Difference of Eye-Movements between Experts and Non-Experts in Fabric Inspection

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Abstract

Using a corneal reflection system consisting of an eye-mark recorder, were measured eye-movement, fixation time at a point and its frequency distribution and vector direction of eye-movements of experts and non-experts when inspecting fabrics moving on a plate or stopped on it. It was discussed what parts of the fabric were observed by inspectors, and how they recognized the part visually as fabric defects.

The results obtained are as follows.

- (1) When experts and non-experts inspect fabrics, their eye-movements are composed of the saccadic movement moving rapidly and the eye fixation at some characteristic parts of the fabric. When the fabric is moving at low speed, all experts and non-experts evaluate both sides of the fabric which may have valuable information.
- (2) The mean fixation time at one point on the fabric by experts is shorter than that by non-experts. The fact may be ascribed to the result of long training of experts who inspect fabric defects.
- (3) The eye-movement pattern shown by experts is almost unchanged irrespective of the fabric speed. But, the eye-movement pattern of non-experts is much different from that of experts in case of high speed fabric.

1. Introduction

The manufacturing process in textile industries depends on visual and tactual senses of workers. In fabric inspection process, many fabric defects are detected not by the automatic fabric inspection machine but by the visual sense of experts only. Many studies have been reported to automate this inspection process by the use of computer image processing technique^{[1]-[11]}.

But, the ability of automatic inspection was lower than that of visual inspection by experts. So it is necessary to examine the visual recognition and estimation by experts in order to develop a high-level inspection system. None of reports discussed the behavior of experts detecting fabric defects.

In this paper, using a corneal reflection system consisting of an eye-mark recorder, were measured eye-movement, fixation time at a intended point and its frequency distribution and vector direction of eye-movement of experts and non-experts when inspecting fabrics moving on a plate or stopped on it. Then, the difference of eye-movements between by experts and non-experts was discussed.

2. Experimental

The sample used in this study was a plain terry fabric, 70 cm wide and 130 cm long, with a hole(1 cm in diameter) in it. The distance between eyes of inspectors and the sample was held 130 cm. Inspectors were two non-experts and two experts.

As shown in Fig.1, the inspector, after putting an eye-mark recorder(EMR model V; Nac Inc.) on his head, examined the stopped or the moving sample. It was confirmed that inspectors didn't feel the eye-mark recorder heavy, as its weight was 0.8 kg.

(1) Visual Test(I)

The inspector searched the defect of the stopped fabric without time limit.

(2) Visual Test(II)

The inspector searched the defect of the fabric moving up at low speed(13.0 cm/s).

(3) Visual Test(III)

The inspector searched the defect of the fabric moving up at high speed(43.3 cm/s). This speed was the standard in inspecting terry fabrics.

Left and right eye-movements of the inspector were recorded by a video tape recorder while he was inspecting under three visual test conditions.

The video tape data were processed through a data

Fig.1 Inspecting scene
 (1)eye-mark recorder,(2)fabric,(3)video tape recorder, (4)light and (5)winding roller

processing apparatus, from which were obtained eye-movement record, frequency and time distribution of eye fixation points and vector direction of eye-movement.

3. Results and Discussion

3.1 Record of eye-movement

(a)

(b)

Fig.2 Eye-movement of experts and non-experts during inspecting the stopped fabric: (a)experts, (b)non-experts

Figures 2, 3 and 4 show records of eye-movements while experts and non-experts were inspecting the stopped or the moving fabrics, where x and y axes show angles(degrees) of the eye-movement in the horizontal and the vertical directions, and lines show the locus of eye-movement. The center of circle is the eye fixation point, and the length of the radius is the fixation time proportional to milliseconds. The square in Fig.2 shows the region of the stopped fabric, and two lines in Figs.3 and 4 show the edges of the moving fabric.

Figure 2 shows that both experts and non-experts inspect each part of the fabric in detail when the fabric stands still. But, the direction of eye-movement from one point to the other seems at random.

When inspecting the moving fabric at low speed, eyes of experts and non-experts moved not in the fabric running direction, but in the direction of fabric width as shown in Fig.3. It means that the visual inspection and recognition of defects is easier by the horizontal eye-movement than by the vertical eye-movement when inspecting the fabric moving vertically.

When inspecting the fabric moving at high speed, the eye-movement of experts is much different from that of non-experts.

Though the eye fixation points of experts decrease as the fabric speed increases, the eye-movement pattern is almost

(a)

(b)

Fig.3 Eye-movement of experts and non-experts during inspecting the fabric moving at 13.0 cm/s: (a)experts, (b)non-experts

(a)

(b)

Fig.4 Eye-movement of experts and non-experts during inspecting the fabric moving at 43.3 cm/s: (a)experts, (b)non-experts

unchanged irrespective of the speed as shown in Figs.3(a) and 4 (a).

On the other hand, non-experts cannot find the fabric defects in the same way, and his eyes move vertically to catch up with the moving fabric as the dotted area shown in Fig.4(b).

Non-experts can inspect the fabric moving at low speed(13.0 cm/s) within 10 seconds which is the mean inspecting time for the stopped fabric. But, when the inspecting time assigned for the fabric moving at high speed(43.3 cm/s) is 3 seconds, they cannot detect the defect. So, non-experts may only be able to inspect the area 910 cm² of the moving fabric per second to recognize the fabric defects visually.

3.2 Distribution of fixation points and vector of eye-movement

Figures 5 and 6 show the eye fixation and the time distributions of experts and non-experts inspecting the moving fabric at low speed. X and y coordinates show angles(degrees) of the eye-movement in the horizontal and the vertical directions on the same fabric. The height of pillar shows the number and the time for one fixation point.

Figures 5 and 6 show that both experts and non-experts watch both sides of the fabric with the mean fixation time

(a)

(b)

Fig.5 The eye fixation distribution of experts and non-experts during inspecting the fabric moving at 13.0 cm/s: (a)experts, (b)non-experts

(a)

(b)

Fig.6 The fixation time distribution of experts and non-experts during inspecting the fabric moving at 13.0 cm/s: (a)experts, (b)non-experts

of 0.11~0.13 seconds^[12]. So, these parts may be useful to get the most valuable and characteristic information.

When the plain terry fabric was checked, from which the sample used in this experiment was cut, the defects were mostly near the edges of the fabric. This agrees well with the eye-movement of this experiment.

Figure 7 shows the vector distribution of eye-movements by experts when the fabric moved at low and high speeds. In Fig.7, 0° indicates the eye-movements from the left hand to the right hand, 90° from the lower part to the upper part, 180° from the right hand to the left hand, and 270° from the upper part to the lower part. For example, point A shows the frequency of eye-movement amounts to 28%

Fig.7 Vector distributions of eye-movements of experts during inspecting the fabric moving at (a)13.0 cm/s and (b)43.3 cm/s

when the direction of eye-movement is 0~15°.

There was no difference between the vector distributions by experts and non-experts when the fabric was stopped or moved at low speed. Fig.7 shows that the eye-movement pattern shown by experts is almost unchanged no matter how the fabric speed is changed.

This may be due to the long experience of experts who had been inspecting fabric defects. Namely they moved their eyes to both sides of the fabric getting some valuable

information of defects quickly and effectively.

The speed of eye-movement from one fixation point to other points was for non-experts 3~490°/s when the fabric speed was 0 cm/s, 2~534°/s at 13.0 cm/s, and 5~512°/s at 43.3 cm/s. That for experts was 2~467°/s at 0 cm/s, 3~467°/s at 13.0 cm/s and 5~447°/s at 43.3 cm/s.

The eye-movement during the search of a moving object is composed of the smooth pursuit movement at low speed and the saccadic movement at very high speed. Man can recognize the moving object only at the speed below 5 °/s in the smooth pursuit movement^[13].

The percentage of the eye-movement speed under 5°/s was 2.2 % at 0 cm/s fabric speed, 3.8 % at 13.0 cm/s and 1.0 % at 43.3 cm/s for experts. That was 2.7 % at 0 cm/s, 9.3 % at 13.0 cm/s and 3.4% at 43.3 cm/s for non-experts. So, the eye-movement may be almost the saccadic movement, in which the visual information from the fabric seems to be obscure if the fabric speed is too fast.

Table 1 shows the relation between the moving speed of fabric and the number of eye fixation points, and that between the speed and the mean fixation time.

As shown in Table 1, the mean fixation time at one point on the fabric by experts is shorter than that by non-experts and the number of eye fixation points by experts are more than that by non-experts. This fact may be ascribed to the result of long training of experts who always inspect the fabric defects.

4. Conclusions

Using a corneal reflection method, the eye-movements by experts and non-experts were measured when inspecting the stopped or the moving fabrics. It was discussed what parts of the fabrics were observed by inspectors, and how they recognized the part visually as fabric defects.

The results obtained are as follows.

- (1)When experts and non-experts inspect fabrics, their eye-movements are composed of the saccadic movement moving rapidly and the eye fixation at some characteristic parts of the fabric.
- (2)When inspecting the stopped fabric, both experts and non-experts watch around all parts of the fabric.
- (3)When the fabric is moving at low speed, all experts and non-experts evaluate both sides of the fabric which may

Table 1 Relations between the moving speed of fabric and the fixation number, and between the speed and the mean fixation time

Moving speed of fabric	Number of eye-fixation points		Mean fixation time(ms)	
	Experts	Non-experts	Experts	Non-experts
0 cm/s	91	79	98	113
13.0cm/s	70	60	114	132
43.3cm/s	34	30	86	99

have valuable information.

(4)The eye-movement pattern of non-experts is much different from that of experts in case of high speed fabrics. In such case, non-experts cannot inspect fabric defects. The eye-movement pattern shown by experts is almost unchanged irrespective of the speed. This may be attributed to the long training to inspect fabric defects.

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