Cloth Weft Densitometer Using a CCD Camera

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A cloth weft densitometer has been proposed and its propriety verified by a preliminary experiment. The method is based on the counting of cloth wefts by a CCD camera with a shutter speed of 1 ms. The experiment shows that the densitometer can be used perfectly for many types of cloth if the cloth speed of less than approximately 10 m/min. The accuracy of the cloth-weft counting is above 99%, provided that the image contrast of the weft on the CCD camera is sufficiently high. Only 2-step digitation by the A/D converter is needed for 99% accuracy.

Key Words: Cloth weft, Densitometer, CCD camera, Counter system

1. Introduction

Two major technological problems remain to be addressed in the textile industry. The first is the measurement of cloth length. Cloth length changes according to a number of factors, including tension and stage of completion (*i.e.*, weaving- or dyeing-stage). To address this problem, we previously proposed a new method in which the number of wefts in a sample of cloth is counted rather than the length of the sample itself.[1,2] The accuracy of the measurement was found to be above 99% during actual factory use.[2,3]

The other problem is that of the weft density of the cloth, *i.e.*, the number of cloth wefts per unit length, variation in which causes a slight lack of uniformity in dyeing and renders the cloth useless in the market. In this sense, this is a more serious problem. Any number of cloth defects other than this slight change of weft density can almost perfectly be detected electronically or by the human eye in the factory.

This paper introduces new method of cloth weft densitometry and discusses its application to industrial use.

2. Method and System

The principle of the method is to count a cloth stitch in a unit length, usually an inch, using a CCD camera. It is inperative that the image of the cloth weft be parallel to the horizontal scanning line of the CCD camera and that the image contrast be high enough. The weft number of the cloth does not necessarily agree with the one of the weft. There is, however, a definite relation between them depending on the knitting. That is, the weft density can be determined by the stitch density.

Figure 1 shows an optical arrangement of the CCD camera for this purpose. The CCD camera is set up so that the image of the cloth weft is parallel to the horizontal scanning line of the camera (see Fig.1 (b)). A line fluorescent light is set up pararell to the cloth stitch and is inclined about 45° to the cloth surface to obtain high image contrast. A close-up lens is used to image the cloth area of 1 inch × 1 inch on the CCD camera frame in full scale. The resolution of the CCD camera is 400 lines/inch in the horizontal direction and 300 lines/inch in the vertical direction. One frame of the image is constructed per 1/60 second. The image signal of the CCD camera is read by a video signal capture board, then stored and processed in a personal computer (PC).

The shutter speed of the camera is 1/1000 second. This limits the moving speed of the cloth because if the cloth moves too fast the image will become dim and the image contrast will be reduced. The optimal shift of the cloth position within this shutter

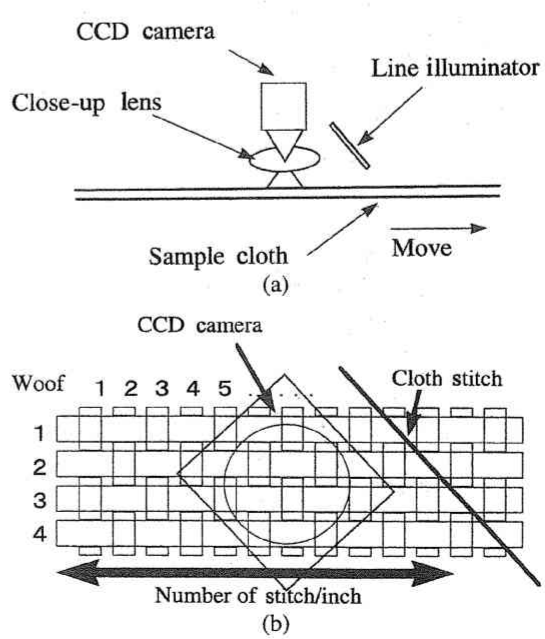

Fig.1 Optical arrangement (a) and CCD camera arrangement (b).

interval should be less than 1/10 of the weft pitch. The practical weft pitch of the cloth is 1 ~ 2 mm. The allowable moving speed of the cloth is then restricted to 10 ~ 20 cm/sec, *i.e.*, 6 ~ 12 m/min, which is too slow for industrial use. This problem will be discussed in Section 3.

Figure 2 shows a signal processing system. The output signal of the stored image is digitized by both 8 bit (256 grades) and 1 bit (2 grades) A/D converters for comparison. The averaged output signal in each horizontal line may become like a sine wave in the vertical direction–*i.e.*, the direction of the cloth's motion– because the light intensity scattered on the cloth varies with the gentle rise and fall of the cloth weft. The sine-like wave is then reformed into a rectangular wave by a ΔV detector (digitizer), and the number of rectangular waves is counted as described in the previous paper.[1)]

Another simple method is to directly count the number of rectangular waves using a digital signal processor (DSP); that is, the signal from the A/D converter is directly processed by this processor. This enables simple and high speed processing suitable for industrial use.

3. Experimental Results and Discussion

A preliminary experiment using a previous method[1,2)] was performed for comparison to the present method.

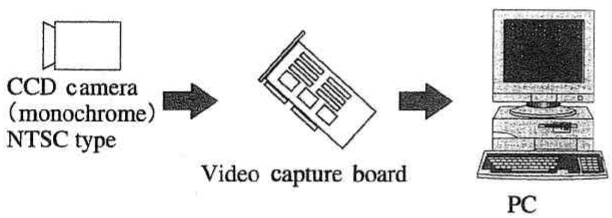

Fig.2 Schematic diagram of the system.

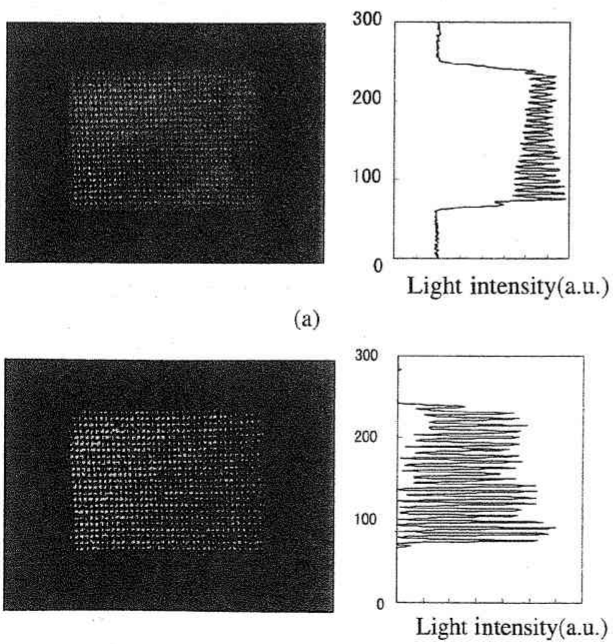

Fig.3 Cloth-weft image on the CCD camera (left) and light intensity histogram (right) in the vertical direction, –*i.e.*, the direction of cloth motion–, using an 8-bit A/D converter (a) and 1-bit A/D converter (b).

Figure 3 shows an example of the image displayed on the CCD camera (left), and its histogram (right) of the light intensity in the direction of cloth motion using an 8-bit A/D converter (a) and then a 1-bit A/D converter (b), for comparison. It was found that the weft density counted by human eye agreed exactly with that counted by the present method. The precision of the optical method was not affected by the digitation. The output histogram by 2 grades has higher contrast than the one by 256 grades as shown in Figs.3 (a) and 3 (b). This further simplifies the system and increases processing speed.

The same results were obtained for various types of cloth having countable wefts. The results are given in Table 1. Thus, the results by both 8 bit and 1 bit A/D converters coincide exactly.

The only limiting factor on the practical use of this method is the image-contrast reduction that results from high-speed motion of the cloth (see section 2). To avoid this problem, the relative velocity between the cloth and CCD camera must be sufficiently small.

Figure 4 (a) and (b) shows two concrete systems for this purpose. The most reliable method is to use a rotary cylinder into which several CCD cameras are set (Fig.4 (a)). The cylinder is rotated synchronously with the cloth moving velocity. The image signal of the cloth to each CCD camera has to be taken just when the CCD camera is parallel to the cloth. This can easily be realized by setting a small electrode on the rotary axis and some electrodes on the rotating cylinder to which the signal wire from all the CCD cameras are connected. These two kinds of electrode are kept in touch only at a short interval when the CCD camera is nearly parallel to the cloth. The relative velocity is exactly zero in this case. We can then take a photograph of the cloth under a resting condition. A signal transmission from each CCD camera to the A/D converter can be realized by using a commutator rectifier. The other method is to move the CCD camera mechanically with the velocity close as possible to that of the motion of the cloth (Fig.4 (b)). In this case, reciprocating (coming and going) mechanism is needed. Only one image signal of the cloth can, therefore, be obtained for each reciprocal motion because an either motion of coming and going will be opposed to the direction of the cloth's motion. At least, two CCD cameras moving in opposite direction are therefore desirable to examine the weft density at short intervals, since it is difficult to drive the motion of the CCD camera abruptly to just the high speed of cloth motion.

4. Conclusion

A cloth weft densitometer using a CCD camera has been developed. Results from a preliminary experiment are as follows:

(1) The accuracy of the method is above 99% under conditions (2) and (3) below.
(2) The method is currently applicable for cloth velocities of less than about 10 m/sec.
(3) The method is applicable for all kinds of cloth having a clearly discernible weft.
(4) A 1-bit A/D converter, *i.e.*, using 2 steps, can be effectively used for this densitometer.

Two practicable methods have been proposed to solve the limitation on the velocity of cloth motion and are currently under investigation.

Table 1 Weft numbers/inch for all cloth types examined by the system shown in Fig.1.

Sample number	Weft numbers/inch	8bit A/D	1bit A/D
1	32	32	32
2	16	16	16
3	24	24	24
4	19	19	19
5	11	11	11
6	21	21	21
7	23	23	23
8	16	16	16
9	15	15	15
10	8	8	8

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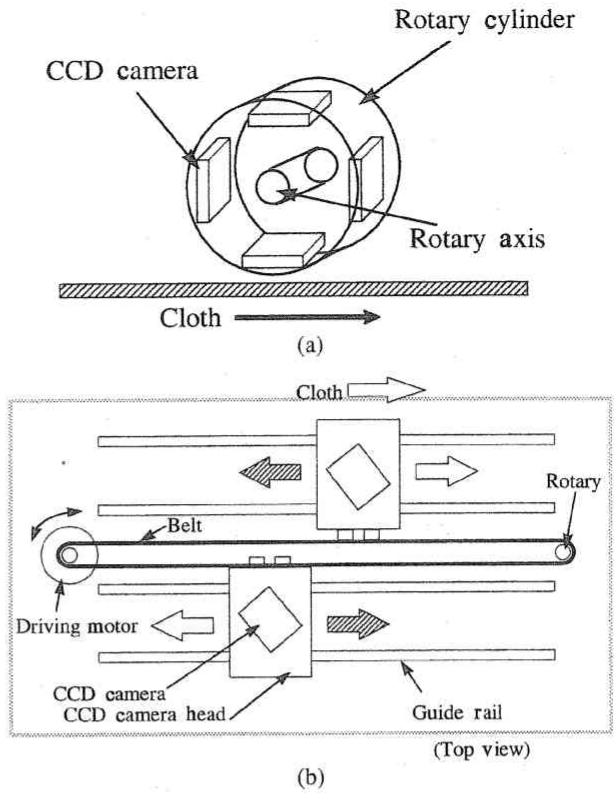

Fig.4 Two practical camera moving system with the speed of cloth motion using the rotary cylinder (a) and the belt conveyor (b).