Journal of Robotics, Networks and Artificial Life, Vol. 1, No. 4 (March 2015), 303-311

Experimental Investigation of Feature Quantity in Sound Signal and Feeling Impression Using PCA

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Abstract

This paper describes experimental investigation of the relationship between feature quantity of sound signal and feeling impression using PCA (Principal Component Analysis). As the feature quantity, we use Fluctuation value and sum of squared errors (Residual) which is calculated by regression analysis of sound signal, in the same way as our previous paper. In order to investigate the feeling impression and effect from sound signal, we use a questionnaire survey method, that is, we ask some examinees to evaluate their feeling impression about sound (music) that we provide. As a result, we have found that the feeling response of examinees can be classified into three groups by a clustering analysis. And we have verified the feeling impression effects depending on each group of examinees and four kinds of frequency zone of sound signal from the results of PCA. In this paper, we also discuss the analysis results on the Kansei (or feeling) effect.

Keywords: Signal processing, Fluctuation, Intercept, Sum of squared errors, Feeling impression, PCA

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, we focused that the power spectrum have same fluctuation but the distribution are different. And we doubted the strong influence of the emotional impression factors other than fluctuation value.[8]

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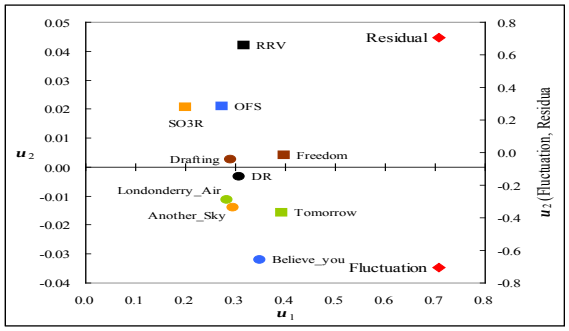
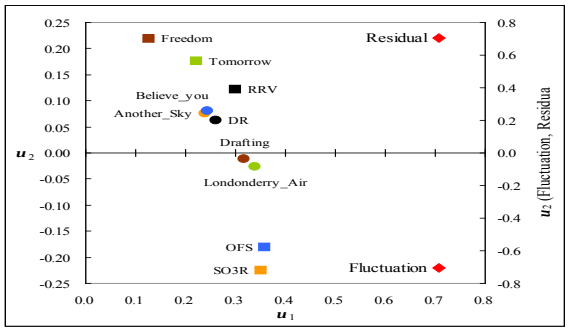
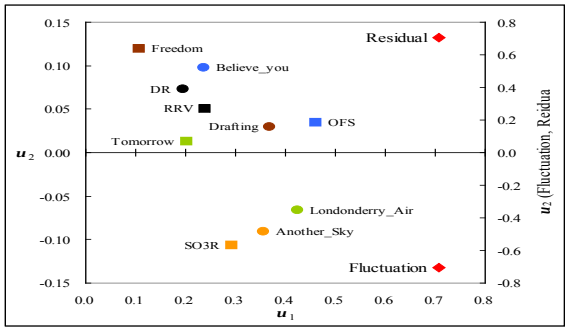
Published by Atlantis Press



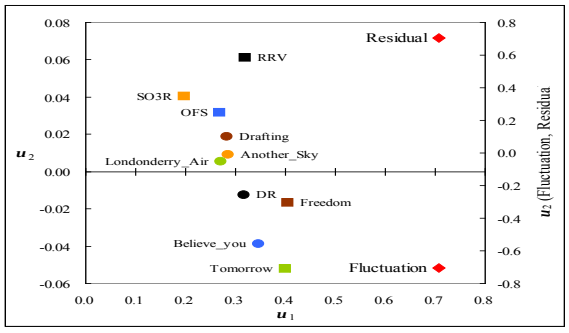
(a) AF (All Frequency domain)



(b) LF (Low Frequency domain)

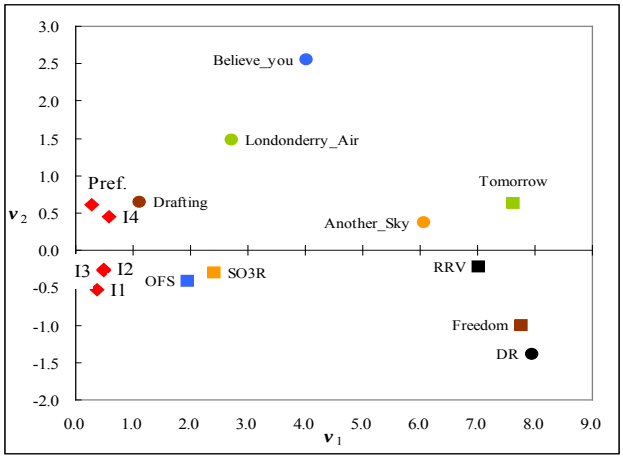


(c) MF (Middle Frequency domain)

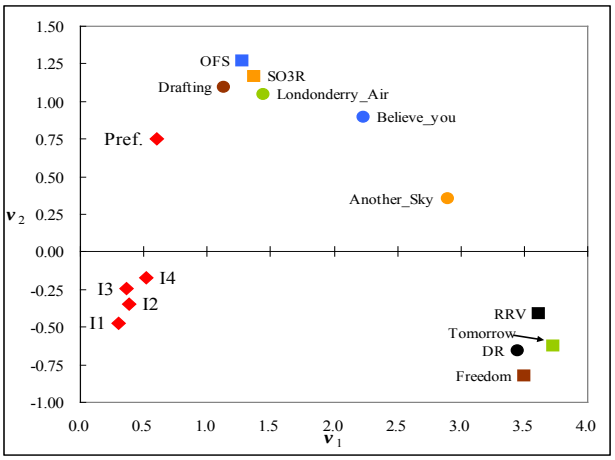


(d) HF (High Frequency domain)

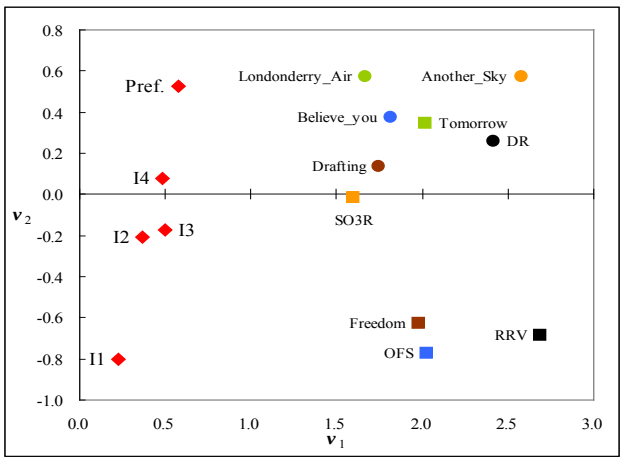
Fig. 5. PCA results on Physical Quantity Space (PQS).[17]
DR: Down_by_the_Riverside, SO3R: Space_Odessey3_Reveration,
OFS: Old_French_Song, RRV: Red_River_Valley (brass)



(a) Group G1



(b) Group G2



(c) Group G3

Fig. 6. PCA results on Feeling Adjective Space (FAS).[17]
DR: Down_by_the_Riverside, SO3R: Space_Odessey3_Reveration,
OFS: Old_French_Song, RRV: Red_River_Valley (brass),
I1: Item1 (Quick), I2: Item2 (Light), I3: Item3 (Artificial),
I4: Item4 (Positive), Pref.: Preference (Like)

Table 5. PCA results on Physical Quantity Space (PQS).

(a) Music vector

No.	Title (*.wav)	AF		LF		MF		HF	
		$\langle f_i \mid u_1 \rangle$	$\langle f_i \mid u_2 \rangle$	$\langle f_i \mid u_1 \rangle$	$\langle f_i \mid u_2 \rangle$	$\langle f_i \mid u_1 \rangle$	$\langle f_i \mid u_2 \rangle$	$\langle f_i \mid u_1 \rangle$	$\langle f_i \mid u_2 \rangle$
1	Another_Sky	0.2959	-0.0139	0.2379	0.0757	0.3567	-0.0907	0.2856	0.0093
2	Londonderry_Air	0.2826	-0.0112	0.3402	-0.0256	0.4235	-0.0659	0.2707	0.0054
3	Believe_you	0.3492	-0.0319	0.2437	0.0802	0.2354	0.0978	0.3454	-0.0390
4	Drafting	0.2904	0.0027	0.3163	-0.0115	0.3679	0.0292	0.2838	0.0186
5	Down_by_the_Riverside	0.3082	-0.0032	0.2604	0.0625	0.1955	0.0726	0.3162	-0.0127
6	Space_Odessey3_Revelation	0.1994	0.0206	0.3514	-0.2257	0.2915	-0.1062	0.1965	0.0404
7	Tomorrow	0.3937	-0.0158	0.2220	0.1759	0.2017	0.0132	0.3991	-0.0523
8	Old_French_Song	0.2736	0.0211	0.3582	-0.1814	0.4610	0.0343	0.2671	0.0315
9	Freedom	0.3966	0.0042	0.1259	0.2185	0.1072	0.1195	0.4039	-0.0168
10	Red_River_Valley (brass)	0.3164	0.0419	0.2992	0.1210	0.2390	0.0502	0.3187	0.0609

(b) Bases vector

Physical parameter	AF		LF		MF		HF	
	u_1	u_2	u_1	u_2	u_1	u_2	u_1	u_2
Fluctuation	0.7071	-0.7071	0.7071	-0.7071	0.7071	-0.7071	0.7071	-0.7071
Residual	0.7071	0.7071	0.7071	0.7071	0.7071	0.7071	0.7071	0.7071

Table 6. PCA results on Feeling Adjective Space (FAS).

(a) Music vector

No.	Title (*.wav)	G1		G2		G3	
		$\langle x_i \mid v_1 \rangle$	$\langle x_i \mid v_2 \rangle$	$\langle x_i \mid v_1 \rangle$	$\langle x_i \mid v_2 \rangle$	$\langle x_i \mid v_1 \rangle$	$\langle x_i \mid v_2 \rangle$
1	Another_Sky	6.0797	0.3689	2.8965	0.3500	2.5807	0.5734
2	Londonderry_Air	2.7105	1.4754	1.4441	1.0455	1.6698	0.5723
3	Believe_you	4.0316	2.5531	2.2330	0.8974	1.8146	0.3734
4	Drafting	1.1179	0.6379	1.1369	1.0948	1.7465	0.1387
5	Down_by_the_Riverside	7.9547	-1.3869	3.4447	-0.6613	2.4187	0.2587
6	Space_Odessey3_Revelation	2.4144	-0.3028	1.3663	1.1635	1.5952	-0.0153
7	Tomorrow	7.6395	0.6232	3.7316	-0.6296	2.0180	0.3437
8	Old_French_Song	1.9509	-0.4201	1.2753	1.2671	2.0279	-0.7724
9	Freedom	7.7726	-1.0138	3.4965	-0.8230	1.9809	-0.6257
10	Red_River_Valley (brass)	7.0231	-0.2201	3.6188	-0.4069	2.6909	-0.6853

(b) Bases vector

Feeling impression	G1		G2		G3	
	v_1	v_2	v_1	v_2	v_1	v_2
Item1 (Quick)	0.366	-0.520	0.296	-0.474	0.227	-0.801
Item2 (Light)	0.482	-0.249	0.382	-0.348	0.364	-0.209
Item3 (Artificial)	0.477	-0.269	0.367	-0.243	0.495	-0.174
Item4 (Positive)	0.570	0.460	0.518	-0.175	0.483	0.078
Preference (Like)	0.285	0.619	0.603	0.751	0.581	0.527

Table 7. Correlation coefficient between principal.[17]

(a) Group G1

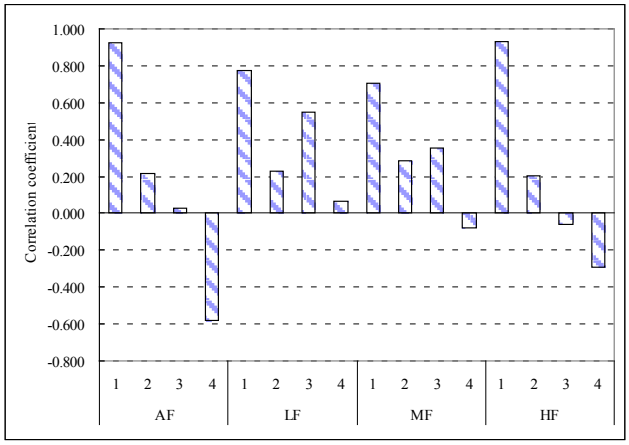
Principal axis	AF		LF		MF		HF	
	u_1	u_2	u_1	u_2	u_1	u_2	u_1	u_2
v_1	0.926	0.028	0.774	0.547	0.704	0.351	0.931	-0.059
v_2	0.216	-0.579	0.230	0.068	0.288	-0.080	0.203	-0.294

(b) Group G2

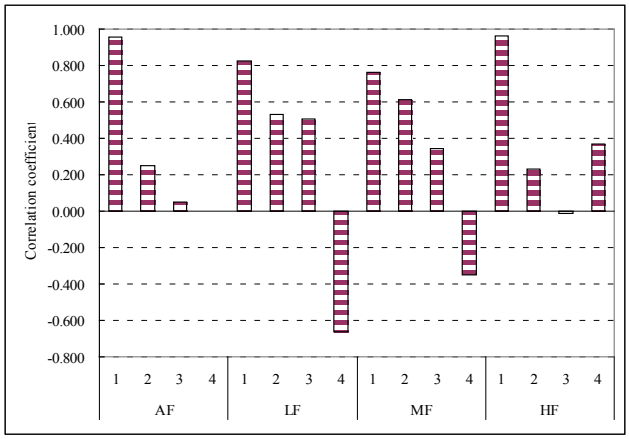
Principal axis	AF		LF		MF		HF	
	u_1	u_2	u_1	u_2	u_1	u_2	u_1	u_2
v_1	0.956	0.049	0.827	0.506	0.761	0.341	0.960	-0.015
v_2	0.251	0.000	0.528	-0.660	0.611	-0.351	0.233	0.371

(c) Group G3

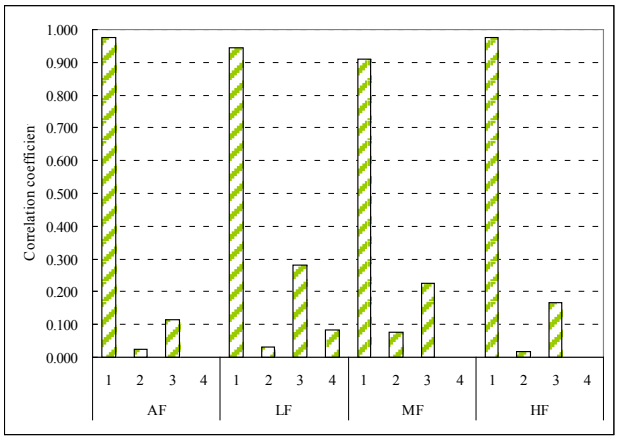
Principal axis	AF		LF		MF		HF	
	u_1	u_2	u_1	u_2	u_1	u_2	u_1	u_2
v_1	0.976	0.115	0.945	0.280	0.911	0.226	0.975	0.166
v_2	0.024	-0.784	0.031	0.083	0.075	-0.425	0.016	-0.482



(a) Group G1



(b) Group G2



(c) Group G3

Fig. 7. Correlation coefficient between principal axes.
1: Correlation between $\langle f_i \mid u_1 \rangle$ and $\langle x_i \mid v_1 \rangle$,
2: Correlation between $\langle f_i \mid u_1 \rangle$ and $\langle x_i \mid v_2 \rangle$,
3: Correlation between $\langle f_i \mid u_2 \rangle$ and $\langle x_i \mid v_1 \rangle$,
4: Correlation between $\langle f_i \mid u_2 \rangle$ and $\langle x_i \mid v_2 \rangle$.

coefficient in each group (G1, G2, and G3). The colored portion of Table 7 indicates that the absolute value of the correlation coefficient is 0.700 or higher.

3.3.1. Group G1

From Table 7 (a) and Fig. 7 (a), the correlation coefficient on AF and HF between $\boldsymbol{u}_1$ and $\boldsymbol{v}_1$ are 0.926 and 0.931 respectively, so they have strong positive correlation.
We refer Fig. 5(a) and (d), increase in Fluctuation and Residual are tendency in response to increase of $\boldsymbol{u}_1$. Also from Fig. 6(a), increase in Item2 (Lightness) and Item3 (Artificial) are tendency in response to increase of $\boldsymbol{v}_1$.
Similarly, the correlation coefficient on LF and MF between $\boldsymbol{u}_1$ and $\boldsymbol{v}_1$ are 0.774 and 0.704 respectively, so they have positive correlation.
We refer Fig. 5(a) ~ (c), Fluctuation and Residual on LF of all music are lower than AF. And the music which Fluctuation and Residual are small on AF, there are tendency they increase on MF.
Therefore, we consider the music become light and artificial impression by increasing Fluctuation and Residual, on AF, MF, and HF.

3.3.2. Group G2

From Table 7 (b) and Fig. 7 (b), we understand that G2 have tendency same as G1. And, the correlation coefficient of each domain between $\boldsymbol{u}_1$ and $\boldsymbol{v}_1$ are higher than 0.761, so they have positive correlation. Besides, we refer Fig. 6(b), increase in Item4 (Positive) is tendency in response to increase of $\boldsymbol{v}_1$.
Therefore, we consider the music become positive impression by increasing Fluctuation and Residual.

3.3.3. Group G3

From Table 7 (c) and Fig. 7 (c), we understand that the correlation coefficient of each domain of G3 between $\boldsymbol{u}_1$ and $\boldsymbol{v}_1$ are higher than 0.911, so they have strong positive correlation. Especially the correlation coefficient of AF between $\boldsymbol{u}_2$ and $\boldsymbol{v}_2$ is -0.784, so they have negative correlation.
We refer Fig. 6(c), increase in Item4 (Positive) is tendency in response to increase of $\boldsymbol{v}_1$. And from Fig 5 (a) ~ (d), increase in Fluctuation and Residual are tendency in response to increase of $\boldsymbol{u}_1$. Furthermore, decreasing Fluctuation and increasing Residual are tendency in response to decrease of $\boldsymbol{v}_2$.
Therefore, we consider the music become positive impression by increasing Fluctuation and Residual. Especially, by increasing Fluctuation and Residual on AF, the music become fast impression.

3.3.4. Overall tendency

We understand that 56% of examinees (Group G1) feel light and artificial impression from the music which both of Fluctuation and Residual are high, and they have tendency that they prefer the music which Fluctuation and Residual are high and low, respectively. We also understand that rest of 44% examinees (Group G2 and G3) feel positive impression, but they don't.
We can judge that the sensitivity of the music impression is strong influence by Fluctuation and Residual of HF, because the above tendencies are common to AF and HF.

4. Conclusion

In this paper, we have investigated the effects between feature quantity of sound signal and feeling impression by using Principal Component Analysis (PCA). As feature quantity, we have used Fluctuation and Residual. As for the feeling impression questionnaire, we have presented 10 piece of music to examinees and they evaluated 5 items, i.e. quickness, lightness, artificial, positiveness, and preference (like or dislike). Then, we performed clustering analysis using Ward method based on the evaluation results, and we understood that the examinees feeling impression could be divided into 3 groups.
Next, we have performed PCA in the Physical Quantity Spaces of the each frequency domain (AF, LF, MF, and HF) and performed PCA in the Feeling Adjective Spaces of each group. Furthermore, we also investigated correlation between the principal component axes.
As the results, we have understood that 56% of examinees feel light and artificial impression from the music in which both values of Fluctuation and Residual are high. And we have also found that they prefer such music.
Although there were not seen such correlativity about the rest 44% of examinees, we were able to understand that they feel positive impression from the music in which the both values of Fluctuation and Residual are high.

Moreover, we have found that the high frequency feature quantity of sound has the strongest influence to people's feeling impression.

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