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1/f Fluctuation in Japanese Brush Calligraphy

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Abstract. Image data of original Japanese brush calligraphy works are read by an image scanner and are transmitted to a host computer (HITAC 660H). The data are analyzed there by the autocorrelation method and the Fourier spectroscopic method with the aid of high level computer languages. Another specimen in which the same sentences as the original work are printed in the Ming-style type letters is also analyzed by the above methods. By comparing the power spectrum of the cursive letter specimen with that of the Ming-style type letter specimen, the source of beauty of Japanese brush calligraphy works is studied quantitatively.

1. Introduction

The beauty of Japanese brush calligraphy works may be discussed from various points of view. In the present study, we focus our attention to the structural difference between the original cursive specimen and the specimen printed in the Ming-style type letters. We expect the beauty of Japanese brush calligraphy works is closely related to the spatial distribution of black (or white) parts in the limited two-dimentional space. If the characters are distributed completely in random or periodic positions, there would be no artistic value at all. There is an artistic correlation between the characters in a good calligraphy work. What kind of correlation of characters looks beautiful? In the present work, we try to answer the question by the computer analysis of the structure of the cursive specimen and that of the Ming-style type letter specimen. This study is very special in itself, however, it is closely related to today's important problems of sciences and engineering: architecture of future computer, man-machine interface, artificial intelligence pattern recognition, ordering process in physical systems, etc. The results obtained in the present experiment is discussed in relation to 1/f fluctuation phenomena which are universally observed in the different fields of sciences.

2. Experimental Method

The first stage of the present study is the data input process. An image scanner and a work station (HITACHI 2020) are used to read the image of Japanese brush calligraphy works. The data obtained by the image scanner is a two-dimensional array of binary quantities. Namely, an image of Japanese brush calligraphy works is expressed in the computer by a two-dimensional array of black and white dots. The finest array obtainable by the present device is 300 dots/inch. Since the original work has a continuous degree of darkness and the obtained data is binary, there is a loss of information in the data input process. Figure 1 shows (A) a photo of the original work and (B) a printed picture which is reproduced as faithfully as possible from the data obtained by the image scanner. It is seen from these pictures that the degree of the loss of information is not so serious that it destroys the artistic balance between the block and the white area of the original work. While, the soft touch of the faint parts of the original work is lost in the reproduced picture.

The two-dimensional image data of Japanese brush calligraphy works stored temporally in the work station are transmitted into a host computer (HITAC 660H), where various kind of analyses and processing of the image data are possible with the aid of high level programming languages. The author developed a file convert software which changes the image scanner data into a Fortran data.

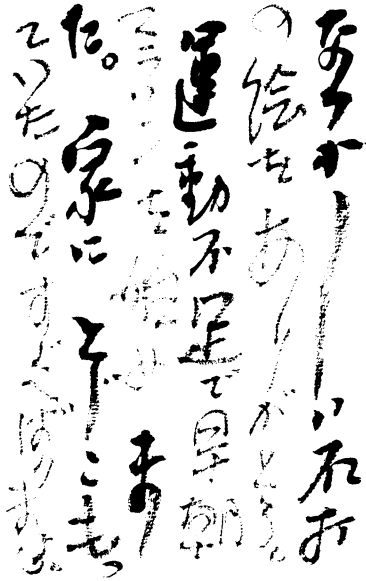
In the present study, the autocorrelation method and the Fourier analysis are used to examine the image data. The autocorrelation function is defined by the following equation:

$$F_{cor}(\boldsymbol{d}) = \int A(\boldsymbol{r}) \cdot A(\boldsymbol{r} + \boldsymbol{d}) \boldsymbol{dr} / \int A(\boldsymbol{r})^2 \boldsymbol{dr}$$

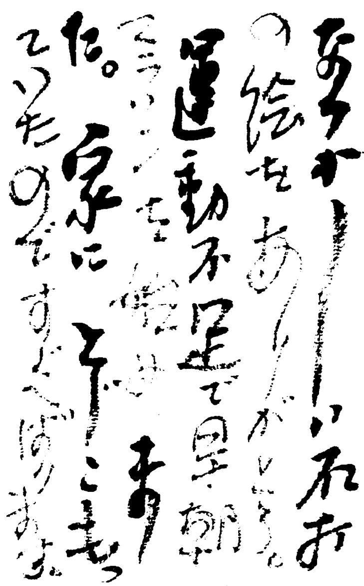
where $A(\boldsymbol{r})$ is an image data function, $\boldsymbol{r}$ the position vector on the image plane and $\boldsymbol{d}$ is the displacement vector. The power spectrum of the image data function is easily obtained by the Fourier transformation of the autocorrelation function(1). The details of the file convert software and the image data processing technique are described elsewhere(2).

3. Results and Discussion

Two kinds of specimens are prepared for the computer analysis of the structural beauty of Japanese brush calligraphy. One is the original calligraphy work and the other is the sentences which are same as the original work and are printed in the Ming-style type letters. Figure 2 shows the examples of these



(A)



(B)

Fig. 1. (A) a photo of an original work of Japanese brush calligraphy; (B) a picture reproduced from the image scanner data of the original work.

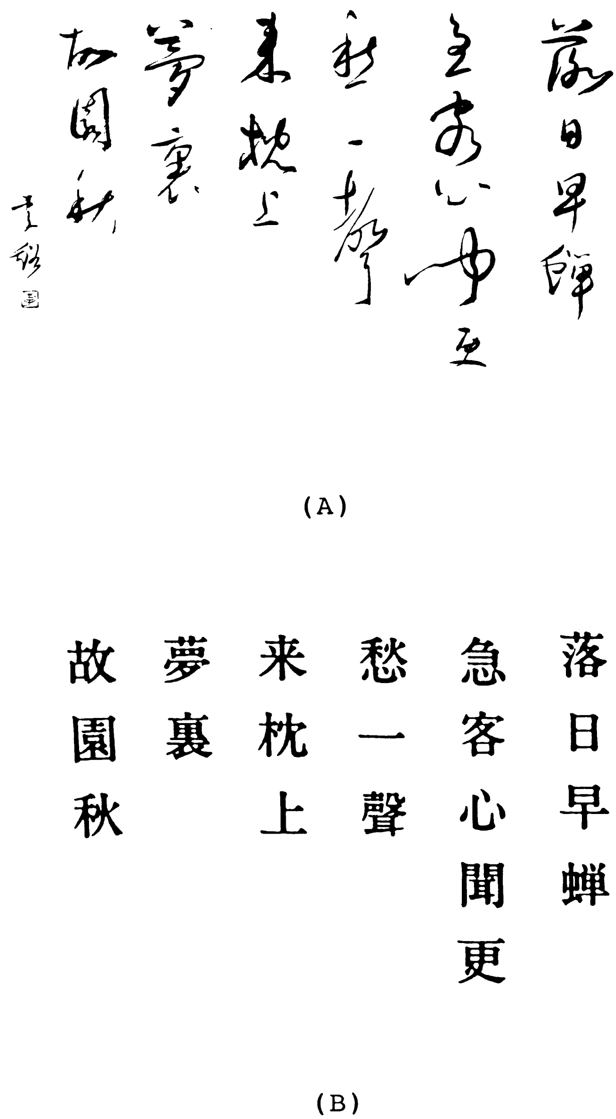


Fig. 2. (A) an original work specimen; (B) a Ming-style type letter specimen.

specimens: (A) an original work and (B) a type letter specimen. In the latter specimen, the Ming-style type letters of a definite size are arranged in almost the same positions as the original work.

Figures 3(A) and 3(B) show the autocorrelation function of the specimen (A) in Fig. 2 and that of the specimen (B) in Fig. 2, respectively, Here, the correlation function is calculated in the direction of the vertical row (downward). A waving structure is seen in the tail part of the autocorrelation function of the type letter specimen. This is reflected by the fact that the arrangement of the type letters is more periodic than that of the cursive letters. The Figure 4 shows the power spectra given by the Fourier transformation of the autocorrelation function: (A) the power spectrum of the original work, and (B) that of the type letter specimen. It is seen from these figures that the power spectra are proportional to the inverse of the frequency f in the range of low frequencies. The broken lines in the figure show the 1/f dependence of the power spectrum. It should be noted that the 1/f power spectrum of the original work is rather smooth, while that of the type letter specimen is modified by some sharp peaks.

Almost the same behaviors as the above are seen in all specimens examined in the present study; these include the Kaisho (non-abbreviated and non-deformed style of Kanji character), the Gyousho (partly abbreviated and deformed style of Kanji character), the Sousho (fully deformed style of Kanji) and the Kana works (the mixed use of Kana letters and the Sousho characters) and the smoothness of the 1/f spectra of the original works increases in this sequence. Figure 5 shows the power spectrum of the Kana work given in Fig. 1. The data line fits well to the broken line (the 1/f structure) in the range of the low frequencies. When we note the fact that the most smooth 1/f structure is seen in the power spectrum of the Kana works, we can conclude that the smoothness of the 1/f spectrum is a measure of the fluency of the brush traces in the calligraphy work, which is one aspect of the beauty of Japanese brush calligraphy.

The 1/f power spectra have been observed by many workers in physiological phenomena of living body (α-brain wave, frequency fluctuation of human pulse, etc.) and also in natural phenomena from which we receive good feelings (breathing of natural wind, frequency fluctuation of classical music, etc.)[(3)]. It has often been said that the fluctuation which is characterized by the 1/f power spectrum is a source of pleasant feeling. In this context, we consider that the smooth 1/f power spectra observed in the Sousho and the Kana works is caused by the fluent movement of the brush whose traces we feel beautiful.

As seen in the above, we examined the structure of Japanese calligraphy works by using the autocorrelation function and the power spectrum. There will be many other approaches to the computer recognition of the beauty of the calligraphy works. The examples of the problems to be discussed in the next stage of our study are the following. What kind of parameter successfully describe the beauty of the Kaisho works? How do we recognize the Houhitsu (sharp touch of brush calligraphy) and the Enhitsu (rounded touch of that) by means of computer? How do we quantitatively express the mixing degree of the Houhitsu and the Enhitsu touches in a particular work? (The author considers this as an important parameter for the characterization of the beauty of the brush calligraphy works.) How does the diffusive motion of Japanese ink on the drawing paper relate to the beauty of the

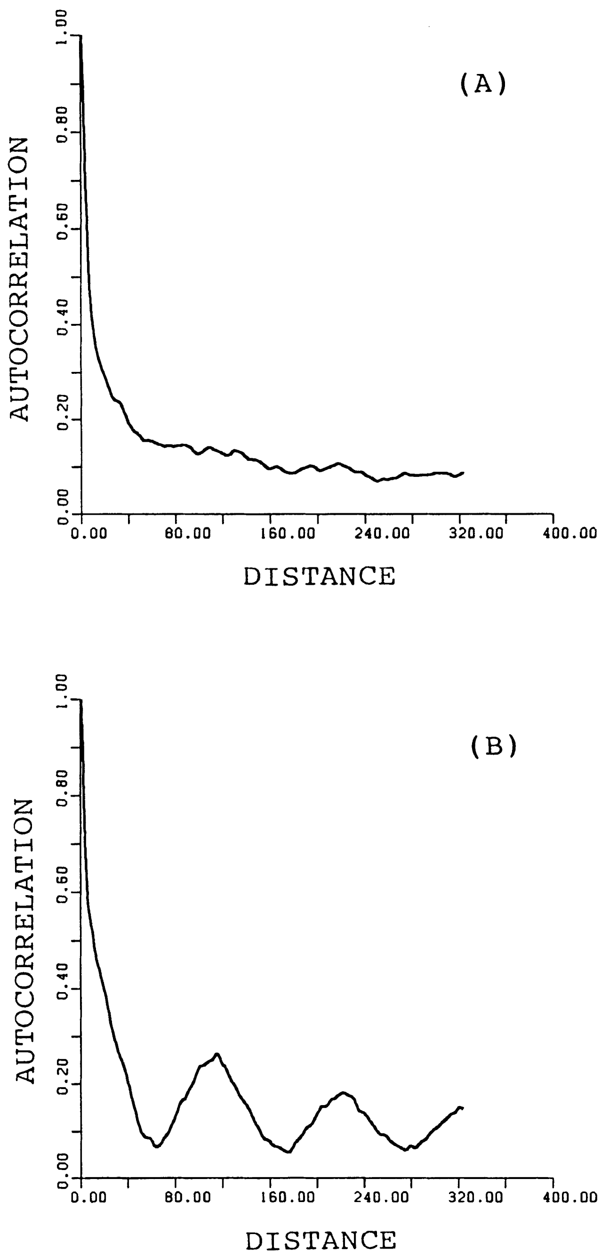


Fig. 3. (A) the autocorrelation function of the original work specimen in Fig. 2; (B) that of the type letter specimen in Fig. 2.

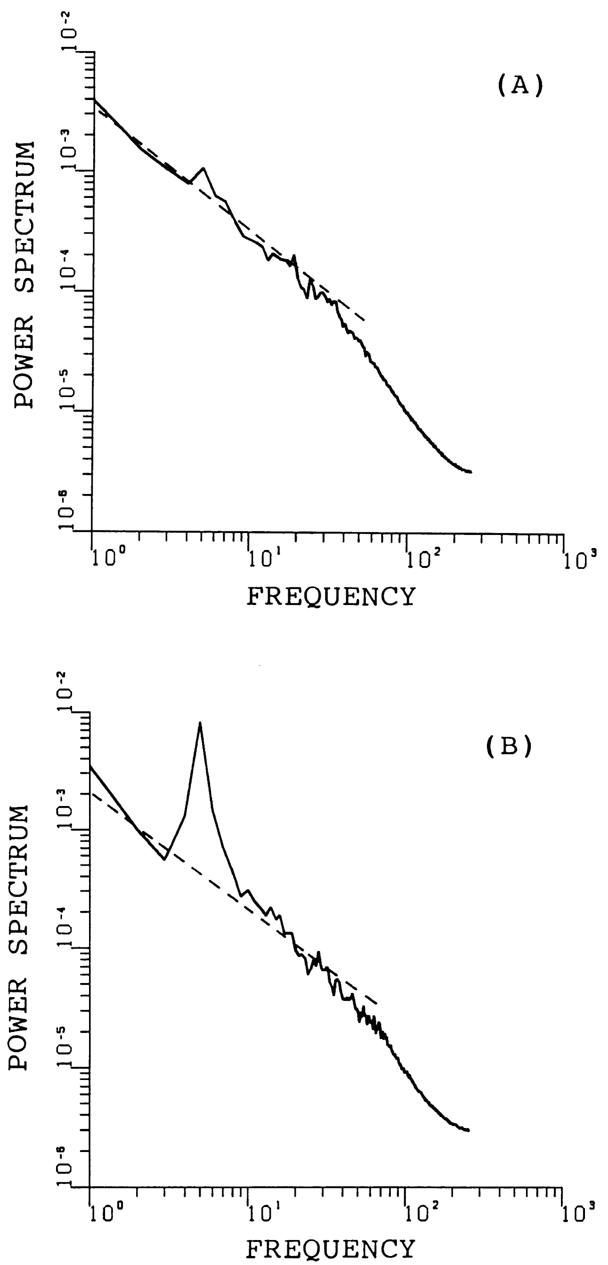


Fig. 4. (A) the power spectrum of the original work specimen in Fig. 2; (B) that of the type letter specimen in Fig. 2. The broken lines show the 1/f dependences of the power spectrum.

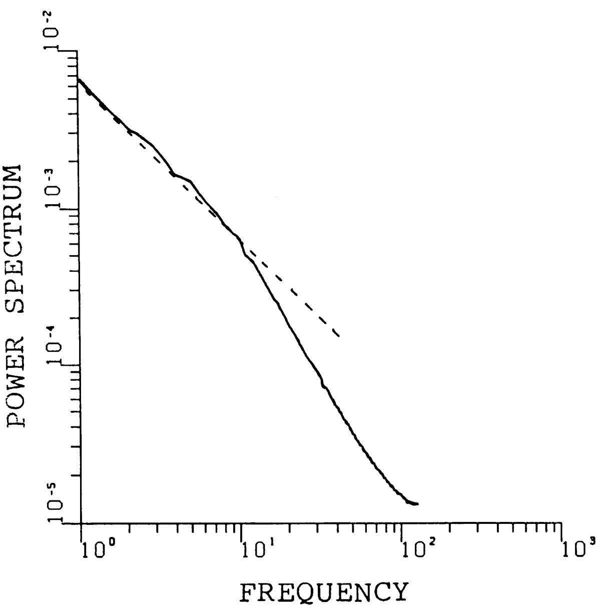


Fig. 5. The power spectrum of the Kana work given in Fig. 1. The broken line shows the 1/f dependence of the power spctrum.

work? How does the area of the grazing touch in the work influence upon its structural beauty?

It is quite interesting to note that the answers for these questions are closely related to the ability of the computer we now use. Usually, the actual research is so planned that the answer is obtainable in the framework of the ability of the present computer. Only a computer of future architecture is able to give an answer in a future fashion. The author consider that, in the architecture of future computer, a quite new system is required for the treatment of the many body problems. Trailblazing study on the future computer architecture is needed for this purpose. We can say that presenting a question to which today's computer can not give a suitable answer is the first stage for the development of future computer. In this sense, we consider that the full recognition of the beauty of Japanese brush calligraphy works by means of computer is one of the most important problems of today's science and engineering.

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