Feeling Information Extraction from Characters

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Abstract: - An automated feature extraction and evaluation method of feeling information from printed and handwritten characters is proposed. This method is based on image processing and pattern recognition techniques. First, an input binarized pattern is transformed by a distance transformation. Second, a two-dimensional vector field is composed from the gradient of the distance distribution. Third, a divergence operator extracts source and sink points from the field, and also the vectors on those points. Fourth, the Fourier transform is done for the vector field as a complex valued function. Differently from conventional methods, we deal with the Fourier transform with Laplacian operated phase. Fifth, applying the KL expansion method to the data of the complex vectors obtained from some kinds of character fonts, we extract some common feature vectors of each character font. Using those common vectors and linear multiple regression model, an automated quantitative evaluation system can be constructed. The experimental results show that our vector field method using the combination of Fourier transform and KL expansion is considerably more efficient in the discrimination of printed characters (or fonts), comparing with conventional method using gray level (or binarized) character pattern and KL expansion. Moreover, we obtain the results that the evaluation system based on the regression model comparatively meets well to the human assessment.

Key-Words: - Feeling information, characters, image processing, vector field, Fourier transform, KL expansion, linear multiple regression model

1 Introduction
As a useful function for a self-education system of writing characters, we proposes a feature extraction method of feeling information from printed and handwritten characters, which is based on a vector field, its Fourier transform, and the Karuhen-Loeve (KL) expansion. In this method, an input binarized pattern is transformed by a distance transformation which can be considered as a diffusion process of pattern's shape information over the frame[1],[2]. Second, a two-dimensional vector field is constructed from the gradient of the distance distribution, where each vector on the character pattern locally represents the direction of the character's line or stroke [3]. The notion of the vector field comes from an analogy of electric field. Then, a divergence operator extracts third, source and sink points, and also the vectors on those points from the field. We consider that the vector field of those source and sink points gives features of the original character pattern. Fourth, the Fourier transformation is done for the vector field as a complex valued function. We notice that not only the amplitude spectrum but also the phase is important information for characters feature extraction.

Differently from conventional methods, we deal with the Fourier transformation with Laplacian operated phase to obtain the translation invariance of fonts, and we regard it as a high dimensional complex vector. Fifth, applying the KL expansion (or Principal Component Analysis) method [1] to the data of the complex vectors obtained from some kinds of character fonts, we extract some basic complex vectors, which are common feature vectors of font. We consider that the basic vectors correspond to the something of human feeling.

After those processing, we have implemented the automated quantitative visual evaluation system for the feeling of input character pattern, using those basic vectors above and linear multiple regression model [4]. From experimental results, we have found that our vector field method using the combination of Fourier transform and KL expansion is considerably more efficient in the discrimination of fonts, comparing with conventional method using gray level character pattern and KL expansion. Moreover, we obtain the results that the evaluation system based on the regression model comparatively meets well to the human assessment.
2 System Overview

The processing are composed of following seven steps. As feature extraction and analysis stage, the Step 1 through 6 are performed for some sets of the same font of characters in order to obtain the eigenspace of each font. Fig. 1 shows the example of five kinds of fonts (same size) and ten printed character patterns in each font. We feel very differently from them. For example, some fonts seem to be hard or very soft.

2.1 Feature Extraction Stage
Step 1: a distance transformation for input binarized pattern.
Step 2: construction of a two-dimensional vector field from the gradient of the distance distribution.
Step 3: extraction of feature points vector field which means two-dimensional vectors at source and sink points in the constructed vector field at Step 2, using a divergence operator.
Step 4: Fourier transform for the resultant vector field at Step 3, dealing with the field as a mathematical complex-valued function (or equivalently complex vector).
Step 5: Laplacian operation on the phase of the Fourier Transform.
Step 6: Karhunen-Loeve (KL) expansion (or Principal Component Analysis) and eigenspace extraction for the set of the complex-valued functions obtained from some kinds of character fonts (or letter fonts).

2.2 Learning Stage in the System
We deal with the processed pattern as a high-dimensional complex vector. The next step is carried out for learning the human feeling, based on linear regression model.
Step 7: Construction of the evaluation function by linear combination of the inner product between the resultant complex vector at Step 5 and orthonormalized eigenvectors of KL expansion, and correspondence between the output value and human feeling.

Fig.2 shows the above linear regression model for learning and evaluation of character’s feeling. In the figure, \( x_1, x_2, \ldots, x_n \) are the aforementioned values of inner products at Step 7. The coefficients \( b1 \) through \( bn \) are decided by making correspondence between the output value \( Y \) and the degree of human feeling, as an analysis and learning processing. After this decision (or learning), we expect that the system can output the degree of feeling in the same way as human being.

3 Feature Extraction

3.1 Vector Field
As mentioned in the Section 2, we use a distance transformation (Step 1) and a vector field to enhance the boundary shape of character pattern (Step 2). And also, we extract a feature points vector field by a divergence operator to acquire the structural information of the pattern (Step 3), as shown in Fig.3.

3.2 Modified Fourier Transform
The feeling for character fonts is insensitive to the positional translation. Then, we have to extract the translation invariant features of pattern to build an evaluation system of the feeling. Conventionally, the amplitude spectrum of Fourier transform of character pattern has been used. But the spectrum loses much information on the original shape of character pattern. To obtain the feature information as much as possible, we have to notice not only the amplitude spectrum but also the phase as important information on feature. Then we deal with a Fourier transform where Laplacian operates the phase, because, also from the transform, we can extract the translation invariant.

[Definition 1] (Fourier Transform)
Let \( x \) and \( \omega \) be two-dimensional positional vectors in real plane and frequency domain, respectively. And, let \( F(\omega) \) be the Fourier transform of \( f(x) \). \( F(\omega) \) is represented as follows.

\[
F(\omega) = \int f(x) \cdot \exp[-j\omega \cdot x] d\mu(x)
\]

And, \( F(\omega) \) is complex valued function, so it is also represented as

\[
F(\omega) = |F(\omega)| \exp j\theta(\omega), \quad \text{where } |F(\omega)| \text{ and } \theta(\omega)
\]

are called amplitude spectrum and phase, respectively. Fig. 4 shows the amplitude spectrum of binarized character pattern, and also shows the amplitude spectrum of its feature points vector field. We can see that the feature points vector field enhances the difference of character pattern (or font).

[Definition 2] (Modified Fourier Transform)
Letting Laplacian operate the phase of Fourier Transform, we have the following modified Fourier Transform.

\[
F^*(\omega) = |F(\omega)| \exp j\{\nabla^2 \theta(\omega)\},
\]

where \( \nabla^2 = \frac{\partial^2}{\partial \omega_1^2} + \frac{\partial^2}{\partial \omega_2^2} \).

We can easily prove that the Laplacian operated phase is shift invariant of input pattern. Then, the modified Fourier Transform is also shift invariant.
The Fourier transformation with Laplacian operated phase is performed at Step 4 and 5 in Section 2.

3.3 Common Features by KL Expansion and Selection of the Number of Eigenvectors
We can extract common features of the same font patterns as a set of eigenvectors spanning the eigenspace, using KL expansion. Utilizing this nature, we can obtain the eigenspaces of Chinese character fonts such as Mincho style, Gothic style, Kaisho style, Sosho style, and Gyoshio style (see Fig.1). Moreover, we can choose the suitable number of the eigenvectors in order to sufficiently discriminate among the eigenspaces of various fonts, using the following measure.

[Definition 3] (Same Font Similarity $S_{\text{sim}}(i,j)$ and Different Font Similarity $D_{\text{sim}}(i,j)$)

Same Font Similarity in Type $i$ font is defined as the minimum energy value of projected vectors (belonging to the same font type) into the $j$ dimensional eigenspace of the Type $i$ font, in the following:

$$S_{\text{sim}}(i, j) = \min \left\{ \sum_{k=1}^{j} \left| \langle u_{ik} \mid F_s^{+} \rangle \right|^2 \right\},$$

$$F_s^{+} \in \text{TYPE} \ (i),$$

where $u_{ik}$ is the $k$th eigenvector whose corresponding eigenvalue is the $k$th greatest in the eigenspace of Type $i$ font.

Similarly, Different Font Similarity in Type $i$ font is defined as the maximum energy value of projected vectors (not belonging to the Type $i$ font) into the $j$ dimensional eigenspace of the Type $i$ font, in the following:

$$D_{\text{sim}}(i, j) = \max \left\{ \sum_{k=1}^{j} \left| \langle u_{ik} \mid F_D^{+} \rangle \right|^2 \right\},$$

$$F_D^{+} \notin \text{TYPE} \ (i).$$

[Definition 4] (Separation Degree $SD(j)$)

The Separation Degree of $j$ dimensional eigenspace is defined as the minimum of the differences in all fonts, in the following.

$$SD(j) = \min_{i} \{S_{\text{sim}}(i, j) - D_{\text{sim}}(i, j)\}$$

If this separation degree is positive for some $j$, it means that the discrimination is possible for various fonts with the $j$ dimensional eigenspace. And it also means that the less the number $j$ is, the more effective the image processing is for the feature extraction of fonts.

3.4 Evaluation Model

To automatically evaluate the feeling of the character pattern, we have to construct the evaluation function, at the aforementioned Step 7 in Section 2. For the simplicity, we have adopted a linear regression model. And, as basic variables in the model, we have chosen the inner products between the feature extracted pattern (or complex vector after the Fourier transform) and orthonormalized eigenvectors. In other words, we select basic general vectors from common feature vectors of each font, for all character patterns, at each item. Then, the output of the function becomes a linear combination of those inner products, and this function is set for each item of feeling. To decide the constant coefficients in the linear combination, we give the degree of our feeling for character pattern to computer. For example, if we feel "soft" from a font pattern, we input the degree of the feeling by five levels to the computer, such as "four". The degree is based on the five-level evaluation, and we make the computer estimate the coefficients by least mean square error method.

4 Experimentation

We have experimented the proposed method to the fifty printed characters and some other handwritten characters of nine categories by fifteen persons. As evaluation items of feeling for character pattern, we have chosen four items, such as (1) hard, (2) strong, (3) good, (4) easy to read, hard to read. The data of evaluation, that we have given to the computer at the learning stage, are gathered by questionnaires of forty persons. And, the evaluation value at each feeling item is the average of the forty persons’ values.

In the experimentation, we have also used the conventional methods for comparison; that is, we have also dealt with gray level (or binarized) character patterns, spectrum of the Fourier transform and KL expansion.

From the results, we have found that our vector field method using the combination of modified Fourier transform and KL expansion is considerably more efficient in the discrimination of fonts, than conventional method using gray level character pattern and KL expansion. And, we have had the result that the worst mean error of outputs in all items for
each character pattern (learned printed characters) is 0.36. Considering that the output is based on five levels, we can see that the system comparatively meets well to the human assessment, for learned character patterns (see Fig.5).

5 Conclusion
We have presented a feature extraction and evaluation method for the feelings of character patterns, in the same way as human being. This research has been done in order that computer can automatically evaluate the character’s feeling and that it can have intelligent education system of writing. In the evaluation method, we use some image processing and mathematical tools such as distance transformation, vector field, Fourier transform, KL expansion, and linear regression model, for the effective extraction and enhancement of features of character font. The experimental results comparatively meet well to the human assessment, for learned character patterns.

Although we have done the research for printed characters (fonts) so far, we consider that this method will be promising also for the evaluation of handwritten character patterns.

References:

Figure 1. Example of five kinds of fonts (same size) and ten printed character patterns in each font

Figure 2. Evaluation system by linear regression model.

Figure 3. Feature points vector field of “聞く” (which means large).
Figure 4. Example of the amplitude spectrum of Fourier Transform of feature points vector field. (Upper and lower figures mean the correspondent amplitude spectrum in different image processing.)

Figure 5. Comparison between human assessment and automated evaluation for learned patterns. (Left circle means the human assessment and right the automated evaluation.)