Mini NIR Auricular BCI Based Visual Imagination Decoding

Chunjie Zhang, Jinwei Cai and Wenshi Li
Department of Microelectronics, Soochow University
Shizi Road, No.1, Suzhou City, China
Email: lwshi@suda.edu.cn

Abstract. Scholars and experts have always dreamed of making brain computer interface (BCI) into a reality for serving brain health. But the mini instrument of BCI has been scarce. We reported in brief an experiment of imagined vision decoding based on mini NIR (near-infrared) auricular BCI. The decoding algorithm (stacked pq-plot) is modified from pq-plot with a tuning chaos-probing parameter and an instruction of “hold on” of MATLAB tool. The identified and imagined objects are one Chinese monograph and three paintings, including “Micronanoelectronics Modeling Case Study” of Wenshi Li, Running horse of Beihong Xu, Starry night of Van Gogh, and Chinese embroidered tiger head. The identification rates results of the measured data touched no less than 60% for vision versus visual imagination of tiger head, more than 70% for above three observed objects. This work may drive the mini smart sensing and effective rapid decoding researches on future BCIs.

1. Introduction
Although the brain computer interface (BCI) had used to be an astronomical night, the first sunshine was pioneered in 1963 by Doctor W.G. Walter in USA [1-2]. The state-of-the-art of information transmission rate (ITR) of BCI (proposed by J. J. Vidal in 1973) had pushed up to 5.32 bps by experts in Tsinghua University in 2015 [3]. Till now all the visual imagination decoding contributions used complex BCIs such as EEG, ECoG and fMRI and fNIRS-based instruments [4-7]. Thus an experiment of mini near-infrared BCI is interesting and non-invasive and inexpensive [8]. The features of our brief report focus on (1) mini instrument of NIR auricular BCI, (2) decoding tricks combined tuning chaos-probing parameter of pq-plot with “hold on” introduction in MATLAB, and (3) stimulus works of vision versus visual imagination, and (4) recognition rates analyses.

2. Methods and Materials
2.1. Methods
The mini instrument of NIR auricular BCI is illustrated in Figure 1. The double devices in 940 nm-wavelength were selected as types of ELICL3 for transmitter and CTICC3H for receiver. The other key parameters include 200 ms/div of timer base scanning and 1399 points of exported data lengths.

The subjects gaze horizontally at the selected objects in distances of 25 centimetres, keeping with sitting posture, at silent lab temperature 18 degrees Celsius.

Figure 2 shows the 66 kHz modulation driver signals (up-port of D1 in Fig. 1) and the auricular NIR signals (output of LM358 in Fig. 1), under AC coupling mode of DS4014E.

The principles’ nature of mini NIR auricular BCI grasps firstly neurovascular mapping of earlobe-brain and then near-infrared human body less-absorbing window [5]. Wherein the eye-point is used.
Figure 1. The schematic diagram of mini NIR auricular BCI.

Figure 2. Two outputs of modulation driving (Ch1) and NIR auricular BCI (Ch2).

On $pq$-plot algorithms for chaos test of signals $\{y(n)\}$, the known formulae are as \[9-12,\]

\begin{align*}
\varphi(n) &= y(n) \quad (1) \\
\theta(n+1) &= c + \theta(n) + \varphi(n) \quad (2) \\
p(n+1) &= p(n) + \varphi(n)\cos(\theta(n)) \quad (3) \\
q(n+1) &= q(n) + \varphi(n)\sin(\theta(n)) \quad (4)
\end{align*}

Wherein the chaos-probing-factor $c$ defined by us is important and interesting parameter in key $c$-scanning for our visual imagination decoding. Here parameter $c$ is in the range of $0$ to $2\pi$.

The principle of 0-1 test for chaos aims at building random-walking feature for chaos state versus cycle signature for period or quasi-period state by the orthogonal modulation and integration in $pq$-plot. By “Hold on” instruction in MATLAB R2016a we stack three or seven $pq$-plots of the data concerned.

2.2. Materials
Figure 3 depicts the stimuli in our tests, including “Micronanoelectronics Modeling Case Study” (in Chinese) of Wenshi Li, Running horse of Beihong Xu (collection at the Museum of Soochow University), Starry night of Van Gogh, and Chinese embroidered tiger head.

The pioneering experiments had finished by Dr. Wenshi Li and Master Student Chongyang Qian in year 2012 with stimulus of a triangle or a circle drawn on A4 paper.
3. Results and Discussions

Figure 4 illustrates contrasted stacked $pq$-plots for the vision decoding results under first three stimuli.
Figure 4. Six stacked $pq$-plots of three stimuli (Subject 1, male, 54 years old). While gazing at a-Book, b-Horse, and c-Starry Night. At repeated six times from (i) to (vi). With optical array-values of chao-probing-factor $c$ weighed 2.6, 3.0 and 3.4.

Apparently every object had been decoded correctly six-time $pq$-plots per ten-group, under stacking key parameter $c$-values of 2.6, 3.0 and 3.4 per group, respectively.

Distinguished from the above decoding results, Figure 5 compares the vision versus visual imagination decoding fruits on Tiger-head.
Figure 5. Six stacked $pq$-plots of two stimuli (S1). Stimulus a-gazing Tiger-head. Stimulus b-imagined Tiger-head. At repeated six times from (i) to (vi). With optical array-values of chao-probing-factor $c$ weigh 2.6, 3.0, 3.4, 3.8, 4.2, 4.6 and 5, respectively.

Self-consistent contrasts had been completed. Seven colours tiger head rebirths in Figure 5 featured NIR auricular signals’ paintings running, and References in [13-14] give examples of comparisons.
The experiment tricks need more values of parameter $c$ while resolving imaginary weak signals versus strong gazing signals.

4. Conclusions
The identified and imagined objects are one book and three paintings. Through our mini NIR auricular BCI, with fitted eye-point selection, we pick up the short data to decode in our novel stacked $pq$-plots imbedded three- or seven-colours. More than 60% correct recognition rates had been touched by only one channel near infrared sensor, without any filter. This work may attract solid interests for repeated tests in future wide brain health caring fields, especially for new brain wave music showing.

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