

IEICE Proceeding Series

Experimental Investigation on Correlation between Kansei Impression
and Feature Quantity of Sound Signal in Fourier Domain

Yusuke Kawakami, Tetsuo Hattori, Hiromichi Kawano, Tetsuya Izumi

Vol. 1 pp. 1-4

Publication Date: 2014/03/17

Online ISSN: 2188-5079

Downloaded from www.proceeding.ieice.org

©The Institute of Electronics, Information and Communication Engineers

Experimental Investigation on Correlation between Kansei Impression and Feature Quantity of Sound Signal in Fourier Domain

Yusuke Kawakami[†], Tetsuo Hattori[†], Hiromichi Kawano[‡] and Tetsuya Izumi^{‡†}

[†]Graduate School of Engineering, Kagawa University
2217-20 Hayashi, Takamatsu City, Kagawa 761-0396, Japan

[‡]NTT Advanced Technology
19-18 Nakamachi, Musashino-shi, Tokyo 180-0006, Japan

^{‡†}Micro Technica Co., Ltd.
3-12-2 Higashi-ikebukuro, Toshima-ku, Tokyo 170-0013, Japan
Email: s11d621@stmail.eng.kagawa-u.ac.jp, hattori@eng.kagawa-u.ac.jp

Abstract– This paper presents an experimental investigation correlation between human Kansei (or feeling) impression and some physical feature quantity in sound signal. As for the feature quantity, we focus on three kinds of values, that is, fluctuation value, intercept, and sum of squared errors that are obtained when making a regression analysis of sound signal in Fourier domain. In our investigation using a questionnaire survey over 34 persons, we apply multiple regression model to the relation between the feature quantity of signal and human evaluation about Kansei impression for each person. And, after making the construction of the regression equation for each person, we show the strength between the quantity and impression. Moreover, we classify the set of coefficients of the equation into three groups and discuss some tendency of human impression resulting from the quantity.

1. Introduction

Recently, $1/f$ fluctuation in various fields of signal has been actively researched, and it brings about an effect of such healing as a human being psychologically feels at ease, if there is a $1/f$ relation between the power spectrum of the signal and the frequency f ([1]-[7]).

However, in the past research about $1/f$ fluctuation focused attention on the value of fluctuation. And it has not yet led to analyze when signals have the same $1/f$ fluctuations those power spectrum distributions. Therefore, we wonder if human feeling impression is strongly affected by not only value of fluctuation but also other factors.

Thus, in this paper, we introduce three kinds of parameters such as fluctuation value, intercept, and sum of squared errors (or residual) as feature quantity in sound signal obtained from the calculation of the signals' fluctuation degree, and we investigate the relation between feeling impression and those parameters. We investigate sensitivity of the feeling impression by those parameters, especially fluctuation value and residual.

2. Quantities Accompanying Calculation of Fluctuation

2.1. Fluctuation and parameters

Among fluctuations, the well-known $1/f$ fluctuation means that the power spectrum (PS) of a signal is proportional to the $1/f$ of frequency. Moreover, it is pointed out that there is an effect that a human being feels pleasantness ([1]-[6]).

Figure 1 shows an example of the regression line. Its horizontal axis shows the logarithm of the frequency and vertical axis shows the logarithm of the PS. Where, this regression line has an absolute-slope of a . In this paper, we call the absolute-degree of the slope "Fluctuation value".

Accompanying when the regression line is computed as shown in Figure 1, three kinds of parameters are defined, i.e., (1) Fluctuation value as the absolute value of slope a , (2) Intercept b , and (3) Residual of the line. We call the set of these parameters "3PACF" that stands for 3 Parameters Accompanying Calculation of Fluctuation [8].

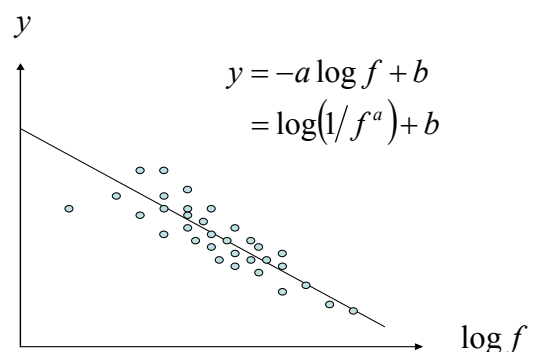


Figure 1: Example of regression line.

The residual of the regression line is defined by the Equation (1) as in the form of a sum of the squared error,

where y and Y show a target variable and an estimated regression value respectively.

$$s = \sum_i e_i^2 = \sum_i (y_i - Y_i)^2 \quad (1)$$

We use two scaling factors to artificially change the parameters of Intercept and Residual (the sum of squared error). In the Equation (2), A and B are the scaling factors and e_i and e_i' are errors from regression line.

$$e_i' = Ae_i + B \quad (2)$$

Where A is multiplier of previous residual e_i , and B is regression-line Intercept. That is, we can modify the Residual amplitude and the intercept by changing A and B . Figure 2 shows the examples of PS when 3PACF are modified from original regression line of Figure 1.

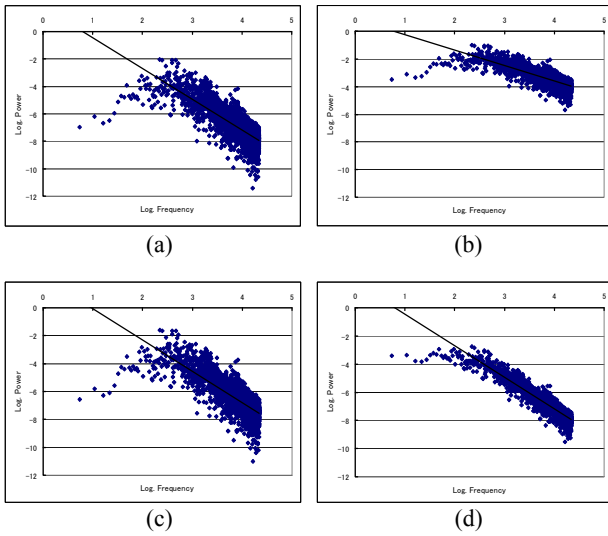


Figure 2: Change of PS by modifying 3PACF. (a) Original, (b) Fluctuation value is modified, (c) Intercept is modified, (d) Residual is modified

2.2. Correlation between 3PACF

We have investigated as to whether or not there exists correlation between 3PACFs of music. Table 1 shows the music list of wave file. Their sampling rate and quantization bit rate are 44.1 kHz and 16 bit. Figure 3 (a)-(c) shows the plotted graph between two parameters of 3PACF of music.

Table 1: Music list of wave file.

| No | Title (.wav) | Genre |
|----|---------------------------|----------------|
| 1 | Another_Sky | Easy Listening |
| 2 | Londonderry_Air | Classic |
| 3 | Blieve_you | Easy Listening |
| 4 | Drafting | Easy Listening |
| 5 | Down_by_the_Riverside | Jazz |
| 6 | Space_Odessey3_Revelation | Easy Listening |
| 7 | TOMORROW | Pops |
| 8 | Old_French_Song | Classic |
| 9 | Freedom | Pops |
| 10 | Red_River_Valley (brass) | Jazz |

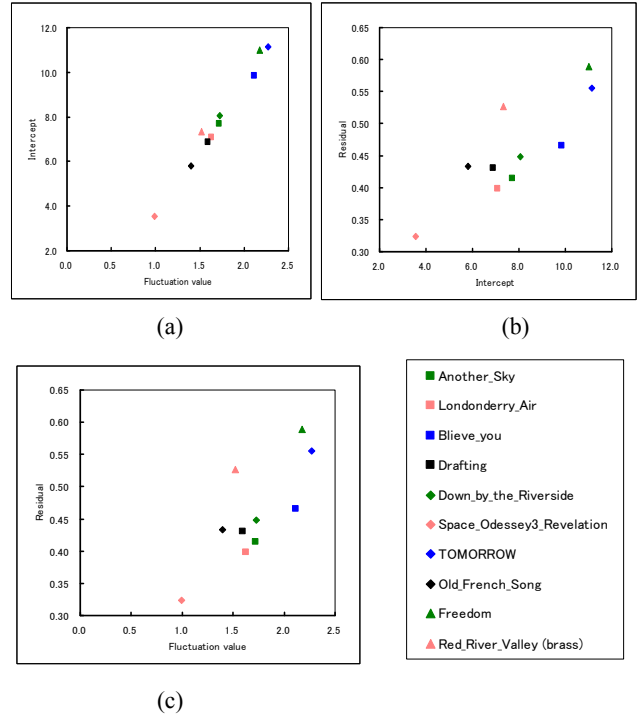


Figure 3: Correlation of 3PACF. (a) Fluctuation value and Intercept, (b) Intercept and Residual, (c) Fluctuation value and Residual

The correlation coefficient in Figure 3: (a) 0.99061 between Fluctuation value and Intercept. (b) 0.85238 between Intercept and Residual. (c) 0.78630 between Fluctuation value and Residual.

From Figure 3, we consider that there exists high correlation between Fluctuation value and Intercept, or between Intercept and Residual. Furthermore, there is high correlation between Fluctuation value and Residual, too.

3. Investigation

3.1. Outline

We have used questionnaire survey in order to investigate relationship between 3PACF and feeling impression of music. The examinees are 34 university students in the age of early twenties. We gave the question that is about feeling impressions for some pieces of music. The list of music used in this survey is the same as shown in Table 1.

In this survey, we asked about the examinees' feeling impression of 10 pieces of music. For every piece of music, it takes 20 seconds to play, and we asked to evaluate the 4 items as shown in Table 2 by scoring from 1 to 4. Also the examinees judged total evaluation for each piece of music by scoring from 1 to 10.

Table 2: Questions in the survey.

| | | | |
|--------|----------|-------|------------|
| Item 1 | Slow | 1 ⇔ 4 | Quick |
| Item 2 | Heavy | 1 ⇔ 4 | Light |
| Item 3 | Natural | 1 ⇔ 4 | Artificial |
| Item 4 | Negative | 1 ⇔ 4 | Positive |

3.2. Feeling impression from parameters

We have conducted multiple regression analysis of the results as shown in Equation (3) in the four-item score (item1, item2, item3, and item4) and the total evaluation score. Where, y is the score of the each examinee. And, x_1 and x_2 are explanatory variable of “Fluctuation” and “Residual”. We eliminate the third variable for “Intercept”, because this quantity (or parameter) is substantially equal to the volume of sound [8].

$$y = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \varepsilon, \quad \varepsilon \sim N(0, \sigma^2) \quad (3)$$

Where error ε is independence variable and follows the normal distribution $N(0, \sigma^2)$.

We have analyzed using Equation (3) for each person and for each item. For example, we assume that an examinee scored Item1 for 10 pieces of music “ y_1, y_2, \dots, y_{10} ”.

Then, we get 10 equations for Item 1 for each person, by the feeling impression of an examinee where the coefficients $\{\alpha_0, \alpha_1, \alpha_2\}$ are unknown as shown as Equation (4).

$$y_i = \alpha_0 + \alpha_1 x_{i1} + \alpha_2 x_{i2} + \varepsilon_i \quad (i = 1, \dots, 10) \quad (4)$$

Then, using the least squares method, we will obtain the concrete the coefficients and regression equation for Item1. However, as a whole, we have set the coefficient $\alpha_0 = 0$, because the multiple correlation coefficient tends to be higher as a result of analysis at this time. In this way, the regression equation for each item of {Item1, Item2, Item3, Item4, Total Evaluation} and for each person will be available. That is, we will get 5 regression equations from feeling impression result of each examinee. And we carry out this analysis for 34 examinees.

After the construction of those regression equations for each item, we try to make a clustering analysis for them, using Ward Method [9]. As the result, those equations are generally classified into three groups. Figure 4 shows the clustering result for Total Evaluation, as an example of classification.

Figure 5 (a) ~ (e) are the plotted graphs which show the relation between Fluctuation coefficient and Residual coefficient those are calculated from Equation (3). As shown in these figures, we can divide them into three groups: Group1, Group2, and Group3. Where, we have to be focused on the interaction of between Fluctuation coefficient (α_1) and Residual coefficient (α_2). In Group1, we make a comparison between α_1 and α_2 , α_2 is much higher than α_1 . Again, α_2 is plus value, but α_1 is minus. So

we considered that feeling impression of Group1 have an impact on α_2 more than α_1 .

Likewise in Group2 or Group3, we make a comparison between the absolute value of α_1 and α_2 , α_2 is higher than α_1 , too. So we considered that feeling impression of them have an impact on α_2 more than α_1 , too.

Moreover, we apply statistical tests to groups of each evaluation item. We use the method of Wilks-Rambda Test [9]. These results are shown in Table 3, where α_1, α_2 are the average of Fluctuation coefficient and Residual coefficient, respectively. They come into effect 1% of significance.

From these results, they have strong negative correlations, and we can explain the result level of regression using Equation (3), at least 94.9%. Also, Residual coefficient is the stronger factor than Fluctuation one in this feeling impression evaluation.

3.3. Discussion

In section 3.2, we have found that each item of feeling impressions can be expressed as Equation (3), and the average of regression coefficient as shown as Table 3.

Table 3: Correlation coefficient and Regression Coefficient.

| Evaluation Item | Multiple correlation coefficient | Significance level of regression | Average of Regression Coefficient | | | | | |
|------------------|----------------------------------|----------------------------------|-----------------------------------|------------|------------|------------|------------|------------|
| | | | Group 1 | | Group 2 | | Group 3 | |
| | | | α_1 | α_2 | α_1 | α_2 | α_1 | α_2 |
| Item 1 | -0.991 | 1% | -2.444 | 13.676 | -0.759 | 7.894 | 0.339 | 3.186 |
| Item 2 | -0.980 | 1% | -2.422 | 14.578 | -1.040 | 9.759 | 0.062 | 5.160 |
| Item 3 | -0.980 | 1% | -1.691 | 12.231 | -0.249 | 6.673 | 1.016 | 1.420 |
| Item 4 | -0.990 | 1% | -2.092 | 13.939 | 0.512 | 4.000 | 1.596 | 0.173 |
| Total Evaluation | -0.949 | 1% | -2.417 | 24.322 | 3.805 | -2.348 | 0.386 | 10.504 |

In Group1, each evaluation item of α_1 is minus and the absolute value is lower than α_2 . When x_1 is getting high, the score of the each examinee (y) will become progressively lower. In other words, x_1 is getting low, y will become slightly higher. But α_2 is much higher than α_1 , so x_2 is getting high or low, y will be quite higher or lower.

In Group2, α_1 of Item1, Item2, and Item3 are minus and the absolute value is lower than α_2 . When x_1 is change, y of those evaluation items will change same as Group1. But α_1 of Item4 is plus, then x_1 is low or high, y of Item4 will be slightly lower and higher. Though α_2 is higher than α_1 , so α_2 has a profound effect on y of Item4. And we have to pay attention that α_1 of Total Evaluation is higher than α_2 . In fact, Total Evaluation of Group2 will be higher when α_1 is getting high.

In Group3, each evaluation item of α_1 and α_2 is plus. So x_1 is getting low or high, y will be progressively lower and higher but the change of x_2 will be heavily affected to y , except Item3 and Item4. Item3 of α_1 and α_2 are same so effect of α_1 is as same as α_2 . But Item4 of α_1 is higher than α_2 , so the change of α_1 will be heavily affected y of it.

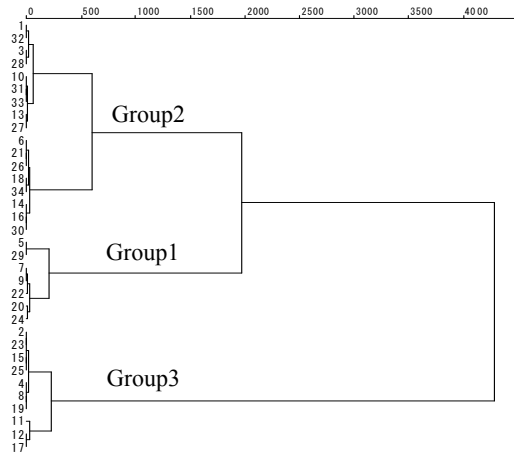


Figure 4: Example of the clustering result for Total Evaluation using Ward method.

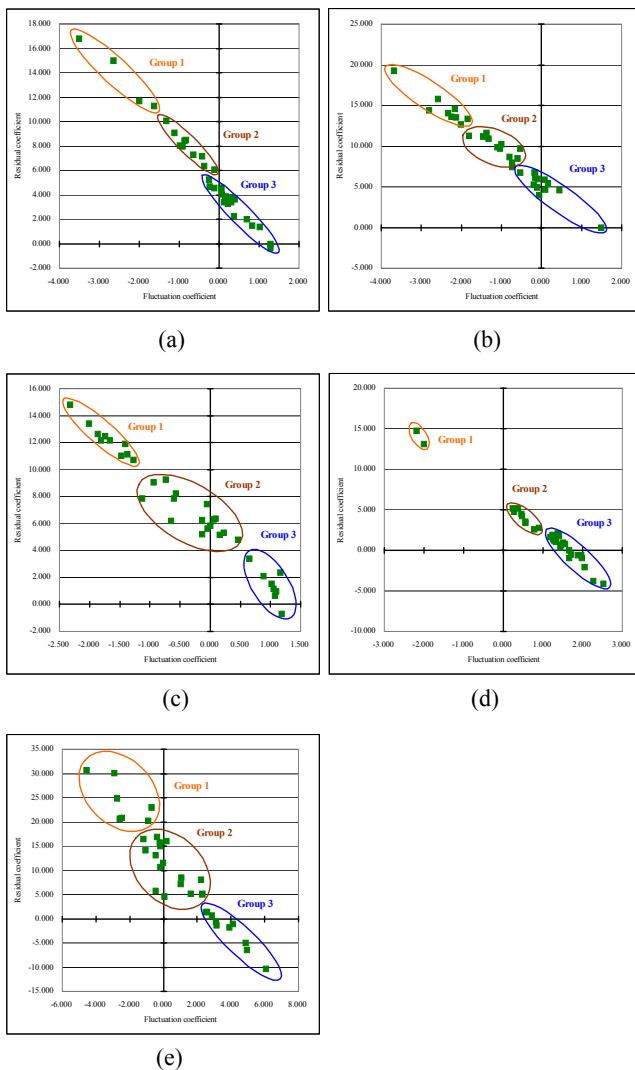


Figure 5: Regression Analysis of Feeling Impression. (a) Item1, (b) Item 2, (c) Item 3, (d) Item 4, (e) Total Evaluation.

Based on the constructed multiple linear regression equations, we can also consider the statistical tendency as to how the human impression will change if the explanatory variable of Fluctuation (x_1) or Residual (x_2) change. Briefly speaking, the effect of the Residual seems to be stronger than that of Fluctuation. For further study, we need some sensitivity analysis for those parameters.

4. Conclusion

This paper has described a relationship between 3PACF and feeling impression in audio signal. As a way of research, we have used a questionnaire survey concerning how is the relation between those parameters and the feeling impression of music, and how the impression varies when Fluctuation or Residual is independently changed through the thought experiment.

Although the questionnaire survey is acquired by limited number of persons or age and the number of music as investigation objects is limited, we have understood the feeling impression of music can be classified using multiple regression analysis. Thus, we may estimate and predict the tendency of feeling impression, based on the results of analysis. However, using the results, we have to investigate and verify how feeling impressions will vary when we artificially change the parameters of the Fluctuation and the Residual, for further study,

References

- [1] T. Musha: Reason why person feels pleasantness and unpleasantness--- sound, image, and sense of touch--- that approaches to the mystery of “pleasantness”, Kawade Shobo Shinsya (KAWADE dream new book), 1999 (in Japanese).
- [2] T. Musha: The world of fluctuation – Mystery of 1/f fluctuations of the world –, Kodansha Bluebacks, Kodansha, 1980 (in Japanese).
- [3] H. Akaike and T. Wada: Fluctuation and rhythm of living body, Kodansha Scientific, 1997 (in Japanese).
- [4] S. Horiuchi: Mystery of fluctuation, Shinano Mainichi Newspapers Co., 1997 (in Japanese).
- [5] E. Teramoto, R. Hirota, T. Musha, and M. Yamaguchi: Infinity, chaos, and fluctuation, Bifukan, 1985 (in Japanese).
- [6] T. Musha: Conception of fluctuation that approaches to the mystery of 1/f fluctuation, NHK Books, 1998 (in Japanese).
- [7] T. Musha: Science of fluctuation, <1> through <10>, Morikita Publication, 1991-1999 (in Japanese).
- [8] Y. Kawakami, T. Hattori, T. Yamamatsu, T. Izumi, H. Kawano: Experimental Investigation of the Relation between Feeling Impression and Quantities Accompanying Fluctuation Calculation in Sound Signal, Transactions of Japan Society of Kansei Engineering, Vol.10, No.3, pp.365-374, 2011 (in Japanese).
- [9] B. S. Everitt: The Cambridge Dictionary of Statistics, Cambridge University Press 2nd edition, 2002