to solve the real-time problem. Namely, we propose a weft thread acquisition method using cylindrical lens as a necessary pre-processing step for the acquisition of weft thread feature. As mentioned above, the density of textile is the crossing number weft thread per square inches. Thus, density measurement method from the weft thread is needed with regard to noise and real-time problem.

To develope this problem, the proposed method uses cylindrical lens to acquire the horizontal information of weft thread from the textile and also uses convex lens to acquire the enlarged image. In the proposed method, cylindrical lens can be only transfer weft thread information to the computer from the high speed running textile straightener.

For the improvement of textile density measurement in the high speed running textile straightener, selecting an illuminant injection method is a important problem which decide a resolution of acquired weft image. Generally, CCD camera with normal shutter speed can be acquired a natural image. However, in order to absorb optimal light in the high speed running textile straightener, additional outer illuminant system is necessary. In the proposed system, we used the direct illumination method of light which penetrate much light to the running textile in the back of camera by using hallogan lamp.

For the ahead of textile density measurement, the complex structure of textile should be converted into the weft image using optical lens. If we can count the number of weft thread within the unit square inches of textile, it is possible to measure the density of textile for the number of weft thread. Thus, we also propose a zone-crossing method which can be count textile density at real-time from the one-dimensional weft image.

In the zone-crossing method, for the count of weft threads in a acquired enlarged weft thread image, we should measure the number of threads which has crossing zero at the center of horizontal image scale. The proposed zone crossing method is powerful to noise and can be solve the real-time problem.

In the zone-crossing method, the mean value of horizontal gray level at the center of image is shown in following equation. Here, X_i isthe horizontal gray value of image and n is the number of horizontal data.

$$\frac{\sum X_i}{n} = E_i \qquad (1)$$

Based on the reference of global mean value E_i, we also calculate two reference value $+Z_i$ and $-Z_i$ for the following conditions as shown in equation (2). Here, m and l are the number of crossing horizontal data in two reference zones, respectively.

Then weft threads are divide into positive reference zone $+Z_i$ and negative reference zone $-Z_i$, it can be regarded as a weft thread in a textile.

$$if \ldots (X_i - E_i) > 0; \quad \frac{\sum_{i=0}^{m-1} X_i}{m} = +Z_i \qquad (2)$$
$$(X_i - E_i) < 0; \quad \frac{\sum_{i=0}^{l-1} X_i}{l} = -Z_i$$

If the number of zone-crossing between positive and negative reference zone in N, then it can be regarded that the number of weft thread is N/2 which is approximately detected within square centimeter. To convert this value into the textile density as the definition of density, additional scale factor is multiplied to this value.

3.2 Textile Defect Inspection Algorithm Using Gray Level Co-occurrence Features from Subband Image

Textile may be defined with respect to the global properties of an image or to the repeating units that compose it. And defect detection can be defined as the process of determining the location and/or the extend of a collection of pixels in a textured image with remarkable deviation in their intensity values.

In this paper, the co-occurrence based method is imployed to extract the textile image for the purpose of finding the defect of various categories of fabrics. This is representative of a statistical approach to textile analysis. A co-occurrence matrix is a square matrix with elements corresponding to the relative frequency of occurrence of pairs of gray level of pixels separated by a certain distance in a given direction.

Suppose, every NN pixel of an image can be represented as $f(x,y)$, the gray level of it is G, distance between two pixels d, and position angle between two pixel θ are imployed. Then there are four directions among the direction position angle such as 0°, 45°, 90°, 135°.

The four kinds of relative position between two pixel can be defined as equation (3).

$$\begin{aligned}
\theta = 0^\circ \quad & R_H(d): |j-m| = d,\ k-n=0 \\
\theta = 45^\circ \quad & R_{RD}(d): (j-m=-d,\ k-n=-d) \\
& \quad or\ (j-m=d,\ k-n=d) \\
\theta = 90^\circ \quad & R_V(d): j-m=0,\ |k-n|=d \\
\theta = 135^\circ \quad & R_{LD}(d): (j-m=-d,\ k-n=d) \\
& \quad or\ (j-m=d, k-n=-d)
\end{aligned} \qquad (3)$$

And also, the relationship between the above-mentioned pixel pair and the co-occurrence probability of gray level p and q can be illustrated as equation (4).

$$\begin{aligned}
P(p,q,d,\ 0^\circ) &= \#\{R(d),\ f(j,k)=p,\ f(m,n)=q\} \\
P(p,q,d,\ 45^\circ) &= \#\{R(d),\ f(j,k)=p,\ f(m,n)=q\} \\
P(p,q,d,\ 90^\circ) &= \#\{R(d),\ f(k,k)=p,\ f(m,n)=q\} \\
P(p,q,d,135^\circ) &= \#\{R(d),\ f(j,k)=p,\ f(m,n)=q\}
\end{aligned} \qquad (4)$$

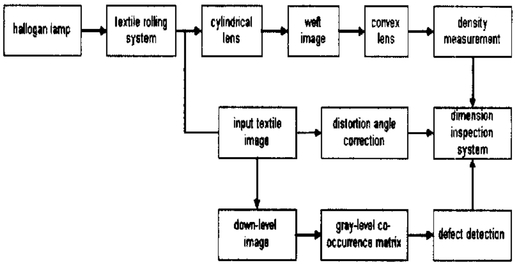
Futhermore co-occurrence matrix is processed by normalization method to make the sum of all the entries in matrix equal to 1. In this paper, for extracting features in the defect detection of textured images are contrast and angular second moment. Based on above equations, ASM(angular second moment) and CON(contrast) features are obtained as following equations. Contrast feature is a measure of the image contrast or the amount of local variations present in an image. And also, angular second moment is a measure of the homogeneity of an image. In equation (5) and (6), R denotes the sum of all the entries of co-occurrence matrix.

$$ASM = \sum_p \sum_q \left(\frac{P(p,q)}{R}\right)^2 \qquad (5)$$

$$CON = \sum_{n=0}^{m-1} S^2 \left\{ \sum_{|p-q|=s} \left(\frac{P(p,q)}{R}\right) \right\} \qquad (6)$$

Based on the above equations, the textile defect inspection procedures are as follows : To save the processing time and find defect positions, 256×256 gray level image is divided into 32×32 subband image. And each subband images are down leveled to 16 gray level. And also, to enhance the data, histogram equalizations are processed for the each down leveled subband images. And then, we find co-occurrence matrix, accumulate CON, accumulate ASM, and average value of these two features. Finally we can estimate the defect and defect subband position of textile from the difference value of CON(ASM) of each subband and average value of CON(ASM).

Based on the proposed textile density measurement and defect inspection algorithms we implement real-time textile dimension inspection system as shown in (Fig. 1).



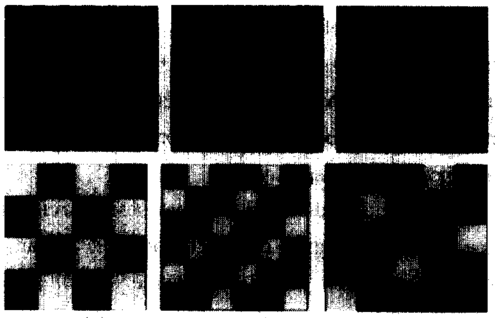
(Fig. 1) Configuration of the proposed textile dimension inspection system.

4. Experimental Results

In the experiment, we experiment with the three original weaves such as plane, twill, and satin weave for the measurement of textile density and the 10 types of defected textiles for the detect of textile defect.

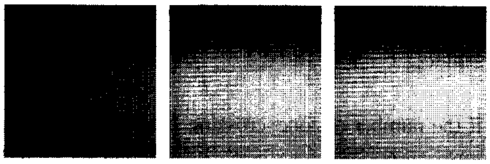
(Fig. 2) shows the three basic textiles and their structures. (Fig. 3) is a resulting weft image of plain weave textile for the outer hallogan lamp. From the result, the brightness of weft threads is changed for the power of outer illuminant and exact density can be calculated from the zone-crossing method. In this experiment, to acquire uniform weft image, we used hallogan lamp with 37-42V.

(Fig. 4) shows the original textile and the 10 types of real defect images such as weft float, hole float, shuttle warp mark defect, shuttle weft mark defect, warp float, paste fleck, warp edge defect, weft edge defect, warp thread defect, and weft thread defect of textile. (Fig. 5) shows the histogram equalized image of 10 types of defected textiles including original image. Through histogram equalization, a more uniform gray level distribution of image is obtained.



(a) (b) (c)

(Fig. 2) Basic textiles and their structures. (a) plain; (b) twill; (c) satin weave.

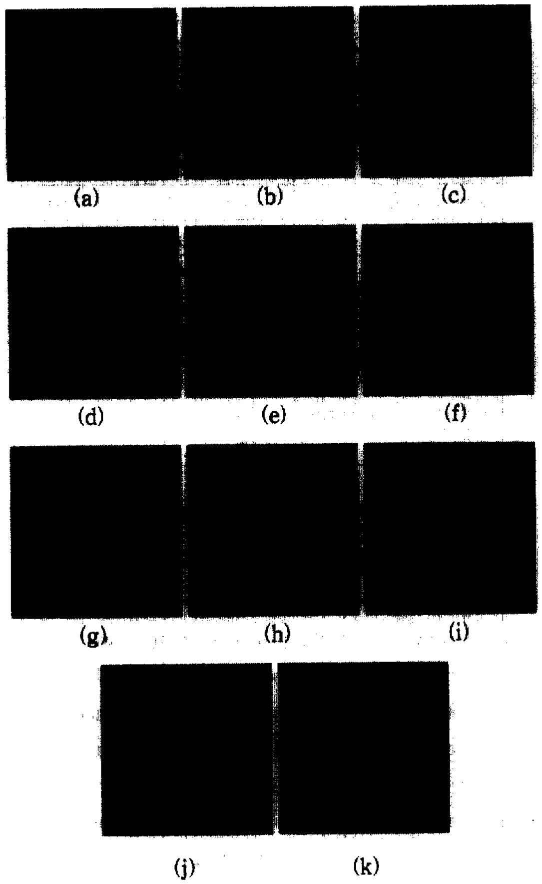


(a) (b) (c)

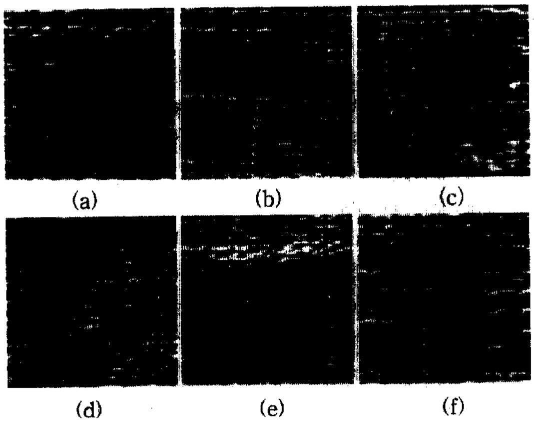
(Fig. 3) Plain weave for the intensity of exterior illuminant: (a) 37V; (b) 40V; (c) 42V.

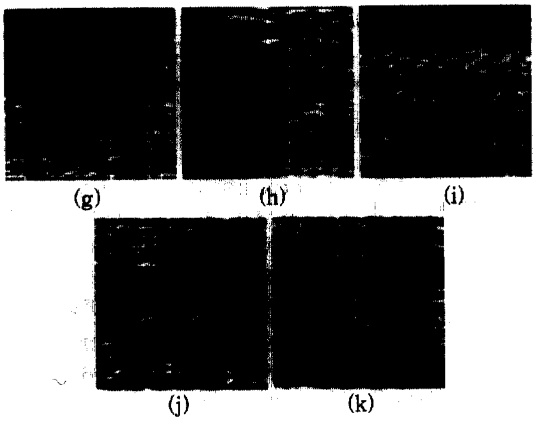
<Table 1> shows the ASM and CON values for the original and 10 values of defects textile image. And also, (Fig. 6) shows the test equalized textiles such as original, shuttle warp mark defect, weft float, small hole float, large hole float textiles. (Fig. 7) shows the resulting detect subbands of defect textiles for each test images in (Fig. 6).

The proposed density measuring system can be acquired enhanced weft thread image and measured desired density within minimum error as well as measured thread density up to 150M/min weft straightener speed. And the implemented textile defect inspection system can detect defect position of textile as well as defects of textile. <Table 2> shows the specification of the proposed textile dimension inspection system.

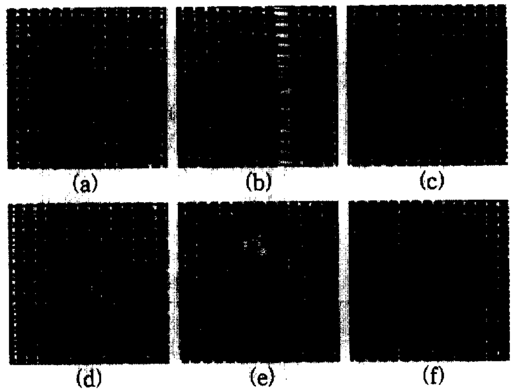


(Fig. 4) Various defect types of textile.
(a) original image; (b) weft float; (c) hole float; (d) shuttle warp mark defect (e) shuttle weft mark defect (f) warp float (g) paste fleck; (h) warp edge defect; (i) weft edge defect; (j) warp thread defect; (k) weft thread defect.

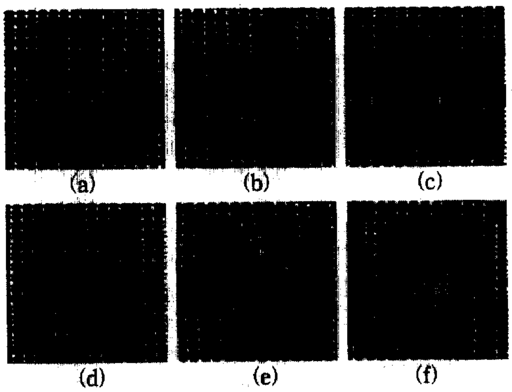




(Fig. 5) Histogram equalization images for the defect images in (Fig. 4).



(Fig. 6) Test equalized defect textiles: (a) original; (b) shuttle warp mark defect; (c) weft float; (d) small hole float; (e) large hole float (g) paste fleck.



(Fig. 7) Resulting detect subbands of defect textiles in (Fig. 6).: (a) original; (b) shuttle warp mark defect; (c) weft float; (d) small hole float; (e) large hole float.

〈Table 1〉 ASM/CON values for the images of 〈Fig. 7〉.

Defect	CON and ASM values of textiles
Original textile	CON 0°, d=1 : 369752 CON 45°, d=1 : 1753210 CON 90°, d=1 : 1441674 CON 135°, d=1 : 1618296 ASM 0°, d=1 : 228811048 ASM 45°, d=1 : 108307562 ASM 90°, d=1 : 124237126 ASM 135°, d=1 : 112952350
Shuttle warp mark defect	CON 0°, d=1 : 375804 CON 45°, d=1 : 1661710 CON 90°, d=1 : 1298006 CON 135°, d=1 : 1458270
Shuttle warp mark defect	ASM 0°, d=1 : 229663402 ASM 45°, d=1 : 111448516 ASM 90°, d=1 : 130330574 ASM 135°, d=1 : 119121654
Weft float	CON 0°, d=1 : 397190 CON 45°, d=1 : 1543880 CON 90°, d=1 : 1254524 CON 135°, d=1 : 1537830 ASM 0°, d=1 : 224188308 ASM 45°, d=1 : 117451996 ASM 90°, d=1 : 134607940 ASM 135°, d=1 : 117141398
Small hole float	CON 0°, d=1 : 397126 CON 45°, d=1 : 1575382 CON 90°, d=1 : 1260756 CON 135°, d=1 : 1490984 ASM 0°, d=1 : 219810618 ASM 45°, d=1 : 113186940 ASM 90°, d=1 : 128845006 ASM 135°, d=1 : 116314358
Large hole float	CON 0°, d=1 : 440400 CON 45°, d=1 : 1267010 CON 90°, d=1 : 1026900 CON 135°, d=1 : 1407680 ASM 0°, d=1 : 218783388 ASM 45°, d=1 : 129103168 ASM 90°, d=1 : 145060814 ASM 135°, d=1 : 124138586
Paste fleck	CON 0°, d=1 : 376448 CON 45°, d=1 : 1376998 CON 90°, d=1 : 1083170 CON 135°, d=1 : 1277808 ASM 0°, d=1 : 279397680 ASM 45°, d=1 : 169508374 ASM 90°, d=1 : 192720698 ASM 135°, d=1 : 172006332

〈Table 2〉 Specification of the proposed textile dimension inspection system.

Specification \ System	Dimension Inspection System
Inspection Types	Computer Vision(optical + image processing)
Inspection Items	Density and Defect of Textile
Lamp type	Hallogan lamp
D.C. power	D.C. 37~42V optimally
No. of Measured Density	Up to 130 threads/inch
Max. speed of Rolling Speed	Up to 150M/min.
Test textile	Plain, twill, satin weave
Errors of Density Measurement	± 1%
Errors of Defect	± 1%

5. Conclusion

In this paper, we implemented textile dimension inspection system. In the proposed system, we provide density measurement method to calculate textile density using optical lens and defect inspection method using gray level co-occurrence matrix to detect the various types of defects.

By the measurement of textile dimensions at continuous stages of the production process, it is possible to monitor the overall textile throughout, at all the significant points. It can be implemented on the fabrication controller to prevent thread irregularities and to hold a constant number of threads. In addition to monitoring and recording the relevant data, the system is able to control fabric machines.

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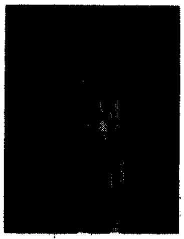

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