Estimation of the Single Evoked Potential Using Dipole Transitional Pattern

Tadanori Fukami* Ryoji Mizuno* Tsuyoshi Shiina* Yoichi Saito**
* Institute of Information Sciences and Electronics, University of Tsukuba,Ibaraki,Japan
** Research Institute for EEG Analysis,Tokyo,Japan
* E-mail: tfukami@milab.is.tsukuba.ac.jp

Abstract - Although averaged responses are usually used to detect ERP (evoked related potential), the ERP component of a single response is required to assess time- varying subjects' state in detail. Therefore we propose a new method of estimating the ERP component from a single response corrupted with background waves. The method estimates the ERP dipole of a single response by modifying the position of dipole applying the DP(dynamic programming) matching to the transitional pattern of ERP dipole in the brain and by detecting the projected components with reference to the dipole estimated from averaged response. Results of simulation indicated that the proposed method could estimate the ERP component from a single response by suppressing the influence of background wave on the dipole level. Results of the EEG data analysis showed that the sway of wavefroms by background waves was suppressed and N1 component became prominent compared with original single response.

Keywords : *ERP(evoked related potential)*, *dipole*, *position modification*, *projection of moment*.

1. INTRODUCTION

The average of many responses has been used to estimate the ERP(event related potentials) by means of suppressing the background wave. But this method prevent us from investigating the time-varying subject's state.

Then we propose a new method of estimating the ERP component from a single response by tracking the transitional pattern of EEG dipole in the brain. The method estimates the ERP dipole from the potentials corrupted with background component on the assumption that the dipole's position of a single response traces the same route as that of averaged responses since the background waves are suppressed by averaging process though the time scale of each single response is stretched or compressed.

2. METHODS

We used the three-layer sphere model of head. These layers consist of brain(8cm in radius), skull (5mm thick) and skin(7mm thick) as shown in Fig.1. Each sphere is divided into 360 triangle mesh and potentials distribution on the scalp is calculated by BEM(boundary element method).

In our research it is assumed that the source of the ERP for the short latency such as N1 can be sufficiently approximated by a single dipole. The trace of dipole's position as the time sequences is obtained for both of averaged response and each single response. It may be reasonable to assume that the ERP dipole estimated from the potentials of a single response is not correct due to the background waves, while more precise dipole can be obtained from the averaged response since the background waves are suppressed by averaging process. Therefore we can expect to get the more correct dipole of a single response by replacing the estimated dipole's position of a single response with that of averaged response on the assumption that each component of the ERP such as N1 occurs at each specific position in the brain. In this case, it is necessary to consider a variation of latency of each component of a single response. Then we employ the DP (dynamic programming) matching which can modify the transitional pattern by stretching and compressing the time axis so as to minimize the distance of two pattern. The process is referred to as 'position modification' in this paper.

Moreover, if the moment of each component of the ERP is oriented in the corresponding specific direction, it may be possible to reduce the effect of background waves by projecting the dipole of a single response to that of the averaged responses.

Figure 2 illustrates the shift of dipole moment by the two processing, that is, position modificaion and projection. Finally, the potentials on the scalp are calculated by forward problem. The flowchart of these processing is shown in Fig.3.

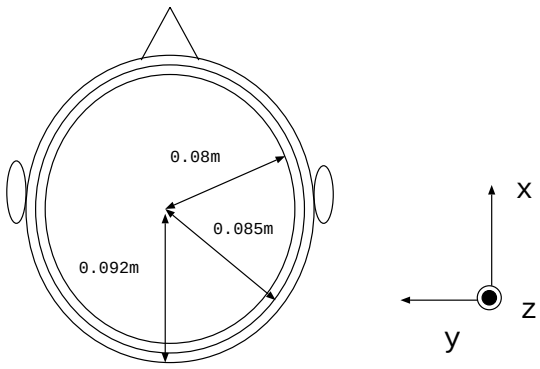

Fig.1 A three-layer sphere model of head

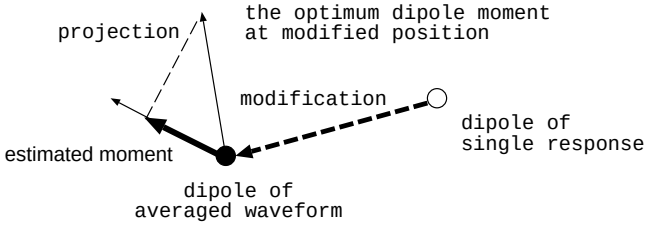

Fig.2 Position modification and projection

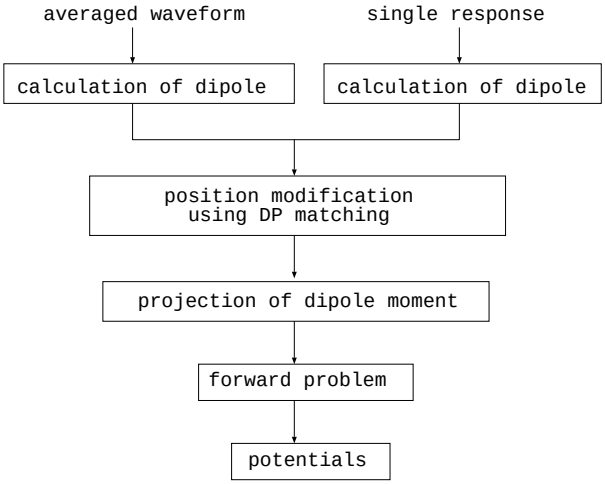

Fig.3 Flowchart of processing

3. SIMULATION

The proposed method was evaluated by simulation. The potentials on the scalp were generated by the ERP dipole located at the position P_{ERP} with the moment M_{ERP}. Background waves were assumed to be expressed as a single moment M_{BG} at the position P_{BG}.

The moment M_{ERP} and position P_{ERP} of the ERP were set to (5,5,5) [$\times 10^{-6}$ A/m] and (-5,5,5) [$\times 10^{-2}$ m], respectively. In this simulation the background waves is also given as a single dipole whose position of the dipole was selected on the xy-plane, namely, (x,y,0) and whose direction M_{BG} was set in the same as M_{ERP} in order to consider the severer case.

The ERP dipole is estimated from the potentials induced on the scalp by the two dipoles by solving an inverse problem. However, in the case where M_{BG} is relatively large, the position of ERP dipole is not correctly estimated at P_{ERP}.

The error of position P_{ERP} between the true and estimated values, which correspond to the distance between two dipole illustrated in Fig.2, are plotted as a function of P_{BG}, as shown in Fig.4. Figure 5 shows the difference between potentials induced by M_{ERP} on the scalp and those by M_{ERP} +M_{BG} as a function of P_{BG}. The potential difference were reduced after the position modification as shown in Fig.6. Moreover the difference was improved by the projection in addition to the position modification as shown in Fig.7.

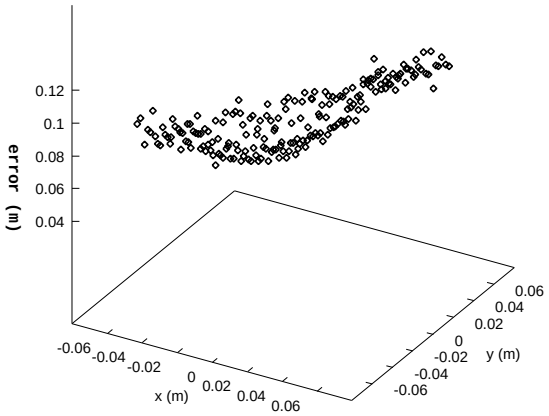

Fig.4 Distriction of errors of the position P_{ERP} between the true and estimated values as a function of positon P_{BG}

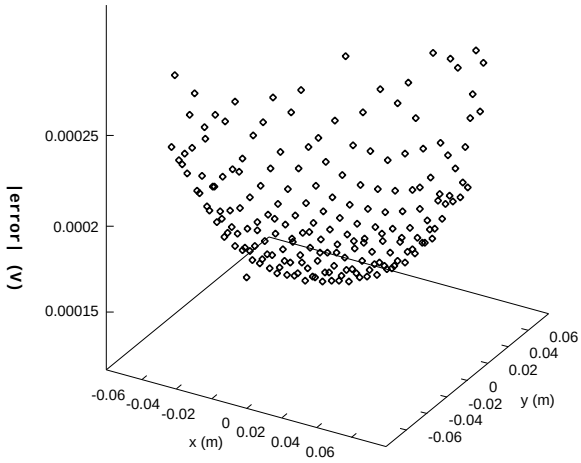

Fig.5 Distriction of potential difference on the scalp as a function of P_{BG}

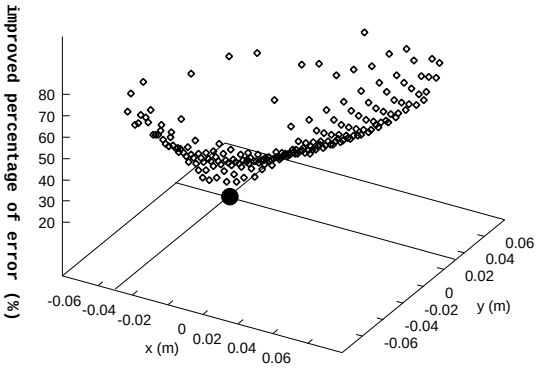

Fig.6 Distriction of improved percentage of errors on the scalp after the position modification

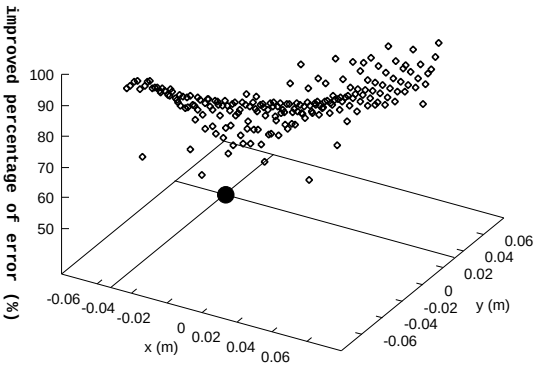

Fig.7 Districution of improved percentage of errors on the scalp after the projection in addition to the position modification

The big circle filled with black indicates that the dipole assumed as P_{ERP} exists right above. These results indicate that the proposed method can estimate the ERP component from a single response by suppressing the influence of background wave on the dipole level.

4. PROCESSING OF EEG DATA

The EEG data of a 25 year-old woman was recorded by auditory odd-ball paradigm from 16 electrodes on the scalp scalp with eye-open state. Transitional patterns of position and moment of the ERP dipole for every time samples were estimated from the averaged EEG data as shown in Fig.8, where sequences x, y and z represent three components of the position or moment vector. Similar patterns of a single response were estimated as shown in Fig.9.

In the EEG data analysis, the ERP dipole estimated from the averaged response was used instead of the true ERP dipole in simulation. The DP matching was employed to detect each component of the ERP of a single response with reference to that of averaged response as a reference. Figure 10 shows a result of position modification when DP window size was set to 50 msec. Moreover moments in Fig.9(b) were projected to the direction of the corresponding moments in Fig.8(b), consequently the pattern shown in Fig.11 was obtained. Finally, waveforms of potentials on the scalp were obtained from patterns in Fig.10 and 11 as shown in Fig.12. The result indicate that the sway of wavefroms by background waves is suppressed and N1 component became prominent compared with oroginal single response.

5.CONCLUSIONS

It was shown that the proposed method could estimate the ERP component from a single response corrupted with background waves based on the transitional pattern of EEG dipole in the brain. On the other hand, results depend on the difference between the ERP and background waves such as the distance of sources and direction of approximated moment. In general, the smaller difference make it more difficult to separate two components. For the future work, we are going to improve the DP matching and introduce more realistic model of brain structure to obtain more precise results.

References

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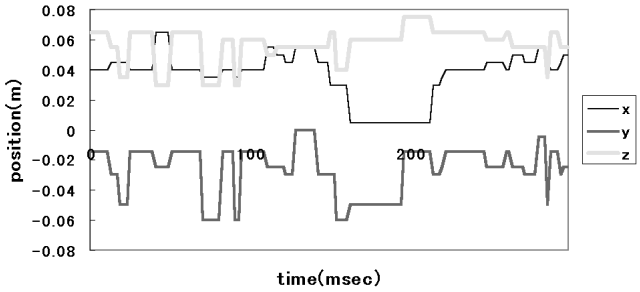
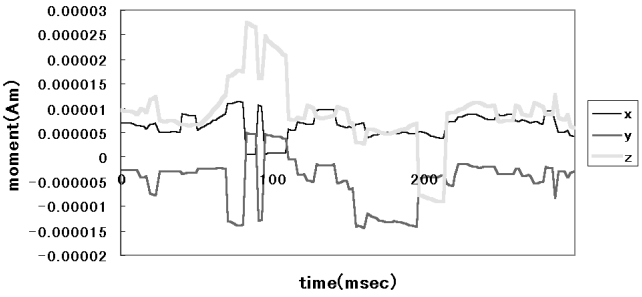
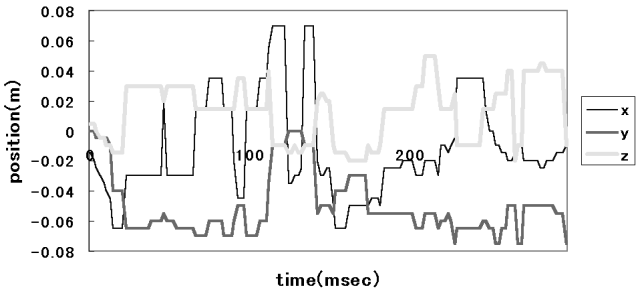


(a) Position

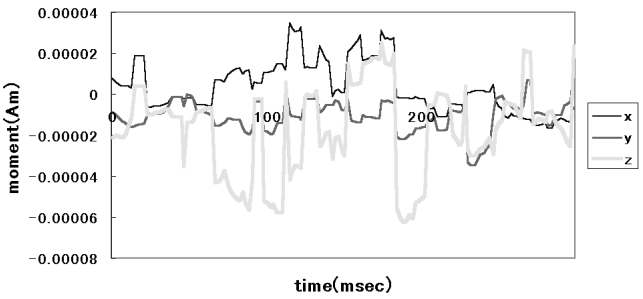


(b) Moment

Fig.8 Transitional pattern of averaged response



(a) Position



(b) Moment

Fig.9 Transitional pattern of single response

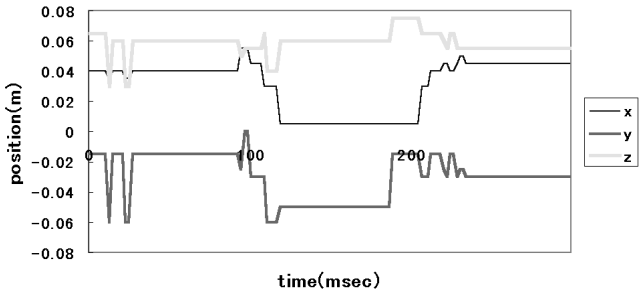


Fig.10 Position modified by DP matching

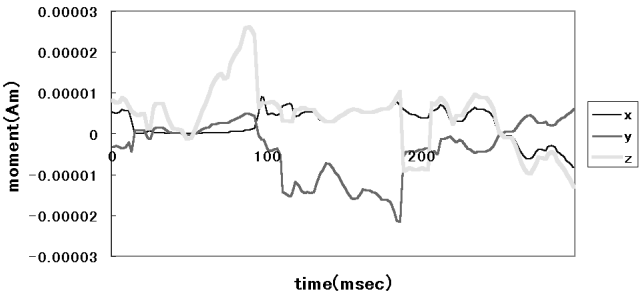
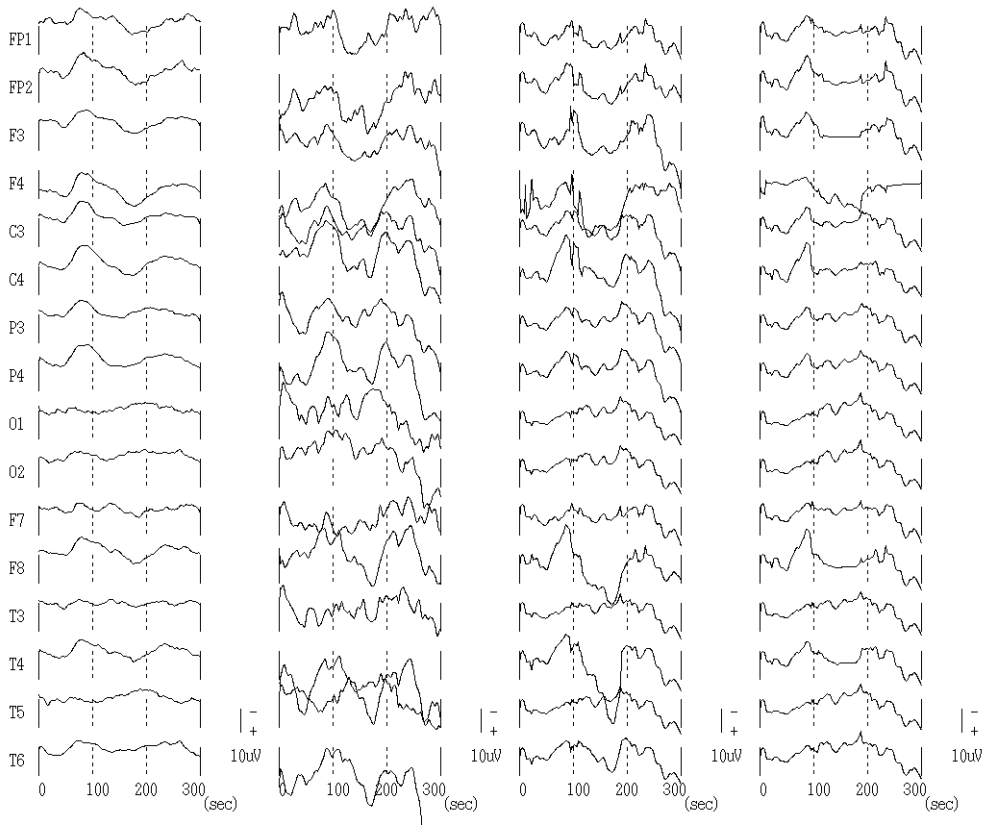


Fig.11 Moment modified by DP matching and projection



(a) (b) (c) (d)

Fig.12 Results of estimation of ERP component,(a) averaged responses for each electrodes for each electrode,(b) single responses,(c) waveforms processed by position modification,(d) waveforms processed by position modification and projection