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Biometric Authentication of Individuals using Electroencephalography (EEG)

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Abstract – *In this research we proposed a novel authentication method based on electroencephalogram (EEG) responses of individuals while writing their own signature and other´s signature. Two healthy male subjects (average years 27) participated in the experiments. In one task of the experiments, we asked them to sign their personal signatures on a paper within 2 seconds just after hearing a beep sound. This was repeated 24 times with an interval of 5 seconds. In addition, the same experiment was done but subjects were asked to sign a new unfamiliar signature, that is, other person´s signature. During these two tasks, EEG was recorded at 14 locations by using Emotiv EPOC neuro-headset. Comparison of the averages of the frequency powers after fast Fourier transformation of EEG data revealed the similarities and differences at different frequencies between two tasks. Average comparison was done for each individual channel in 10 frequency ranges within 4 to 43.5 Hz showed the significant differences between the two groups are found in beta rhythm, particularly from 16 to 23.5 Hz at O1, O2, and P7 ($p < 0.05$; Two-way repeated ANOVA).*

Keywords*:* EEG, Authentication, Neurofeedback, Biometric

1.0 INTRODUCTION

Biometric authentication is the method of uniquely identifying individuals according to one or more physical or behavioural characteristics. Physiological biometrics is related to the shape of the body while behavioural biometrics is related to the individual´s habits. Utilizing EEG has several advantages in compared with traditional biometric methods: (1) It is confidential, (2) it is very difficult to mimic, and (3) it is almost impossible to steal.

One of the earliest examples of biometrics based on brain signals was Paranjape et al.'s work [1]. They considered brain signals measured while both resting with eyes closed and resting with eyes open, and used the autoregressive model for the identification of 40 subjects. Miyamoto et al. [2] proposed spectral features for more practical applications with less computational load. They used EEGs recorded at rest with eyes closed in which the alpha rhythm was yielded. Zhao [3] used a single electrode to measure brain signals evoked during relaxation with eyes closed and extracted the alpha power features from the EEG for individual identification [4].

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2.0 METHOD OF RECORDING EEG

Two young (25 and 29) subjects were selected to perform signing task while recording EEG. An experiment started with explaining the procedure to subjects, and asked them to try to feel comfortable. A timing application was designed to play a beep sound every 5 seconds and stops 2 minutes after the onset of a task with different sound that shows the end. There were two tasks. After each beep sound, subject started to sign self-signature in task 1 and to copy someone else's signature in task 2. A whole experiment was recorded using a web camera and simultaneously the beep sound and EEG signals were recorded using Camtasia Studio software (TechSmith Co., USA). EEG signals were recorded by Emotiv Neuroheadset from 14 channels (AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4) at 128Hz sampling rate using Emotiv TestBench.

This experiment was approved by the Internal Ethics Committee at Kyushu Institute of Technology. The possible risks, mental task, and approximate measurement time were explained to all participants. In addition, all participants gave their written informed consent before participating in this experiment.

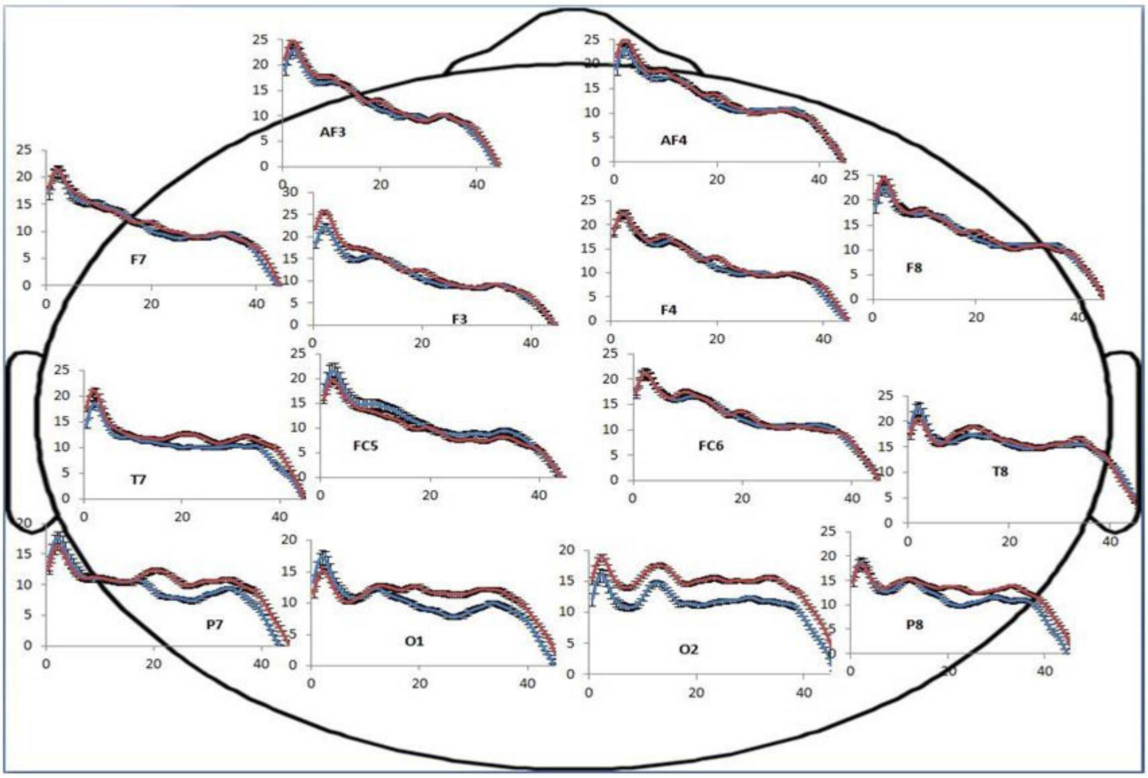

Figure 1: Frequency comparison between self-signature (------) and other signature (-------) in subject 1. (┬ shows Standard Error of Mean) The results show clear differences in posterior area.

3.0 METHOD OF ANALYSIS

Recorded data were imported to EEGLAB software for further processing. After marking the events points in EEG data using EEGLAB and Camtasia Studio, EEG data for two seconds

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after each beep sound in time domain were converted to the data in frequency domain using fast Fourier transformation (FFT). Frequency results were divided into 10 groups from 4 Hz to 43.5 Hz and were analyzed in all 14 channel locations.

Using Microsoft Excel software, we calculated the P-Value by 2-way repeated ANOVA analysis and showed a significant difference between self and others signature with the significant probability p less than 0.05. T-test was performed as a post-hoc test to calculate the P-Value for each frequency range between all data between self and other signature. Results are illustrated at Table 1 and 2.

Utilizing IBM SPSS Statistics software, we calculated classification success rate between self and other signatures using leave-one-out method as a cross validation. The outcome results for both subjects are shown at Table 3 and 4.

Table 1: This table shows P-Value at 14 channels and related frequency range for subject 1. Highlighted cells are P-values smaller than 0.05. The results indicate that there are significant differences in 16 to 43.5 Hz particularly at posterior area.

	AF3	F7	F3	FC5	T7	P7	O1	O2	P8	T8	FC6	F4	F8	AF4
4-7.5	0.309	0.435	0.003	0.436	0.186	0.480	0.160	5.73E-05	0.525	0.626	0.974	0.308	0.793	0.176
8-11.5	0.200	0.508	0.006	0.107	0.342	0.812	0.774	1.92E-07	0.199	0.030	0.176	0.155	0.503	0.078
12-15.5	0.537	0.321	0.596	0.034	0.098	0.058	0.058	2.01E-08	0.430	0.001	0.699	0.664	0.347	0.731
16-19.5	0.596	0.652	0.369	0.153	0.001	0.037	5.14E-06	3.38E-10	0.001	0.411	0.895	0.447	0.967	0.289
20-23.5	0.044	0.007	0.006	0.699	5.28E-06	2.20E-10	3.22E-08	4.61E-11	2.31E-11	0.109	0.032	0.005	0.007	0.011
24-27.5	0.890	0.117	0.491	0.102	0.007	7.01E-06	9.99E-08	1.99E-09	1.34E-06	0.801	0.507	0.615	0.698	0.943
28-31.5	0.270	0.968	0.718	0.030	0.051	4.63E-06	2.82E-07	1.07E-09	3.23E-04	0.493	0.354	0.346	0.218	0.236
32-35.5	0.768	0.971	0.945	0.062	0.003	0.002	1.41E-05	1.82E-10	4.18E-06	0.048	0.102	0.796	0.284	0.253
36-39.5	0.267	0.955	0.453	0.254	8.74E-06	0.001	2.50E-04	1.67E-08	6.06E-05	0.273	0.761	0.315	0.989	0.872
40-43.5	0.064	0.006	0.520	0.473	2.15E-04	3.06E-05	6.55E-07	5.53E-09	6.86E-08	0.063	0.526	0.009	0.514	0.559

Table 2: This table shows P-Value at 14 channels and related frequency range for subject 2. Highlighted cells are P-values smaller than 0.05. The results indicate that there are significant differences within 16 to 31.5 Hz but no specific channel location.

	AF3	F7	F3	FC5	T7	P7	O1	O2	P8	T8	FC6	F4	F8	AF4
4-7.5	0.870267	0.098705	0.598636	0.707279	0.277174	0.926995	0.02145	0.932957	0.371129	0.162371	0.261214	0.982598	0.12474	0.237103
8-11.5	1.27E-09	0.075774	0.000797	0.179031	2.69E-06	0.002577	0.337689	0.124619	0.103947	0.632257	0.36097	0.049491	0.099188	3.13E-05
12-15.5	0.101736	0.454051	0.110978	0.110443	0.059957	0.000111	0.276604	0.445322	0.187752	0.399319	0.155005	0.498252	0.070417	0.948633
16-19.5	1.07E-07	8.55E-06	1.26E-08	0.089179	0.21361	0.029473	0.000782	0.189997	0.005297	0.488301	0.57776	0.914478	0.894608	1E-07
20-23.5	0.002287	0.000767	2.64E-06	0.176609	0.007416	0.00422	0.176883	0.343629	0.000124	0.025419	1.92E-08	0.002669	0.006981	0.000144
24-27.5	2.64E-11	1.98E-08	2.71E-10	5.07E-05	0.000487	0.016262	1.18E-05	0.000298	0.309748	0.003648	0.004628	7.82E-06	0.023539	0.000133
28-31.5	0.030432	0.299119	8.99E-09	0.001138	0.158349	0.081091	0.758138	0.037238	0.015676	0.054823	1.26E-09	0.405174	0.002579	1.07E-07
32-35.5	0.612297	0.056654	0.150029	0.00172	0.255793	0.543848	0.073648	0.073337	0.929772	0.704547	1.87E-06	0.359598	0.643121	0.047988
36-39.5	0.450665	0.454143	0.338731	0.536403	0.551174	0.939894	0.604396	0.099215	0.714899	0.536159	0.021291	0.249544	0.744484	0.954576
40-43.5	0.77212	0.377587	0.20162	0.755795	0.306134	0.692973	0.619041	0.653137	0.155352	0.884982	0.031561	0.652813	0.472508	0.743171

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4.0 RESULTS AND DISCUSSION

Analyzing EEG signals of two subjects in frequency domain showed clear differences between signing self-signature and others signature. As shown in Fig. 1 the clear differences are at posterior area (P7, O1, O2, and P8) for subject 1 and the result from subject 2 showed a clear difference at T7. Differences from posterior area probably resulted because of different visual responds in two conditions. Higher power frequency in others signature could be because of higher required attention while trying to copy others signature. On the frequencies, the results between two subjects were as follows:

A. Difference between self-signature and others signature happened at beta rhythm with the frequencies between 12 and 31.5 Hz.
B. Signing others signature produced the higher power at beta rhythm in comparison with the self-signature.

The beta power was different with the self-signature and the other's signature. It is thought that the reason is because Low amplitude beta waves with multiple and varying frequencies are often associated with active, busy, or anxious thinking and active concentration [4]. Over the motor cortex beta waves are associated with the muscle contractions that happen in isotonic movements and are suppressed prior to and during movement changes [5]. Bursts of beta activity are associated with a strengthening of sensory feedback in static motor control and reduced when there is movement change [6]. Beta activity is increased when movement has to be resisted or voluntarily suppressed [7].

Table 3: Following table provides classification success rate in percentage for subject 1. Highlighted cells have the highest classification rate. The results indicate O2 has the highest score in discrimination accuracy specially within 16 to 35.5 Hz.

	AF3	F7	F3	FC5	T7	P7	O1	O2	P8	T8	FC6	F4	F8	AF4		Average
4-7.5	57%	44%	83%	48%	61%	48%	54%	76%	44%	52%	44%	22%	50%	65%	→	53%
8-11.5	52%	54%	65%	54%	63%	41%	48%	83%	54%	67%	61%	59%	41%	52%	→	57%
12-15.5	39%	50%	48%	63%	46%	35%	52%	78%	52%	65%	26%	59%	37%	48%	→	50%
16-19.5	72%	65%	67%	59%	67%	59%	74%	94%	74%	65%	65%	72%	59%	61%	→	68%
20-23.5	65%	59%	70%	54%	76%	85%	76%	89%	91%	52%	65%	72%	67%	65%	→	70%
24-27.5	57%	57%	52%	46%	76%	85%	85%	85%	80%	52%	52%	63%	67%	61%	→	66%
28-31.5	46%	52%	39%	54%	61%	72%	78%	89%	80%	39%	52%	48%	52%	44%	→	58%
32-35.5	24%	54%	37%	54%	72%	74%	74%	87%	78%	54%	41%	33%	52%	50%	→	56%
36-39.5	48%	57%	54%	57%	76%	67%	72%	76%	70%	59%	52%	63%	61%	52%	→	62%
40-43.5	61%	65%	48%	50%	76%	80%	87%	85%	80%	63%	65%	67%	57%	46%	→	66%
	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓		
Average	52%	56%	56%	54%	67%	65%	70%	84%	70%	57%	52%	56%	54%	54%		

Utilizing the present results could lead to an authentication scheme using EEG signals of Beta rhythm by asking users to sign their self-signature and others signature. Each user must be associated by one self and other signature and since according to our finding others signature must have a significant higher power at beta rhythm, there will be two scenarios:

A: If we have 10 users and user number 3 comes and claims to be number3 (true claim) system will ask him to sign his signature and others signature and compares beta rhythm. According to conclusion number 2 others signature should have higher power at beta rhythm in compare to self-signature and if so, it is successful claim.

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B: If user number 3 comes and claims to be number 4 (wrong claim) there should be no significant differences which concludes to reject the claim.

Table 4: Following table provides classification success rate in percentage for subject 2. Highlighted cells have the highest classification rate. The results indicate that T7 has the highest score in discrimination accuracy specially within 12 to 27.5 Hz.

	AF3	F7	F3	FC5	T7	P7	O1	O2	P8	T8	FC6	F4	F8	AF4		Average
4-7.5	63%	51%	56%	49%	51%	54%	70%	51%	28%	47%	51%	58%	70%	63%	→	54%
8-11.5	47%	58%	58%	51%	61%	47%	49%	33%	26%	44%	42%	61%	74%	61%	→	51%
12-15.5	47%	47%	58%	51%	74%	23%	28%	37%	42%	56%	47%	42%	44%	30%	→	45%
16-19.5	54%	63%	63%	54%	70%	35%	44%	47%	49%	56%	49%	63%	47%	58%	→	53%
20-23.5	58%	56%	63%	51%	74%	37%	44%	35%	51%	49%	63%	61%	67%	58%	→	55%
24-27.5	65%	63%	63%	51%	70%	54%	42%	54%	49%	49%	63%	58%	65%	54%	→	57%
28-31.5	56%	58%	61%	58%	47%	61%	40%	72%	37%	49%	56%	58%	44%	44%	→	53%
32-35.5	49%	37%	61%	49%	42%	44%	51%	49%	26%	61%	61%	47%	67%	56%	→	50%
36-39.5	54%	58%	44%	49%	51%	56%	49%	56%	51%	54%	51%	49%	49%	54%	→	52%
40-43.5	47%	63%	44%	61%	42%	44%	54%	54%	65%	37%	70%	63%	51%	40%	→	52%
	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓		
Average	54%	55%	57%	52%	58%	45%	47%	49%	42%	50%	55%	56%	58%	52%		

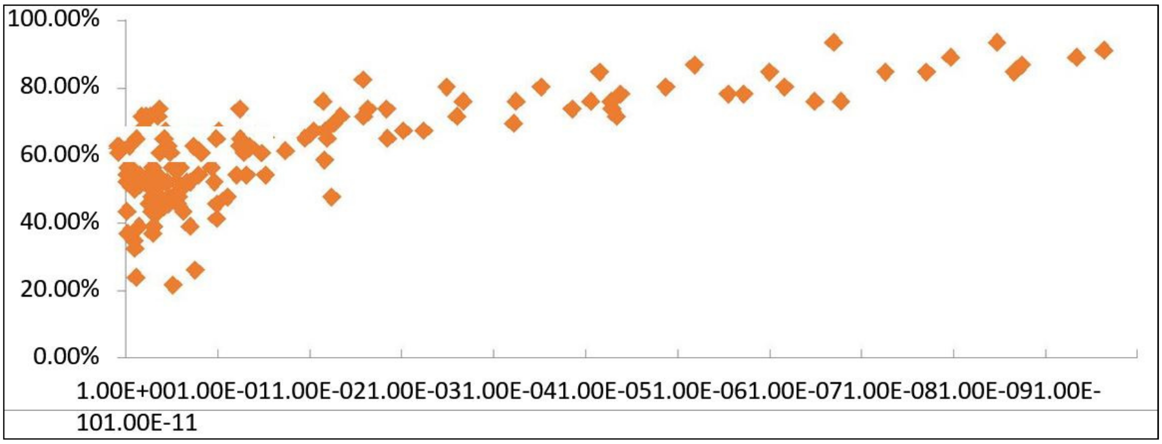

Figure 2: This scatter plot illustrates the relationship between P-Value and Discrimination results. The results indicate that while P-Value decreases discrimination accuracy increases.

5.0 CONCLUSIONS

The fact that there is a clear difference between own signature and other´s signature suggests that the task of signature may be used as one of authentication methods to identify an individual and it will result its best, if it is part of multimodal security system. It is necessary to collect more data based on the proposed task of signature in order to realize the novel authentication method by using EEG data.

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