Estimation of Amplitude and Latency Changes of P300 Response in Real-Time

Moncef Benkherrat, Radouane Bouguerra, Tarik Choufa

Abstract — **The present study focused on changes in P300 of the event-related potential (ERP) in subjects with Parkinson's disease (PD). Changes in latency and amplitude of P300 are very useful indicators that can be used for clinical diagnosis. A low signal-to-noise ratio of the ERP signals makes it difficult to estimate small changes in latency and amplitude.**

In this paper, we propose a new method based on Least Mean Square (LMS) algorithm to estimate the latency and amplitude changes of the ERP P300 response in real-time.

Keywords — **Event related potentials, P300, latency, amplitude, adaptive time delay estimation, LMS.**

I. Introduction

THE event-related potential (ERP) has been used to evaluate the cognitive function and to examine neurological disorders. In particular, P300 potential of the ERP has been used widely, due to the ease of its observation in a simple discriminative task. There is a widespread evidence of the reduction of amplitude and increased latency of P300 in Parkinson's disease patients. In the time domain, the P300 ERP component has been correlated with general cognitive functions such as attention and memory as in [1], with its peak latency proposed to reflect the speed with which the attention resources are allocated when immediate memory is updated.

During acquisition, we can observe changes in the amplitude and latency of the P300 response between normal people and Parkinson's disease patients. In addition, changes in latency and amplitude between PD patients at different stages can be observed. These variations in the amplitude and latency are significant and can be used for clinical diagnosis as in [2].

In this paper, we have applied an adaptive time delay estimation method proposed by Etter et al. as in [3] and improved by Kong et al. as in [4], [5], [6] to estimate in real-time the amplitude and latency variations of P300 ERP component.

M. B. Author is an Assistant Professor with the School of Electrical Engineering, EPMI, 13 bd de l'Hautil 95092 Cergy, France (e-mail: m.benkherrat@epmi.fr).

R. B. Author is a Senior Research Engineer with Cardiodynamics, Inc, San Diego, CA (e-mail: rbouguerra@cdic.com).

T. C. Author is a Senior Consultant with Fennec, Inc, Montreal Canada (e-mail: tchoufa@fennec.ca).

II. Methodology

The recording of EEG and EOG was made with CED 1401 system connected in parallel to the amplifier of the evoked potentials analyzer Neuropack 8. The cerebral potentials were recorded from the recommended electrodes silver-silver chloride (Ag-AgCL) at Fz and Cz referenced to linked earlobes as in [7]. The filter bandpass was set at 0.1-50 Hz. The sensitivity was set to 50 μV/div. The electro-occulogram (EOG) was recorded and trials with a large EOG potential were autorejected. The visual stimulus is displayed on the PC screen. The target signal corresponds to a small rectangle (0.5cm by 1.5cm). It is displayed randomly on the screen at different locations and instants. The age of the patients ranges between 25 and 50 years. The patient's task is to press the space bar each time when the target signal appears on the screen. Whenever, the patient is waiting for a new target signal, a non-target signal (1.5cm by 1.5cm) is displayed on the screen. The display on the screen lasts 200ms and the duration between stimuli varie s between 500ms and 3s.

III. Algorithm

The latency is computed between two signals. Let us consider $x_1(k)$ *and* $x_2(k)$ represented by the following equations:

$$\begin{aligned} x_1(k) &= s(k) + n_1(k) \\ &= s(t) + n_1(t)\big|t = kT_s \end{aligned} \quad (1)$$

$$\begin{aligned} x_2(k) &= \lambda s(k - \theta(k)) + n_2(k) \\ &= \lambda s(t - \theta(t)) + n_2(t)\big|t = kT_s \end{aligned} \quad (2)$$

where $T_s = 1$. $s(k)$ is the utile signal, $s(k-\theta(k))$ is a delayed version of $s(k)$. $n_1(k)$ *and* $n_2(k)$ represent the noise, λ is the attenuation factor and $\theta(k)$ is the delay.

The signal $x_1(k)$ corresponds to the first response recorded. It is applied as the reference input. In our application, the utile signal $s(k)$ is the cognitive event related (CEP) and $n_1(k)$ is the biological noise. $x_2(k)$ is considered as the successive responses of the subject. We suppose that $s(k)$ *and* $s(k-\theta(k))$ are correlated. We also assume that $s(k)$ *and* $s(k-\theta(k))$ are uncorrelated from the

1-4244-0049-X/05/$20.00 ©2005 IEEE

noise $n_1(k)$ and $n_2(k)$.

The algorithm used to estimate the latency changes is based on gradient method as in [8]. The algorithm consists of adjusting the parameter $\hat{\theta}(k)$ in order to minimize the mean square error (MSE) given by:

$$e(\hat{\theta}(k))^2 = \frac{\left(x_1(k-\hat{\theta}(k)) - x_2(k)\right)^2}{2} \quad (3)$$

The update of the delay and the attenuation factor is given by the following equations:

$$\hat{\theta}(k+1) = \hat{\theta}(k) - \mu\hat{\lambda}(k)(x_2(k) - \hat{\lambda}(k)* x_1(k-q(\hat{\theta}(k)))\Delta x_1(k-q(\hat{\theta}(k))) \quad (4)$$

$$\hat{\lambda}(k+1) = \hat{\lambda}(k) - \mu(\hat{\lambda}(k)x_1(k-q(\hat{\theta}(k))) - x_2(k))* x_1(k-q(\hat{\theta}(k))) \quad (5)$$

Where $q(\theta)$ is the closest integer of θ and μ is the adaptation step controls the adaptation speed of the LMS. In our application, $\mu = 0.05$.

IV. RESULTS

Figs 1 and 2 show respectively the estimation of the latency and the attenuation factor variations for 3 normal subjects. We can observe a constant increase of the latency. For the same number of responses for all subjects, which is 27, the maximum value is about 1.6 ms. From Fig2, it is quite obvious that the amplitude of the signal passes by two phases: the first phase is characterized by an increase of the amplitude during the first five to ten ERP responses and the second phase is characterized by a decrease of the amplitude of the following ERP responses.

Figs 3 and 4 correspond respectively to the estimation of the latency and the attenuation factor changes of 3 Parkinson's disease subjects. From Fig3, we can observe that the latency values are bigger than the latency values of normal subjects. The maximum value of the latency for all PD subjects is about 5 ms.

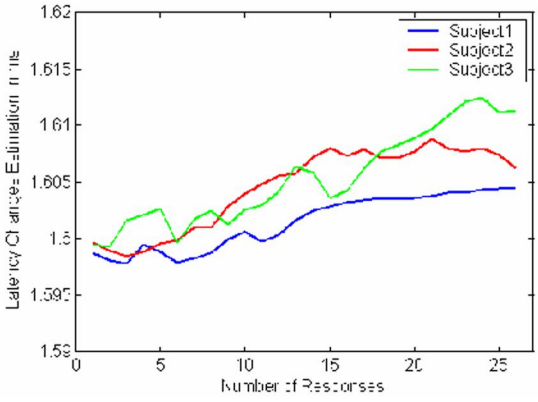

Fig. 1. Latency changes of 3 normal subjects

V. DISCUSSIONS

The present work was designed to estimate the amplitude and the latency changes of P300 wave of Parkinson's disease subjects in real-time. The algorithm processes the signal comprised between 280ms and 700ms and this interval corresponds to the changes interval of the P300 wave. The fact that the amplitude of the P300 wave passes by two phases means that a normal subject passes first by a training phase and then followed by an acclimatization phase. The amplitude decrease of the P300 wave for all PD subjects shown in Fig 4 can be interpreted as a deficit of attention. The principal finding of this work was that P300 latency was prolonged in Parkinson's disease patients compared to normal subjects.

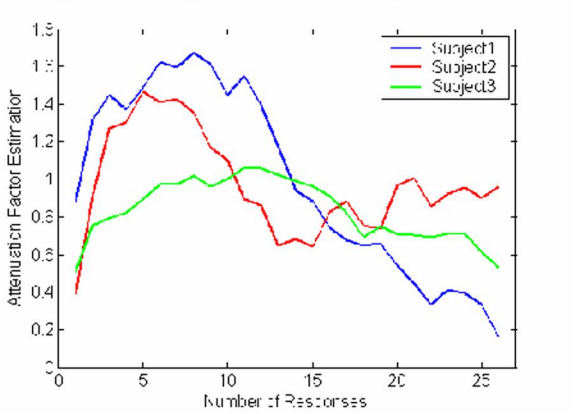

Fig. 2. Attenuation factor of 3 normal subjects

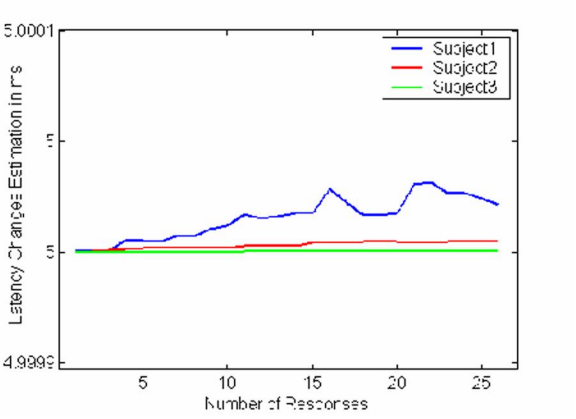

Fig. 3. Latency changes of 3 Parkinson's disease patients

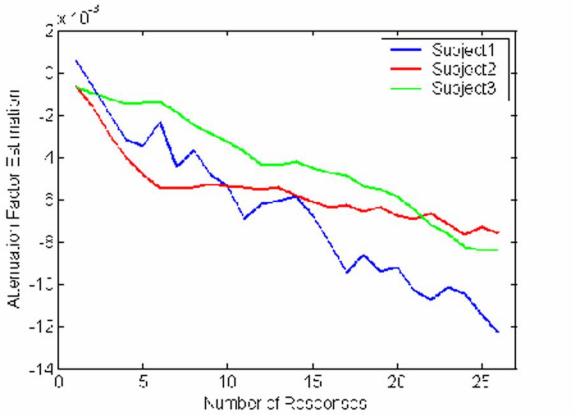

Fig. 4. Attenuation factor of 3 Parkinson's disease patients

VI. CONCLUSION

In this paper, we have successfully shown that the proposed adaptive time delay estimation algorithm is applicable to estimate the latency and the amplitude of the P300 ERP in real-time. The results have shown that the proposed algorithm is capable to track in real-time the latency and amplitude changes even if the changes are very small. In addition, given the small computation complexity of the algorithm, we can easily implement the algorithm in the acquisition system and replace the classical methods such as the peak-to-peak method or the correlation function based method.

VII. REFERENCES

[1] Picton, T.W. (1992) The P300 wave of the human event-related potential. Journal of Clinical Neurophysiology, 9: 456-479.

[2] N. Bathien, D. Bazalgette , M. Benkherrat, A. Hugelin, Y. Wu, 'ERPs changes during visuo-spatial discrimination in patients with Parkinson's disease', Europ. Congress of Psychophysiology, Barcelona, 7-10, 1994.

[3] D. Etter, S. Stearns, 'Adaptive estimation of time delays in sampled data systems', IEEE Trans. on ASSP., 29, 582-587, 1981.

[4] X. Kong, V. Solo, ' Effects of attenuation factor on adaptive time delay estimation', in Proc. Int. Conf. Acoust. Speech Signal Processing, 2121-2124, 1991.

[5] X. Kong, 'Availability and approximation of signals in adaptive time delay estimation', in Proc. Int. Conf. Acoust., Speech, Signal Processing, 481-484, 1992.

[6] X. Kong, V. Solo, ' Stochastic averaging analysis of a steepest-descent-type adaptive time-delay estimation algorithm', Math. Control Signals Systems, 7, 121-147, 1994.

[7] H. H. Jasper, « The ten twenty electrode system of the international Federation», 1958, Electroencephalography and Clinical Neuro-physiology, Vol. 10, pp. 371-375.

[8] B. Widrow, S. D. Stearns, 'Adaptive Signal Processing', Englewo od Cliffs, NJ: Prentice-Hall, 1985.