Enhancing EEG Signals of Steady-state Visual Evoked Potential Using a Noise-assisted Multivariate Empirical Mode Decomposition

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Abstract—This paper presents noise-assisted multivariate empirical mode decomposition (NA-MEMD) - based method to extract steady-state visual evoked potential (SSVEP) in Oz electroencephalogram (EEG) data. The acquired EEG data were segmented into 1-s epochs, and each epoch was then decomposed by NA-MEMD into a series of intrinsic mode functions (IMFs). We used four visual stimuli with flickering rates at 13, 14, 15, and 16 Hz to induce the subject’s SSVEPs. The signal-to-noise ratio shows the proposed NA-MEMD method performed better than the empirical mode decomposition (EMD) method.

I. INTRODUCTION

Many groups have developed signal processing techniques for noise reduction to achieve steady-state visual evoked potential (SSVEP)-based brain-computer interfaces (BCIs). Bin et al. presents an online multi-channel SSVEP-based BCI system using a canonical correlation analysis (CCA) method [1]. Lee et al. utilized ensemble empirical mode decomposition (EEMD) - based approach to extract SSVEPs for wireless handling a small robot car [2]. However, the CCA method required a pre-defined basis for signal extraction. The principle of EEMD is it must add white noise which is canceled out in the ensemble mean of enough trails.

II. MATERIALS AND METHODS

This study develops an SSVEP-based BCI system, which includes a visual stimulus device (four visual targets), a microprocessor, an EEG acquisition system, and a personal computer. An electrode placed at the Oz position and a reference electrode placed at the subject’s left mastoid, with respect to a ground electrode placed at frontal position, were used to record EEG signals. The EEG signals were amplified, and then digitized at 1 kHz. Five subjects were asked to gaze binocularly at the centers of the four visual stimuli (13, 14, 15Hz, and 16Hz). One-minute recordings were made for each visual stimulus. This study was designed to explore the capability of the proposed noise-assisted multivariate empirical mode decomposition (NA-MEMD) method [3] in distinguishing four different gazed targets.

III. RESULTS

Figure 1 shows an example of the NA-MEMD process 1-s Oz EEG when the subject was gazing at the 14Hz flicker. It can be observed IMF6 presented enhanced power spectrum with peak frequency at 14Hz and recognized as a valid gazed target. The IMF4 has peak amplitude frequency at 60 Hz which can be categorized as 60Hz electricity noise. The IMF5 with peak amplitude frequency (f_{peak} = 28Hz) doubling the 14Hz frequency might be the second harmonic component of 14Hz SSVEP. Other IMFs were considered as SSVEP-unrelated IMFs and should be excluded to avoid the interference of task-unrelated noise. Table I shows the signal-to-noise ratio (SNR) [4] over the five subjects of the proposed NA-MEMD system and conventional EMD method. The results illustrate proposed NA-MEMD method performed better than the EMD method.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>NA-MEMD (SNR)</th>
<th>EMD (SNR)</th>
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<tbody>
<tr>
<td>13Hz</td>
<td>3.39 ± 0.83</td>
<td>2.45 ± 0.56</td>
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<tr>
<td>14Hz</td>
<td>2.89 ± 0.68</td>
<td>2.37 ± 0.51</td>
</tr>
<tr>
<td>15Hz</td>
<td>3.30 ± 0.75</td>
<td>2.41 ± 0.59</td>
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<tr>
<td>16Hz</td>
<td>2.02 ± 0.13</td>
<td>1.66 ± 0.16</td>
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REFERENCES


