Method for 1/f Fluctuation Component Extraction from Images and Its Application to Improve Kurume Kasuri Quality Estimation

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***Abstract*—Method for 1/f fluctuation component extraction from images is proposed. As an application of the proposed method, Kurume Kasuri textile quality evaluation is also proposed. Frequency component analysis is used for 1/f fluctuation component extraction. Also, an attempt is conducted to discriminate the typical Kurume Kasuri textile quality, (1) Relatively smooth edge lines are included in the Kurume Kasuri textile patterns, (2) Relatively non-smooth edge lines are included in the patterns, (3) Between both of patterns (1) and (2) by using template matching method of FLANN of OpenCV. Through experiments, it is found that the proposed method does work for extraction of 1/f fluctuation component and also found that Kurume Kasuri textile quality can be done with the result of 1/f fluctuation component extraction.**

***Keywords*—1/f fluctuation component extraction; Kurume Kasuri textile quality; FLANN; OpenCV**

I. Introduction

Many natural objects in the natural world are known to have fluctuations. Fluctuation is a partly random spatial and temporal fluctuation while following a certain average. 1/f fluctuations can be seen in temporal color changes such as autumn leaves, the rhythm of sea waves, and human heartbeats. Depending on the interpretation of fluctuations, the results are often highly hypothetical or oversimplified. It is considered to be of great significance.

Complex phenomena and shapes in the natural world include unpredictable subtle differences and unpredictable disturbances, and it has been reported that both these complex phenomena and irregular shapes follow the regularity of fluctuations. However, little research has been done on the relationship between color schemes and fluctuations. If there is a color scheme that shows 1/f fluctuation, it can be used in various fields such as interiors, exteriors, and urban planning.

It may say that beautifulness of drawings, textiles and the other images can be explained with 1/f fluctuations. 1/f fluctuation has the effect of suppressing the excitement of the sympathetic nerves and has the effect of making the listening side relaxed, comfortable, and sleepy. 1/f noise is a signal or process with a frequency spectrum such that the power spectral density (power per frequency interval) is inversely proportional to the frequency of the signal. In pink noise, each octave interval (halving or doubling in frequency) carries an equal amount of noise energy.

1/f noise is one of the most common signals in biological systems [1]. The name arises from the pink appearance of visible light with this power spectrum [2]. This is in contrast with white noise which has equal intensity per frequency interval. Within the scientific literature the term 1/f noise is sometimes used loosely to refer to any noise with a power spectral density of the form $S(f) \propto 1/f^{\alpha}$, where f is frequency, and $0 < \alpha < 2$, with exponent α usually close to 1. The canonical case with $\alpha = 1$ is called pink noise [3].

General $1/f^{\alpha}$-like noises occur widely in nature and are a source of considerable interest in many fields. The distinction between the noises with α near one and those with a broad range of α approximately corresponds to a much more basic distinction. The former (narrow sense) generally come from condensed-matter systems in quasi-equilibrium, as discussed below [4]. The latter (broader sense) generally correspond to a wide range of non-equilibrium driven dynamical systems.

Pink noise sources include flicker noise in electronic devices. In their study of fractional Brownian motion [5], Mandelbrot and Van Ness proposed the name fractional noise (sometimes since called fractal noise) to describe $1/f^{\alpha}$ noises for which the exponent α is not an even integer [6], or that are fractional derivatives of Brownian ($1/f^2$) noise.

As for methods of 1/f fluctuation extraction, frequency component analysis is usually used. Namely, (1) extract frequency components from signal sources, first and then, (2) α is calculated from the components. The proposed method allows extraction of frequency components from images in concern using Fast Fourier Transformation: FFT, or Discrete Cosine Transformation: DCT, and also, calculate α from the components. After that, image quality, in terms of textile of the images is evaluated.

As one of the applications of the proposed method, Kurume (Name of the city in Japan) Kasuri textile quality evaluation is conducted. Because humans feel comfortable with the 1/f fluctuation pattern. Therefore, Kurume Kasuri textile quality can be evaluated with the extracted 1/f fluctuation components. Kurume Kasuri is a traditional cotton fabric from the Chikugo region, Japan. By dyeing the cotton yarns first and then weaving them, slight shifts in the pattern occur. Such pattern shifts create a unique "texture" of the fabric, which is one of the main characteristics of Kurume Kasuri. It is also the appealing point of Kurume Kasuri.

There is a problem about the degree in the pattern shift. A moderate amount of pattern shifting brings out a good texture, but if the shifting is too large, the product will not sell, and the fabric has to be sold at a lower price. The problem is that the judgements of the degree of shifting by weavers and dealers are not always the same. In addition, it is necessary to adjust yarns at the stage of weaving Kurume Kasuri, but it is extremely difficult for inexperienced craftsmen (young people) to adjust yarns to achieve a moderate pattern shift. Furthermore, since skilled craftsmen adjust yarns based on their many years of experience and intuition, it is difficult to pass on their tacit knowledge, and there is a shortage of successors. Therefore, a system which can show the acceptable degree of shifting of patterns will help both weavers and dealers for their judgements, and will also improve quality. Furthermore, tacit knowledge can be passed on to younger weavers as explicit knowledge, thus supporting weavers who are suffering from a shortage of successors.

We will use image recognition technology to evaluate the texture (quality) of Kurume Kasuri and build a system to classify whether or not the texture is acceptable as a high-quality (whether or not the pattern shift (or misalignment) is within an acceptable range). By using Artificial Intelligence: AI technology, the team will challenge to make the advanced skills (tacit knowledge) of Kurume Kasuri craftsmen explicit on a computer screen.

In the next section, related research works are described followed by research background and theoretical background. Then, the proposed system is described at first followed by some experiments are described together with conclusion and some discussions.

II. Related Research Works

There is the following quality evaluation related papers,

Method for video data compression based on space and time domain seam carving maintaining original quality when it is replayed is proposed [7]. 3D skeleton model derived from Kinect depth sensor camera and its application to walking style quality evaluations is also proposed [8].

Quality flag of GOSAT/FTS products taking into account estimation reliability is proposed and evaluated with actual remote sensing satellite data [9]. Then report on vicarious calibration and image quality valuation of LISA/LISAT (Optical sensor onboard remote sensing satellite) is reported [10] together with methods for vicarious calibration and image quality evaluation of LISA/LISAT [11].

On the other hand, there are the following papers which deal with frequency component analysis,

Polarimetric SAR image classification with high frequency component derived from wavelet multi resolution analysis: MRA is proposed [12]. Meanwhile, hearing aid method by equalizing frequency response of phoneme extracted from human voice is proposed [13].

Incorporating frequency filtering into the tensor singular value decomposition (t-SVD) in robust tensor principal component analysis (RTPCA) is shown to improve the performance of RTPCA [14]. A sensitive frequency component analysis method for cavitation fault using Empirical Mode Decomposition (EMD) method, Fourier Transform and neural network is also proposed [15].

Meanwhile, there are the following papers which deal with noise analysis,

A method of speckle noise reduction for SAR data is proposed [16] together with a new method for SAR speckle noise reduction (Chi Square Filter: CSF) [17]. On the other hand, sensitivity analysis of Fourier Transformation Spectrometer: (FTS) against observation noise on retrievals of carbon dioxide and methane is conducted [18].

Noise suppressing edge enhancement based on Genetic Algorithm (GA) taking into account complexity of target image measured with Fractal dimension is proposed [19]. Meantime, a method for aerosol parameter estimation error analysis is proposed with a consideration of noises included in the measured solar direct and diffuse irradiance [20].

Method of noise reduction in passive remote sensing is proposed for noise and clutter rejection [21]. On the other hand, speckle noise removal of SAR images with Digital Elevation Model: DEM is proposed [22] together with a new method for SAR speckle noise reduction by Chi-Square test filter is proposed and validated with real SAR imagery data [23].

In addition, the higher-order detrending moving-average cross-correlation analysis (DMCA) is proposed to show that physical activity in daily life has a common long-range correlate with heart rate (HR) variability that shows 1/f fluctuation [24].

III. Theoretical Background and Proposed Method

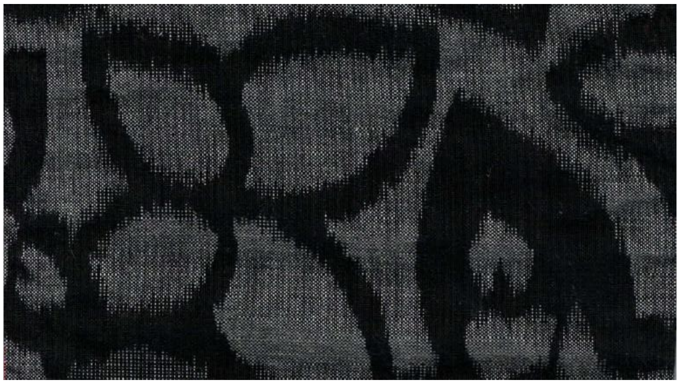
We will evaluate the texture (quality) of Kurume Kasuri, build a system to classify whether it is an appropriate texture (whether the pattern shift is within the acceptable), and verify it.

A. *Examples of Fluctuation Pattern of Kurume Kasuri*

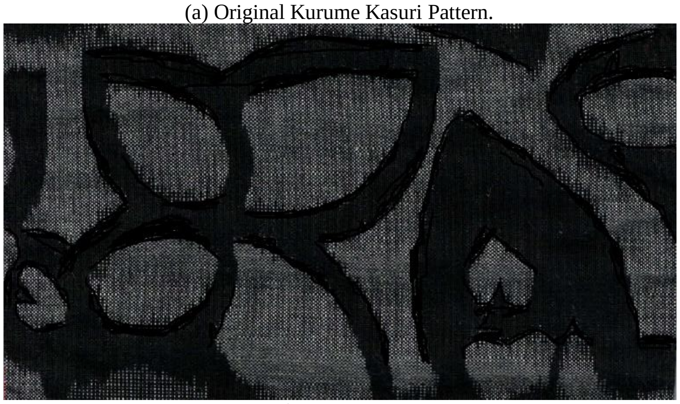
Fig. 1(a) shows one of the examples of the fluctuation patterns of Kurume Kasuri. As shown in Fig. 1, due to the irregular weaving timing of the loom, the Kasuri pattern does not become linear.

This non-smooth Kasuri pattern has a quaint texture and seems beautiful to the human eye. To put it the other way around, a smooth Kasuri pattern is boring and tasteless to the human eye. For instance, if the pattern edge of the current image in Fig. 1(a) is artificially smoothened, the pattern will be dull and boring as shown in Fig. 1(b).

DCT is applied to these patterns of Fig. 1(a) and (b), then Fig. 2(a) and (b) are obtained. High frequency components of the original pattern are smaller than that of the artificially smoothened edge pattern.

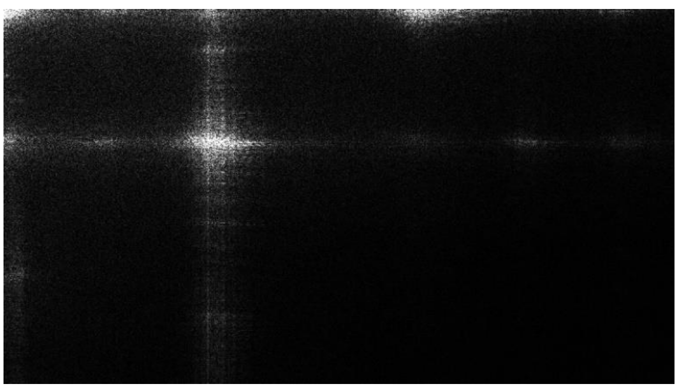


(a) Original Kurume Kasuri Pattern.

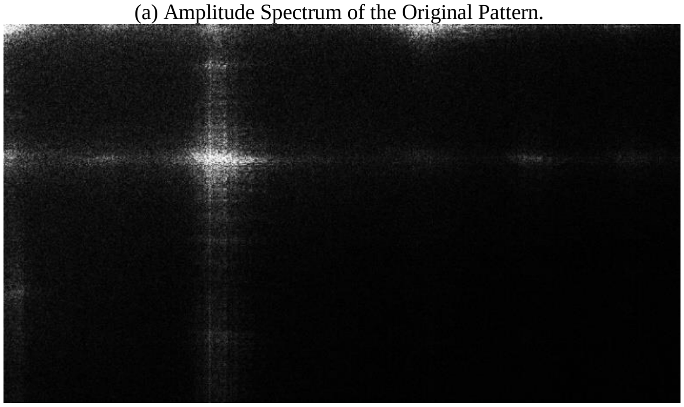


(b) Artificially Smoothened.

Fig. 1. One of the Examples of Kurume Kasuri Pattern and its Artificially Smoothened Pattern.



(a) Amplitude Spectrum of the Original Pattern.



(b) Amplitude Spectrum of the Artificially Smoothened Pattern.

Fig. 2. Amplitude Spectra of the Original and the Artificially Smoothened Patterns of Kurume Kasuri.

B. Procedure of the Proposed Method

The procedure of the proposed method is as follows:

1) Extraction and accumulation of image data for learning: Only the pattern part is cut out from the image of Kurume Kasuri (Fig. 3) by image processing by OpenCV.

2) Comparison of the number of feature points: Detect the feature points of the image obtained in 1), and compare the number of feature points with the ideal pattern and other features.

3) Comparison with 1/f fluctuation: Frequency analysis is performed on the image obtained in 1), the power spectrum is obtained, and the power spectrum is linearly approximated to obtain the proportional coefficient and the coefficient of determination.

4) Creation of image recognition model: Based on the collected image data for learning and the results obtained in 2) and 3), deep learning is performed based on the evaluation by experts, and an image recognition model is created.

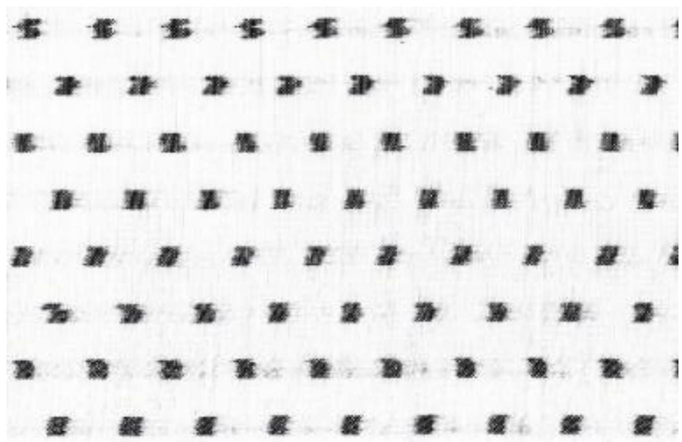


Fig. 3. Image Example of Kurume Kasuri (Sideways).

As shown in Fig. 4, there are three types of Kurume Kasuri edge patters, (1) green colored rectangles of relatively smooth edge line patterns, (2) red colored rectangles of relatively non-smooth edge line patters and (3) yellow colored rectangle of the middle patterns between (1) and (2). The pattern type of (1) is boring and tasteless while the pattern type of (3) is quaint texture and seems beautiful. On the other hand, the pattern (2) is that the smooth line fluctuates too much, giving the impression of an unstable pattern.

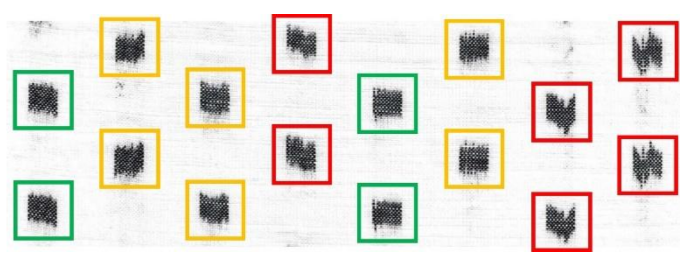


Fig. 4. Three Types of Kurume Kasuri Edge Patters, (1) Green: Relatively Smooth Edge Line Patterns, (2) Red: Relatively Non-smooth Edge Line Patters and (3) Yellow: The Middle Patterns between (1) and (2).

In order to extract the rectangle of the outline of the Kurume Kasuri in concern, the following four steps are conducted.

1) Find the outline of the pattern

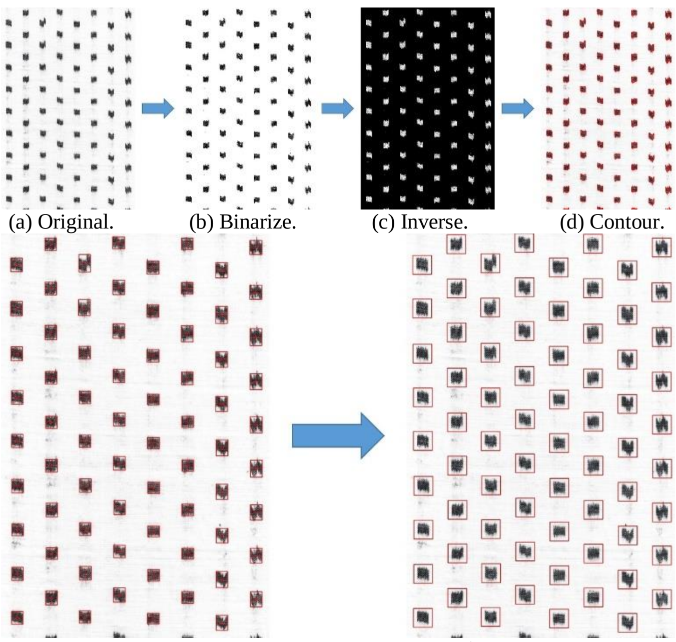
- Binarization (in black and white)
- Inversion of color (because the background is white)
- Contour extraction

2) Find the circumscribed rectangle based on the contour information

3) Find the center coordinates of the circumscribing rectangle

4) Specify the extraction range

Fig. 5 shows the procedure of the extraction of the rectangle of the outline of the Kurume Kasuri.



(a) Original. (b) Binarize. (c) Inverse. (d) Contour.

(e) Rectangle and Center (f) Extraction Range.

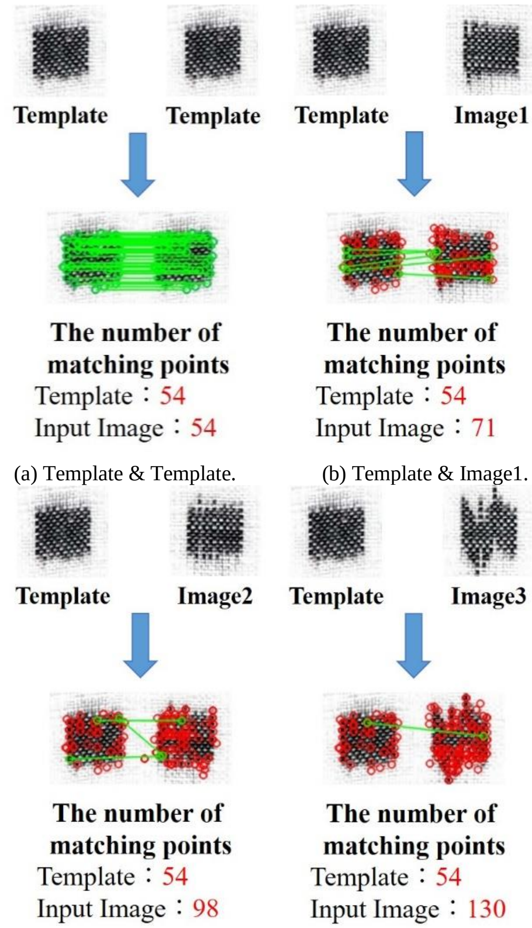
Fig. 5. Procedure for Extracting of the Rectangle of the Outline of the Kurume Kasuri.

IV. Experiments

A. Pattern Comparison with Template Matching

In order to compare the patterns in concern, the ideal pattern selected by the expert (Kurume Kasuri Producer: Orimoto in Japanese) from the obtained images was used as the template image, and the feature points of the template image and other images were compared using Fast Library for Approximate Nearest Neighbors: FLANN (high-speed nearest neighbor search) of OpenCV (Fig. 6).

Namely, the results show that the larger the fluctuation, the larger the number of feature points and the smaller the number of matching feature points. Therefore, it is possible to discriminate among three edge line patterns (1) relatively smooth edge line patterns, (2) relatively non-smooth edge line patters and (3) the middle patterns between (1) and (2).



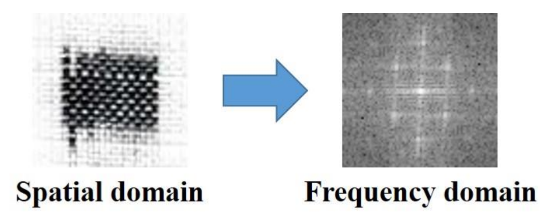
(a) Template & Template. (b) Template & Image1.

(c) Template & Image2.. (d)Template & Image3.

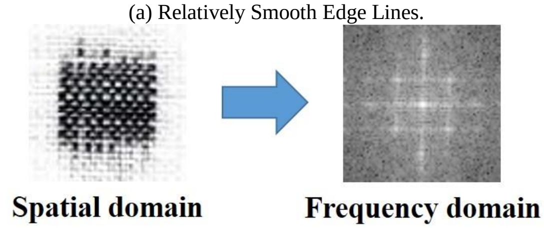
Fig. 6. The Number of Matching Points between Template and the other Images, Image1: Relatively Smooth Edge Line Patterns, Image3: Relatively Non-smooth Edge Line Patters and Image2: the Middle Patterns between Both.

B. Frequency Component Analysis

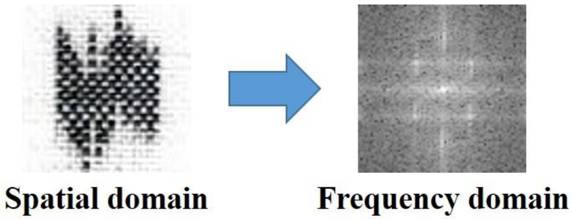
Fig. 7 shows aforementioned typical pattern images of three types of Kurume Kasuri patterns and their frequency components.



(a) Relatively Smooth Edge Lines.



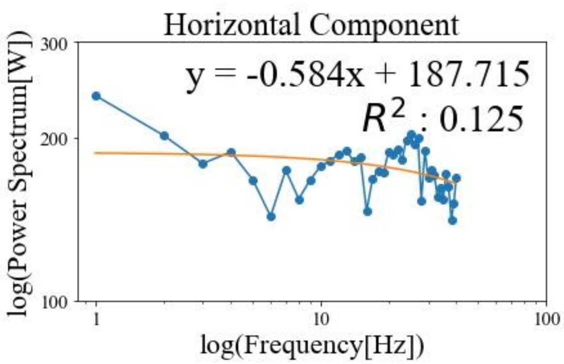
(b) Between Both Smooth and Non-smooth Edge Lines.



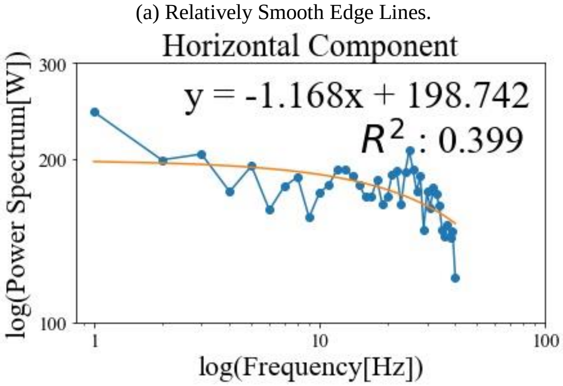
(c) Relatively Non-smooth Edge Lines.

Fig. 7. Frequency Components of the Typical Three Kurume Kasuri Patterns.

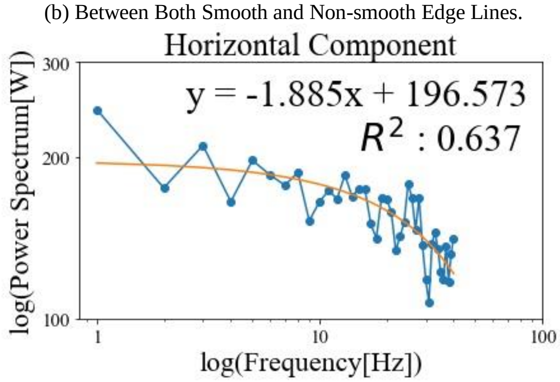
Also, Fig. 8 shows the vertical and horizontal frequency components of the pattern images of Fig. 7. The negative slope (proportional coefficient) did not become one, which is the same as the 1 / f fluctuation, but the larger the fluctuation, the better the accuracy of linear approximation (coefficient of determination), and the larger the negative slope (proportional coefficient). Obtained (Table I).



(a) Relatively Smooth Edge Lines.



(b) Between Both Smooth and Non-smooth Edge Lines.



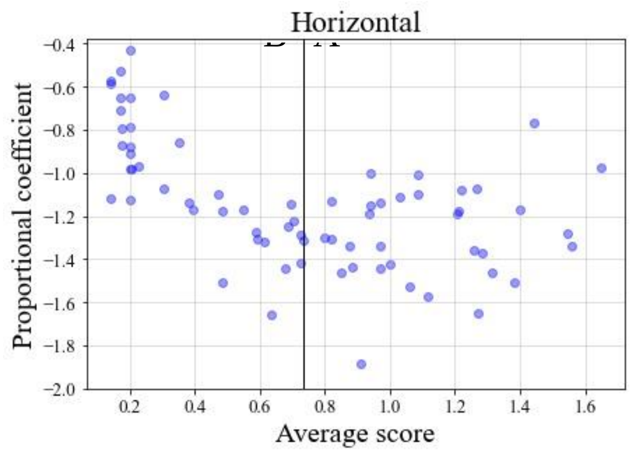
(c) Relatively Non-smooth Edge Lines.

Fig. 8. Amplitude Spectra of the Vertical and Horizontal Directions for the Typical Three Kurume Kasuri Patterns.

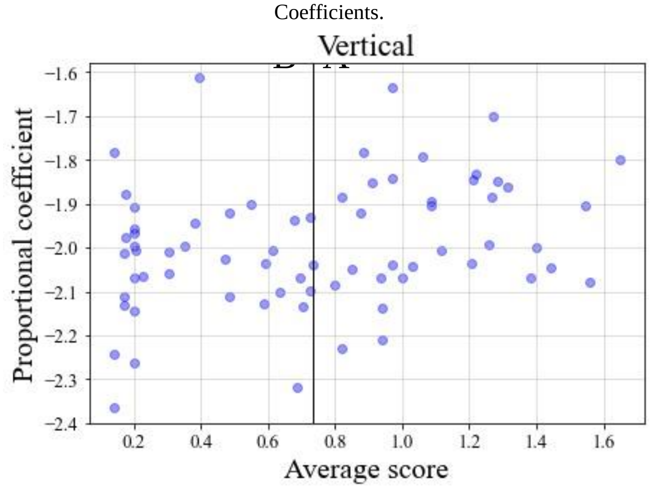
TABLE I. PROPORTIONAL COEFFICIENTS AND R^2 VALUES OF THE TYPICAL THREE PATTERNS

Types of patterns	Proportional coefficient	R^2	Proportional coefficient	R^2
	Horizontal		Vertical	
(1) Smooth edge lines	-0.584	0.125	-1.850	0.589
(3) Between both	-1.168	0.399	-2.001	0.688
(2) Non-smooth edge lines	-1.885	0.637	-2.365	0.782

With a negative slope (proportional coefficient) of two as the threshold value, it may be possible to classify anything that exceeds it as excessive fluctuation. It is found that the fluctuation in vertical direction is greater than that of horizontal direction. It is also found that proportional coefficient of two is much comfortable than proportional coefficient of one (the 1/f fluctuation).



(a) Relationship between Average Scores and Horizontal Proportional Coefficients.



(b) Relationship between Average Scores and Vertical Proportional Coefficients.

Fig. 9. Scatter Plots Showing the Relationship between Average Scores of Evaluations by Orimoto and Proportional Coefficients for each of 70 Patterns.

Finally, we compared proportional coefficients with results of a questionnaire conducted in advance to 35 experts (Kurume Kasuri Producer: Orimoto) in order to check if it is actually possible to classify patterns. Regarding the questionnaire, each of 70 patterns used in this experiment was evaluated as good (2 pt), acceptable (1 pt), and unacceptable (0 pt). As a result, the average score for the overall Orimoto evaluation was 0.733. Fig. 9 shows the relationship between average scores and proportional coefficients for each pattern, which is classified into Group A and Group B using the average score (0.733) as the threshold.

As for the horizontal, most of the proportional coefficients for group A are less than -1, indicating a negative correlation. As for the vertical, most of the proportional coefficients for group A are more than -2.1, indicating a positive correlation. It is found that pattern shift can be classified by proportional coefficient because t-test was performed at significance level of 5% and found to be significantly different.

V. Conclusion

Method for 1/f fluctuation component extraction from images is proposed. As an application of the proposed method, Kurume Kasuri textile quality evaluation is conducted. Frequency component analysis is used for 1/f fluctuation component extraction. Also, an attempt is conducted to discriminate the typical Kurume Kasuri textile quality,

1) Relatively smooth edge lines are included in the Kurume Kasuri textile patterns.

2) Relatively non-smooth edge lines are included in the patterns.

3) Between both of patterns (1) and (2) by using template matching method of FLANN of OpenCV.

Through experiments, it is found that the proposed method does work for extraction of 1/f fluctuation component and is also found that Kurume Kasuri textile quality can be done with the result of 1/f fluctuation component extraction.

This research not only helps improve the quality of Kurume Kasuri, a local traditional craft, but also allows young people to pass on the tacit knowledge of skilled craftsmen as explicit knowledge, supporting Orimoto who is suffering from a shortage of successors.

VI. Future Research Works

In the future, to improve the quality of Kurume Kasuri, we would like to build a model that machine-learn patterns, classifies images to determine if pattern shift is within acceptable limits, and prevents pattern shift outside of acceptable limits.

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