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Automatic evaluation of the appearance of seam puckers on suits using fractal dimensions

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Abstract

This paper deals with a fundamental method of automatic assessment of the appearance of seam puckers (SP) on suits. Taking the fractal dimensions of SPs as features, we process the problem as pattern recognition. Twenty suits were used for the evaluation experiment and we could obtain a result close to the human inspection. The result was also compared to the evaluation of our previous paper, where we used the wavelets transform to extract feature. The comparison result shows that the present method yields better evaluation than the system using the wavelet feature.

1 Introduction

Visual inspection of products or parts is one task within manufacturing that has been automated at comparatively slow pace. Recently, however, the techniques of visual inspection are studied and applied in many fields like forest products, paper, metal casting, steel, and textiles[1][2][3]. This paper studies a fundamental method of automatic evaluation of the appearence of SPs on suit and suggests the possibility of practical use. The International Organization for Standardization enacts the criterion to evaluate the appearence of SPs on suits into five categories (ISO 7770). The Japanese Industrial Organization for Standardization also provides a similar criteron (JIS L 1905). They provide five photographic standards as the reference for the assessment (Fig.1). At present, the assessment is done by assigning the number of photographic standards that most nearly matches the appearance of seam in the test specimen. In order to avoide the human errors, automatic evalution is desired.

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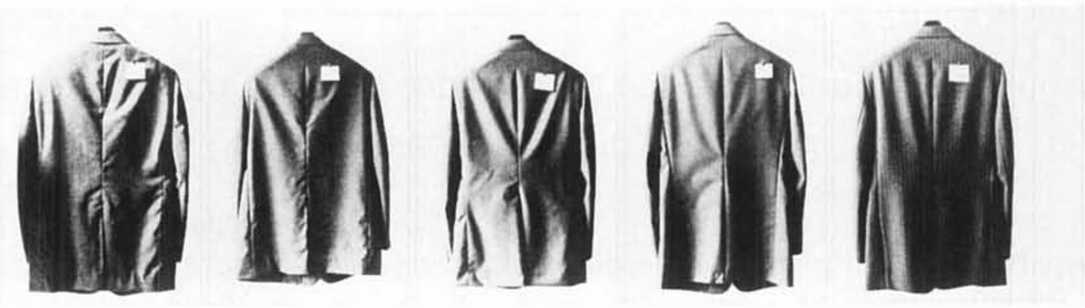
The related topics of this paper are the automatic defect detection / classification. In [4], a method of detection of defects in textiles using wavelet packets decomposition with statistical features is presdented, however, classification of defects is not considered. Detection method of small or low-contrast defects in web is proposed[5], but the classification is done only by the number of pixels in defects. Evalution of SPs is considered as a kind of the surface roughness classification. Although there are several papers about this topics, assessment of SPs is not studied[6].

The problem of evaluation of the appearance of SPs differs from the above papers in the following points: (1) reference patterns (Fig.1) are provided, (2) it is difficult to distinguish gray levels of texture of textiles from those of SPs.

In our previous papers[7][8], we used the Hough transform, the second-order statistics, and the wavelet transform to extract features of SPs from photographs of suits. We processed the problem as pattern recognition[7], The features extracted from the photographic standards are used as template patterns, those extracted from suits to be assessed are used as input patterns. In this paper, we use the fractal dimensions of SPs as the feature for the evaluation. Twenty suits are used for the assessment experiment. The result was very close to that of human inspection, and it suggests the possibility of automatic evaluation.

2 Preprocessing

Suits are made of many kinds of textiles, which have many different textures. In order to emphasize the images, if we apply gray level transform to images including no SPs, only textures are emphasized. In gray level images, the stressed textures are confused with SPs. Therefore, in the preprocessing,we must distinguish images with SPs from images with-



(a) class 1 (b) class 2 (c) class 3 (d) class 4 (e) class 5

Figure 1: Standard photographs for the assessment

out SPs. To images without SPs, we do not apply the gray level transform. For the discrimination, we note the fact that textures in suits are usually regular pattern, like striped pattern.

2.1 To Distinguish Image with SPs from One without SPs

Appearance of SPs is like that of an irregular pattern, whereas a texture is formed with regular iteration patterns. For a given image of $M \times N$, we calculate the variance σ_p^2, in the range of $p \times p$. Then we take the average, $ave\ \sigma_p^2$, according to the following equation,

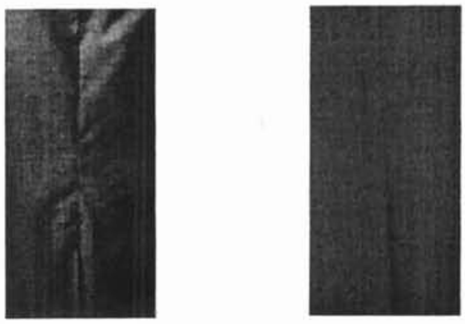
$$ave\ \sigma_p^2 = \frac{1}{(M-p+1)(N-p+1)p^2}$$

$$\sum_{i=0}^{M-p}\sum_{j=0}^{N-p}\sum_{k=0}^{p-1}\sum_{l=0}^{p-1}(f(i+k,j+l)-\bar{f}(i,j))^2 \quad (1)$$

$$(i=0,1,\cdots,M-1\ ,\ j=0,1,\cdots,N-1),$$

where $f(i,j)$ is a target image, and $\bar{f}(i,j)$ is an average of gray levels in the target region. If an image includes SPs, the image is irregular, consequently the $ave\ \sigma_p^2$ is large compared to the $ave\ \sigma_p^2$ obtained from an image of regular pattern (without SPs). An example of images with SPs and without SPs is shown in Fig.2. The $ave\ \sigma_p^2$ of Fig.2(a) and (b) is shown in Table 1. In the bottom row, the ratios $ave\ \sigma_{10}^2/ave\ \sigma_2^2$ are shown. The average ratio is small for image without SPs, as we expected. Experimentally, we set the value of threshold to discriminate the images at 3.3 ($ave\ \sigma_{10}^2/ave\ \sigma_2^2$).

Using this threshold value, we distinguish images including SPs from images without SPs.



(a) (b)

Figure 2: An example of images: (a) an image with SPs, (b) an image without SPs

Table 1: $ave\ \sigma_p^2(p=2,10)$ of Fig.2(a),(b)

	(a)	(b)
$ave\ \sigma_2^2$	44.55	8.00
$ave\ \sigma_{10}^2$	197.29	16.37
$ave\ \sigma_{10}^2/ave\ \sigma_2^2$	4.43	2.05

2.2 Contrast Transform

For images having SPs, the linear contrast transform is applied, but for images without SPs, the transform is not applied.

2.3 Filtering

For both transformed images and images to which the transform is not applied, the median filter, smoothing filter, then band-pass filter are applied. The band pass filter deletes noises and unnecessary low-(spatial)frequency information. We designed the bandpass filter using the discrete cosine transform(Type II). The transfer function of the bandpass filter is determined by the convolution of highpass filter and lowpass filter,

$$H(u,v) = \varepsilon^{-(D_H/D(u,v))^n - (D(u,v)/D_L)^n}, \quad (2)$$

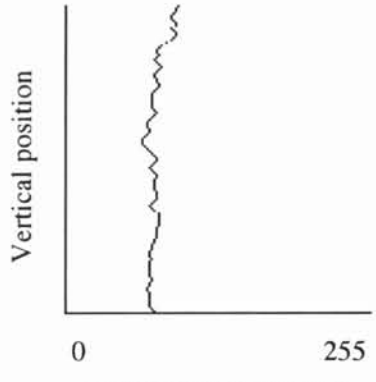
where $D_L(D_H)$ is the cut-off frequency of lowpass(highpass) filter, $D(u,v)$ is the distance to the origin of $u-v$ plane. In our experiment, we set $n=2$. We make the locus of the $D(u,v)$ elliptic as shown below,

$$D(u,v) = \sqrt{u^2 + (\frac{128}{16}v)^2}. \quad (3)$$

3 Feature Extraction

We cut a target portion (16×128) including SPs out of the central part of each photograph of Fig.1, as shown in Fig.2(a),(b). From these images we obtain the fractal dimensions. In order to make it easy to obtain the fractal dimension of the appearance of SPs, we calculate the average of gray levels in each horizontal line and plot the average value. For example, from the target image of Fig.3(a), we get the horizontal average gray level as shown in Fig.3(b). From the curve, we calculate the fractal dimensions using the mPD method[9],[10].

(a) Target image



(b) Resultant curve

Figure 3: Target image and plots of the horizontal average gray levels of (a)

The fractal dimensions (obtained from the five photographs) vs. the ratings of photographic standards are plotted in Fig.4. This curve shows that the interset distances are almost equal. This means that the fractal dimension is a good feature for the evaluation.

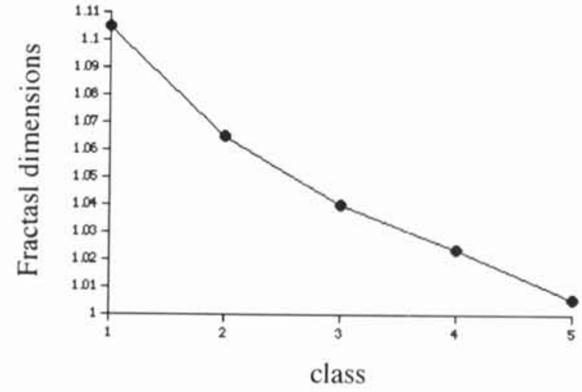


Figure 4: Features of Template Patterns

4 Assessment

The assessment is processed as the pattern recognition. For the evaluation we calculate,

$$D_i = |X - X_i| \quad , \quad (i = 1 \sim 5), \quad (4)$$

where X and X_i are the fractal dimensions of an input(test) sample and the photographic standards, respectively. If the D_i has the minimum value, we assign the rating i to the input sample. Using 20 suits, we made an evaluation experiment. In order to check the validity of the evaluation, the result of human visual inspection was used for reference, because at the present time it is the most general purpose vision system. As the human visual inspection, we took the average of the evaluations of ten students. We define the following value D, which indicates the deviation from the evaluation by human being,

$$D = |H - I|, \quad (5)$$

where H and I stand for the ratings determined by the human being and by the present system, respectively. The average value of D was 0.45. This means that the evaluation of the new method is close to that of human being.

5 Comparison with the Evaluation Based on the Wavelet Features

In[8], we proposed a method of assessment of the SPs based on the wavelet transform, where we used the Haar transform.The laveling of wavelet transform at the third step is shown in Fig.5.

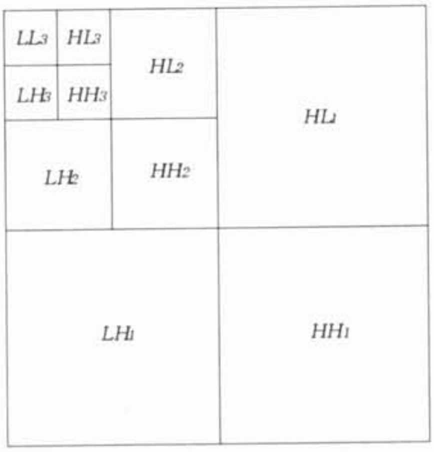


Figure 5: Laveling of wavelet transform at the 3rd step

We formed a feature vector C as follows:

$$C = (ALH_1, AHH_1, ALH_2, AHH_2, ALH_3, AHH_3), \quad (6)$$

where AXY_i indicates the average of the components of XY_i region. For the same samples used in the above experiment, we carried out the evaluation experiment using the feature vector of eq.(6). The average deviation D was 1.10. Comparing this value with the value 0.45 (in the case of fractal dimensions) we can say that the method proposed in this paper shows the noticeable improvement.

6 Conclusion

We have proposed a fundamental method of assessment of the appearance of SPs on suits, and have obtained a result almost similar to that of human inspetion. We distinguished images containing SPs from images without SPs, using the concept of variance. This played an important role for the good evaluation. Further, to calculate fractal dimensions of SPs, we got the curve containing the gray level variation of SPs. The result of experiment suggests that there is a possibility of the automatic assessment. For practical use, however, much efforts must be done. Methods of preprocessing, conditions of taking photographs, and the use of 3-D images are future problems to be studied.

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